3.3.11 Airborne Transport of Radionuclides

3.3.11.1 Description of Issue

Basaltic volcanic eruptions produce volcanic ash plumes that can transport particulate matter tens to thousands of kilometers downwind from the erupting volcano (e.g., Blackburn, et al., 1976, Walker, 1993). In the event of a volcanic eruption through the proposed repository, high-level waste may also be transported in the volcanic ash plume. Deposition of radionuclides could occur at the reasonably maximally exposed individual location, either from direct sedimentation from the volcanic ash cloud, or from the remobilization of the radionuclides and volcanic ash after initial deposition by wind or surface water. Airborne transport and deposition of radionuclides in volcanic ash plumes should be modeled to estimate the dose consequences and risk associated with these phenomena. Radionuclide transport in volcanic plumes and subsequent deposition are the topics of this integrated subissue. The inputs on probability of volcanic activity disrupting the proposed Yucca Mountain repository and the consequences of this activity for waste package integrity are covered in five integrated subissues. These integrated subissues include Biosphere Characteristics, Volcanic Disruption of Waste Packages, Mechanical Disruption of Engineered Barriers, Airborne Transport of Radionuclides, and Radionuclide Redistribution in Soil. The relationship of this integrated subissue to other integrated subissues is depicted in Figure 3.3.11-1. The overall organization and identification of all the integrated subissues are depicted in Figure 1.1-2.

This section provides a review of the abstractions of airborne transport of radionuclides incorporated by DOE in its Total System Performance Assessment. The DOE description and technical basis for the airborne transport of radionuclides abstractions are primarily documented in CRWMS M&O (2000a). Results are used and documented in CRWMS M&O (2000b–d). Portions of additional analysis and model reports were reviewed if they contained data or analyses that supported the proposed total system performance assessment abstractions (CRWMS M&O, 2000e,f).

3.3.11.2 Relationship to Key Technical Issue Subissues

The Airborne Transport of Radionuclides Integrated Subissue incorporates subject matter previously captured in the following key technical issue subissues:

- Igneous Activity: Subissue 2—Consequences of Igneous Activity (NRC, 1999)
- Total System Performance Assessment and Integration: Subissue 1—System Description and Demonstration of Multiple Barriers (NRC, 2000)
- Total System Performance Assessment and Integration: Subissue 2—Scenario Analysis and Event Probability (NRC, 2000)

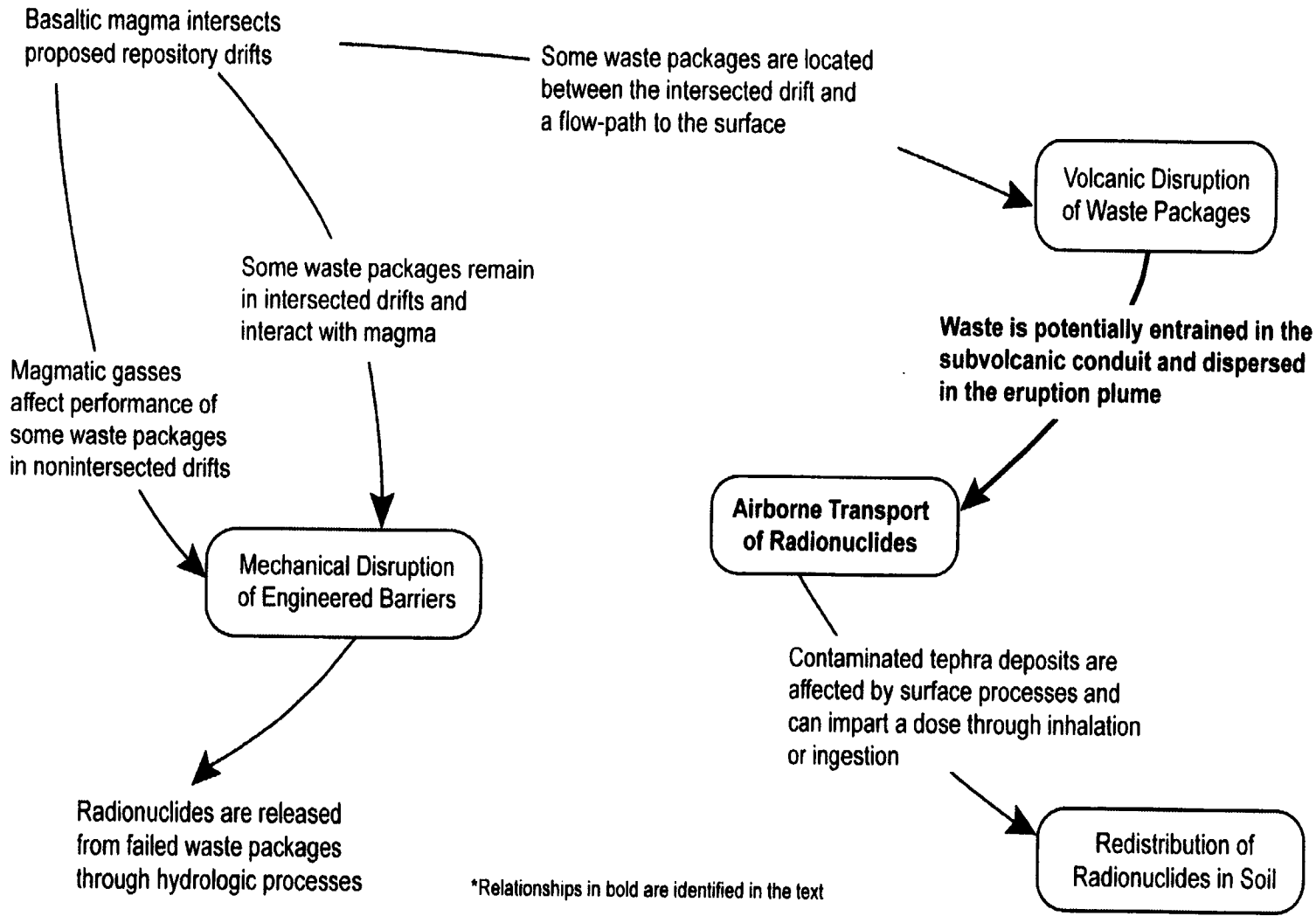

Figure 3.3.11-1. Diagram Illustrating the Relationship Between Airborne Transport of Radionuclides and Other Integrated Subissues

- Total System Performance Assessment and Integration: Subissue 3—Model Abstraction (NRC, 2000)

- Total System Performance Assessment and Integration: Subissue 4—Demonstration of Compliance with the Postclosure Public Health and Environmental Standards (NRC, 2000)

The key technical issue subissues formed the basis for the previous versions of the issue resolution status reports and also were the basis for technical exchanges with DOE where agreements were reached on what additional information DOE needed to provide to resolve the subissue. The resolution status of this integrated subissue is based on the resolution status of each of the contributing key technical issues subissues. The subsequent sections incorporate applicable portions of these key technical issue subissues but no effort has been made to explicitly identify each subissue in the text.

3.3.11.3 Importance to Postclosure Performance

Eruption processes, such as diffusion and advection of tephra and radionuclides, form the primary emphasis of the Airborne Transport of Radionuclides Integrated Subissue. These processes directly affect the amount of radionuclides potentially deposited at the reasonably maximally exposed individual location by volcanic eruption through the repository. Igneous processes, partly evaluated in this integrated subissue, provide a mechanism for such rapid transport of radionuclides to a reasonably maximally exposed individual. The importance of this integrated subissue, as well as the integrated subissues of Volcanic Disruption and Mechanical Disruption of Engineered Barriers, are best documented in the DOE Total System Performance Assessment for the Site Recommendation and the Supplemental Science and Performance Analysis, Volumes 1 and 2 (CRWMS M&O, 2000h; Bechtel SAIC Company, LLC, 2001a,b). As is stated in Section 5.3 of Volume 2 of the Supplement Science and Performance Analysis (Bechtel SAIC Company, LLC, 2001b), "For the TSPA–SR [Total System Performance Assessment for the Site Recommendation] and the supplemental TSPA [Total System Performance Assessment] model, probability-weighted mean annual dose from igneous disruption determine the magnitude of the overall mean annual dose from nominal and disruptive performance during the first 10,000 years."

3.3.11.4 Technical Basis

NRC developed a plan (2002) consistent with the acceptance criteria and review methods found in previous issue resolution status reports. A review of the DOE approach for including airborne transport of radionuclides in total system performance assessment abstractions is provided in the following subsections. The review is organized according to the five acceptance criteria identified in Section 1.5 as follows: (i) System Description and Model Integration Are Adequate, (ii) Data Are Sufficient for Model Justification, (iii) Data Uncertainty Is Characterized and Propagated Through the Model Abstraction, (iv) Model Uncertainty Is Characterized and Propagated Through the Model Abstraction, and (v) Model Abstraction Output Is Supported by Objective Comparisons.

3.3.11.4.1 System Description and Model Integration Are Adequate

Overall, the current information, along with agreements reached between DOE and NRC (Section 3.3.11.5), is sufficient to conclude that the necessary information will be available at the time of a potential license application to assess airborne transport of radionuclides with respect to system description and model integration.

Basaltic volcanic eruptions produce volcanic ash plumes that transport particulate matter tens to thousands of kilometers downwind from the erupting volcano. In the event of a volcanic eruption through the proposed repository, high-level waste may also be transported in the volcanic ash plume, with the potential deposition of radionuclides at the reasonably maximally exposed individual location, either from direct sedimentation from the volcanic ash cloud or from the remobilization of the radionuclides and volcanic ash after initial deposition by wind or surface water. Airborne transport and deposition of radionuclides in volcanic ash plumes must be modeled to estimate the dose consequences and risks associated with these phenomena.

ASHPLUME uses the Suzuki (1983) model to abstract the thermo-fluid dynamics of ash dispersion in the atmosphere,

$$X(x,y) = \int_{\varphi_{min}}^{\varphi_{max}} \int_0^H \frac{5 f_z(z) f_\Phi(\varphi) Q}{8\pi C(t+t_s)^{5/2}} \exp\left\{ -\frac{5\left[(x-ut)^2 + y^2\right]}{8C(t+t_s)^{5/2}} \right\} dz\, d\varphi \qquad (3.3.11\text{-}1)$$

where X is the mass of ash and radionuclides accumulated at geographic location x, y, relative to the position of the volcanic vent; $f_z(z)$ is a probability density function for diffusion of particles out of the eruption column, treated as a line source extending vertically from the vent to total column height, H; $f_\Phi(\varphi)$ is a probability density function for grain size, φ; Q is the total mass of material erupted; u is wind speed in the x-direction; t is the particle fall-time through the atmosphere; t_s is diffusion time of tephra and high-level-waste-laden tephra; and C is eddy diffusivity. Most of these parameters, in turn, depend on additional parameters that are estimated as part of performance assessments (Jarzemba, 1997; CRWMS M&O, 2000a,c; Connor, et al., 2001).

In ASHPLUME, the erupting column is treated as a line source reaching some maximum height governed by the energy and mass of the eruption. A linear decrease in the upward velocity of particles is assumed, resulting in segregation of ash or ash and waste particles in the ascending column by settling velocity, which is a function of grain size, shape, and density. Tephra and high-level waste particles are removed from the column based on their settling velocity, the decrease in upward velocity of the column as a function of height, and a probability density function [$f_z(z)$] that attempts to capture particle diffusion out of the column. These relationships are valid for particles larger than 15 μm [0.0006 in] in diameter, but do not capture the atmospheric dynamics of settling for smaller particle diameters (Suzuki, 1983). Dispersion of the tephra and high-level waste diffused out of the column is modeled for a uniform wind field and is governed by the diffusion-advection equation with vertical settling. Thus, results derived using this model depend heavily on assumptions about the shapes of the distributions $f_z(z)$ and $f_\Phi(\varphi)$.

In CRWMS M&O (2000g), DOE demonstrated that the ASHPLUME code, as implemented by DOE, can reasonably represent an actual basaltic volcanic eruption. In addition, this document provides the parameters used in the analysis. In CRWMS M&O (2000c), DOE provided the cumulative distribution functions for both the mean ash particle diameter used in its models and the ash-dispersion controlling constant. These values appear reasonable and, therefore, NRC considers that DOE has the means to satisfactorily address this acceptance criterion.

3.3.11.4.2 Data Are Sufficient for Model Justification

Overall, the current information, along with agreements reached between DOE and NRC (Section 3.3.11.5), is sufficient to conclude that the necessary information will be available at the time of a potential license application to assess airborne transport of radionuclides with respect to data being sufficient for model justification.

The ASHPLUME model itself was first developed for use in the high-level waste program by Jarzemba, et al. (1997) and later modified by DOE. Most of the parameters, with the notable exception of parameters related to the transport of high-level waste, used as input to ASHPLUME are derived from the volcanological literature (CRWMS M&O, 2000a,c). Because many of the volcanic processes important for consequence evaluation are not preserved in the Yucca Mountain region geologic record, proposed process-level consequence models should be verified with data from reasonably analogous small-volume basaltic volcanic systems to be acceptable. In CRWMS M&O (2000a), analogous eruptions, including but not limited to the 1975 Tolbachik, Russia; 1943–52 Paricutin, Mexico; and 1850–1999 Cerro Negro, Nicaragua, and violent strombolian eruptions are cited as the sources of acceptable parameter distributions for use in ASHPLUME. Staff agree these data and the volcanological processes evinced by these eruptions are reasonable analogs for potential volcanic eruptions in the Yucca Mountain region and ASHPLUME inputs.

Issues related to data sufficiency and model justification in the Airborne Transport of Radionuclides Integrated Subissue involve three topics: (i) the range of eruption energetics used by DOE in the ASHPLUME simulations, (ii) the method of incorporation of high-level waste into erupting tephra, and (iii) the use of a uniform windfield in ASHPLUME simulations of tephra and high-level waste dispersion using data derived from near-surface meteorological observations at the site. Each of these three topics is addressed in this section.

There has been extensive concurrent work on the nature of violent strombolian eruptions and application of numerical models of tephra dispersion in hazard assessments, simultaneous with the development of ASHPLUME (e.g., Woods, 1995; Sparks, et al., 1997; Hill, et al., 1998; Rosi, 1998; Connor, et al., 2001). The greatest relevance of this work is in bounding the energetics of potential future volcanic eruptions in the Yucca Mountain region. ASHPLUME Version 1.3 uses eruption power, volume, and conduit diameter [directly related to muzzle velocity at the vent (Wilson and Head, 1981)] to characterize the eruption. These parameters bound eruption energetics and are used to estimate steady-state eruption duration and column

height, assuming that eruption column height, H (kilometers); eruption volume, V (cubic meter, dense rock equivalent); and duration of the violent strombolian phase of the eruption, T (seconds), are related by

$$\frac{dV}{dt} = \left| \frac{H}{1.67} \right|^4 \qquad (3.3.11\text{-}2)$$

and

$$V = \frac{dV}{dt} T \qquad (3.3.11\text{-}3)$$

These relationships provide a check on input parameters. It is crucial for DOE to track also the mass flow rate together with the muzzle velocity at the vent for simulated eruptions in ASHPLUME to ensure that all eruptions used in the simulations have simple-to-super-buoyant plumes, as expected for the violent strombolian phase of cone-building eruptions (Woods and Bursik, 1991). Verification is needed in the model that mass flow and vent velocity regimes are sufficient to maintain such columns for all ASHPLUME simulations. Currently, it appears that some modeled events have mass flow rates and vent velocities that are too low to sustain such plumes (CRWMS M&O, 2000c). DOE has agreed to model the interaction of magma with the repository.[1] This model will provide a better understanding of flow velocities, mass rates, and other important properties of the eruption, which will be used to constrain the eruptive characteristics and, therefore, better justify the input parameters into ASHPLUME. As such, NRC has no questions related to this concern at this time.

CRWMS M&O (2000a) notes that the most difficult aspect of the ASHPLUME model abstraction involves quantifying high-level waste transport. Currently, the fuel fraction model developed by Jarzemba, et al. (1997) is used to abstract the complex process of high-level waste incorporation and transport. Waste particles are assumed to be incorporated into erupting pyroclasts following the rule

$$\rho_c = \log \left| \frac{d^a_{min}}{d^f} \right| \qquad (3.3.11\text{-}4)$$

where d^f is the diameter of the waste particle to be incorporated and d^a_{min} is the minimum diameter of a pyroclast required to transport this particle. Motivation for this approach, detailed in Jarzemba, et al. (1997), was to bound the particle size and density distribution for estimating the dispersion of contaminated waste. Jarzemba, et al. (1997) arbitrarily chose a value of $\rho_c = 0.3$ to illustrate the application of the model. The assumption that $\rho_c = 0.3$ is propagated through the Total System Performance Assessment–Site Recommendation (CRWMS M&O, 2000c). That Jarzemba, et al. (1997) made this assumption about the incorporation ratio, as an

[1]Reamer,C.W. "U.S. Nuclear Regulatory Commission/U.S. Department of Energy Technical Exchange and Management Meeting on Igneous Activity (September 5, 2001)." Letter (September 12) to S. Brocoum, DOE. Washington, DC: NRC. 2001.

example, is not a sufficient basis for DOE to make this assumption in a license application. Additional documentation will be required to justify assumptions about the incorporation of high-level waste. DOE agreed to describe the method of high-level waste incorporation used in the DOE models.[2]

Wind speed is a parameter that significantly affects tephra dispersion models for basaltic volcanoes (e.g., Hill, et al., 1998). The column from the next Yucca Mountain region eruption will likely reach altitudes of 2–6 km [1–4 mi] above ground level, as is observed for most violent-strombolian basaltic eruptions. Although near-ground-surface wind data are available for the proposed repository site, low-altitude winds will be affected significantly by surface topographic effects and, thus, have little relevance to modeling dispersal from 2–6-km [1–4-mi]-high eruption columns. For Total System Performance Assessment–Site Recommendation analyses, DOE used wind speeds and directions obtained from near-surface stations (CRWMS M&O, 2000a,c). It is much more appropriate to use data sets that extend to higher altitudes (e.g., data available from the Desert Rock Airstrip, Nevada) and to model the effects of stratified wind velocities and directions for eruptions (e.g., Glaze and Self, 1991). A stratified windfield is incorporated into ASHPLUME by specifying variation in the windfield as a function of height. A starting height, z_k, and windspeed and direction, u_k, are associated with each k stratum, within which wind speed and direction are held constant. With a windfield that varies with height, the site of particle deposition is controlled by the release height of the particle from the eruption column and the average windspeed and direction encountered during particle settling through the atmosphere. This average wind vector can be calculated using

$$u_{avg} = \frac{1}{Z} \sum_{k=0}^{N_k} u_k \Delta z_k \qquad (3.3.11\text{-}5)$$

where Z is the height above the ground from which the particle is released; N_k is the number of wind strata between Z and the ground; Δz_k is the thickness of the wind stratum, within which the windfield is assumed to be uniform; u_k is the wind vector in stratum k; and u_{avg} is the average resulting wind vector for particles released at height Z. This average wind vector for a specific height above the ground is independent of particle size. Therefore, the average wind vector experienced by all particles released from the eruption column at height Z need only be calculated once for a given eruption realization. DOE agreed to evaluate the wind speed data appropriate for the height of the eruptive columns being modeled.[3]

Staff conclude that the current version of ASHPLUME will be greatly improved (more realistic) if these three changes are incorporated. The resulting model will more accurately reflect outcomes of volcanic eruptions through the proposed repository. Furthermore, each of these

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[2]Reamer,C.W. "U.S. Nuclear Regulatory Commission/U.S. Department of Energy Technical Exchange and Management Meeting on Igneous Activity (September 5, 2001)." Letter (September 12) to S. Brocoum, DOE. Washington, DC: NRC. 2001.

[3]Schlueter, J. "U.S. Nuclear Regulatory Commission/U.S. Department of Energy Technical Exchange and Management Meeting on Igneous Activity (August 29–31, 2000)." Letter (October 23) to S. Brocoum, DOE. Washington, DC: NRC. 2000.

changes could significantly affect estimates of dose and risk at the receptor location. Of course, their impact on risk cannot be evaluated until the changes are included in the model.

In summary, DOE agreed to provide the additional information necessary for model justification. For example, the agreements to model repository/magma interactions will result in the use of appropriate wind speeds for the height of the columns being modeled. The evaluation of the incorporation of high-level waste into the magma results also will result in a better justification of the methodology.

3.3.11.4.3 Data Uncertainty Is Characterized and Propagated Through the Model Abstraction

Overall, the current information, along with agreements reached between DOE and NRC (Section 3.3.11.5), is sufficient to conclude that the necessary information will be available at the time of a potential license application to assess airborne transport of radionuclides with respect to data uncertainty being characterized and propagated through the model abstraction.

Parameter distributions for inputs into ASHPLUME are discussed in CRWMS M&O (2000a) and presented in detail in CRWMS M&O (2000c, Table 5). Most of these parameter distributions are well-documented and supported and, therefore, are not discussed further. In addition to the parameter distributions discussed in Section 3.3.11.4.2 (i.e., wind speed and direction, eruption velocity, and conduit diameter), the distribution function for distribution of tephra and high-level waste in the vertical eruption column, β, requires further attention.

In the ASHPLUME model, tephra is released from the eruption column for advective transport downwind at a height depending on grain size, total column height, and the parameter β. Essentially, a small value of β (e.g., 0.1) will result in a tendency for particles to be released low in the eruption column, with only very fine grained material reaching the top of the column. A large value of β (e.g., 1) results in most of the tephra reaching the top of the column. Large values of β (e.g., 10) result in a point source of tephra at height H in the atmosphere. Because particle advection downwind is strongly dependent on the height in the eruption column at which particles are released, β potentially has a strong influence on dose. In CRWMS M&O (2000c), β is limited to a range of 0.01 to 0.5, or a range that limits the ascent of particles, particularly large high-level waste bearing particles, in the tephra column. Hill, et al. (1998), however, found that $\beta = 10$ best fits the observed distribution of tephra at 20 km [12 mi] from the vent, using data from the 1995 Cerro Negro eruption. Further, in CRWMS M&O (2000g), a value of $\beta = 10$ was used by DOE to demonstrate that the ASHPLUME code can reasonably replicate a natural eruption (i.e., the 1995 Cerro Negro eruption).

In summary, CRWMS M&O (2000c) is one of the many reports that is scheduled for revision by the end of 2003 and DOE agreed that the discrepancies between CRWMS M&O (2000c) and CRWMS M&O (2000g) will be addressed at that time.

3.3.11.4.4 Model Uncertainty Is Characterized and Propagated through the Model Abstraction

Overall, the current information, along with agreements reached between DOE and NRC (Section 3.3.11.5), is sufficient to conclude that the necessary information will be available at the time of a potential license application to assess airborne transport of radionuclides with respect to model uncertainty being characterized and propagated through the model abstraction.

DOE notes that there are uncertainties in the use of the ASHPLUME model, and this model cannot be used to capture the total range of eruption conditions that may occur in the Yucca Mountain region (CRWMS M&O, 2000a). This is correct: ASHPLUME can only model the violent strombolian phases of future Yucca Mountain region basaltic volcanic eruptions. One way to approach this limitation is to assume that only the violent strombolian phase of a cone-building eruption will result in a significant dose to the reasonably maximally exposed individual. This assumption is the current approach, and eruption durations are shortened appropriately (CRWMS M&O, 2000a).

Alternative models, such as PUFF and the Gas-Thrust models (CRWMS M&O, 2000c), are currently not implemented. This is a potential shortcoming in three respects. First, the input parameters most easily gleaned from the volcanological literature (e.g., initial volatile content and magma density) (CRWMS M&O, 2000a) are not directly input into ASHPLUME because it is not a physical abstraction; rather, ASHPLUME is empirical. This limitation means it is not possible to evaluate the effects of variation of some physical parameters (e.g., initial volatile content) directly to expected dose to the reasonably maximally exposed individual. As DOE has demonstrated that the ASHPLUME code can reasonable replicate analog eruptions (CRWMS M&O, 2000g), this concern has been generally alleviated. Second, because ASHPLUME is an empirical model, it is difficult to gain confidence in the manner that ASHPLUME treats high-level waste dispersion (CRWMS M&O, 2000a). Although it may be possible for DOE to bound this model uncertainty with sensitivity analyses, this has not yet been reported, although DOE agreed to conduct some sensitivity studies.[4] Third, there is potential that the repository engineered system may have substantial impact on the near-surface flow of magma. Magma flow through drifts, for example, may substantially change the mass flow and eruption velocity, resulting in altered airborne transport of high-level waste. The current version of ASHPLUME cannot account for these physical processes. DOE agreed to evaluate how the repository itself may modify flow conditions and, therefore, the eruptive characteristics.[5] Depending on the results of this analysis, it may be necessary to reevaluate, and possibly modify, the ASHPLUME code to account for these changes in physical processes.

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[4]Schlueter, J. "U.S. Nuclear Regulatory Commission/U.S. Department of Energy Technical Exchange and Management Meeting on Igneous Activity (August 29–31, 2000)." Letter (October 23) to S. Brocoum, DOE. Washington, DC: NRC. 2000.

[5]Reamer,C.W. "U.S. Nuclear Regulatory Commission/U.S. Department of Energy Technical Exchange and Management Meeting on Igneous Activity (September 5, 2001)." Letter (September 12) to S. Brocoum, DOE. Washington, DC: NRC. 2001.

The staff note that DOE conceptually evaluated the PUFF code based on descriptions in the scientific literature, but could not obtain a working version of the code from its originators. DOE concluded, however, that the code was not designed to model atmospheric transport and settling of waste and ash and, therefore, is not appropriate for current programmatic needs. (CRWMS M&O, 2000c).

The Suzuki (1983) model does not attempt to quantify the thermo-fluid dynamics of volcanic eruptions. The more recent class of models, pioneered by Woods (1988), concentrates on the bulk thermophysical properties of the column, defining a gas-thrust region near the vent and a convective region above, within which the thermal contrast between the atmosphere and the rising column results in the entrainment of air and buoyancy forces that loft particles upward. In contrast to Suzuki (1983), this class of models results in a highly nonlinear velocity profile within the ascending column. This difference can have a profound effect on the ascent height of high-level waste particles in an ascending eruption column and ensuing dispersion in the accessible environment (Hill and Connor, 2000). DOE considered the Gas-Thrust model, but concluded that the parameter β has a similar effect (CWRMS M&O, 2000c). If DOE continues to use a value of β similar to that used in its demonstration that the ASHPLUME code can replicate natural eruptions (CWRMS M&O, 2000g), this concern is generally alleviated.

Less energetic stages of a cinder-cone-forming eruption produce weak plumes that bend over as they rise because of wind advection. Sparks, et al. (1997) note that these weak plumes can remain highly organized as they are advected downwind. Such plumes can form convection cells or retain a puffy character with little entrainment and mixing with air. Thus, sedimentation out of these plumes may be slower than expected using the diffusion-advection equation. For example, although the 1995 eruption of Cerro Negro produced a relatively small volume of tephra {3×10^6 m^3 [1×10^8 ft^3]} in a column that rose to only 2–2.5 km [1.2–1.5 mi], ash-fall deposits 20 km [12 mi] downwind were 0.5 cm [0.2 in] (Hill, et al., 1998). Eruptions of this magnitude are capable of effecting peak annual total effective dose equivalents for individuals located 20 km [12 mi] from a repository-penetrating volcanic eruption (Hill and Connor, 2000). Clearly, realistic consequence analyses will be needed to evaluate dose from large, convective eruptions that ascend to atmospheric levels of neutral buoyancy as well as smaller eruptions with column ascent limited by prevailing winds. Finally, changes in the physics of the eruption caused by the development of complex near-surface magma flow in the repository can be incorporated in total system performance assessment.

In summary, both DOE and NRC can demonstrate that the ASHPLUME code, as implemented, can reasonably replicate a natural analog eruption (Hill et al., 1998, and CRWMS M&O, 2000g). It is recognized, however, that the changes in physics of an eruption, because of the interactions with the repository, may necessitate modifications to the code. This can not be determined until the analyses, being conducted under the Volcanic Disruption of the Waste Package Integrated Subissue have been completed.[6] Also, the basis for the incorporation ratio is the observation of incorporation of xenoliths in natural flows and eruptions; however, further

[6]Reamer,C.W. "U.S. Nuclear Regulatory Commission/U.S. Department of Energy Technical Exchange and Management Meeting on Igneous Activity (September 5, 2001)." Letter (September 12) to S. Brocoum, DOE. Washington, DC: NRC. 2001.

work is needed by both DOE and NRC to evaluate if the incorporation ratio can be justified, and if not, which alternative method should be used as a substitute.[7] The accuracy of the air transport models, however, may not be that significant in evaluating total risk. The air and water transport of the ash and waste particles from the area of deposition to the area of the reasonably maximally exposed individual, with subsequent exposure of the reasonably maximally exposed individual, may overshadow the effect of uncertainty in the air transport during the eruption. Ash redistribution is being evaluated in the Radionuclide Redistribution in Soil Integrated Subissue.[8] Therefore, to get a reasonably accurate evaluation of the risk from a volcanic eruption, work for these three integrated subissues needs to be integrated and correlated. There are agreements in place in all three integrated subissues to cover these concerns as they relate to model uncertainty.

3.3.11.4.5 Model Abstraction Output Is Supported by Objective Comparisons

Overall, the current information, along with the agreements reached between DOE and NRC (Section 3.3.11.5), is sufficient to conclude that the necessary information will be available at the time of a potential license application to assess airborne transport of radionuclides with respect to model abstraction output being supported by objective comparisons.

Verification of ASHPLUME was provided, in part, by Hill, et al. (1998) in their analysis of the 1995 eruption of the Cerro Negro volcano in Nicaragua. DOE has performed a similar analysis. As demonstrated in Figure 6 of CRWMS M&O (2000g), the ASHPLUME code, as implemented by DOE, can also reasonable replicate the 1995 Cerro Negro eruption. NRC, therefore, considers this concern closed (Igneous Activity Agreement 2.04). In addition, DOE considers Cerro Negro as an analog for the eruption that could occur at the Yucca Mountain site and will document this in a revision to CRWMS M&O (2000a) (Igneous Activity Agreement 2.04).[9]

The questions remaining about the use of the ASHPLUME model are related to the incorporation and transport of high-level waste in the eruption column and dispersal in the volcanic plume. Uncertainty in this parameter distribution results from the lack of natural analogy in the geologic record. Basaltic eruptions that build cinder cones show dramatic variations in energy, duration, and style. Numerical models that quantify the physics of these eruptions have reached a stage of development that allows exploration of the parameters governing these variations. Thus, many of the nuances of observed eruption columns and their deposits can now be understood in terms of fundamental physical processes (e.g., Sparks, et al., 1997). Such an understanding is important for volcanic risk assessment related to the proposed Yucca Mountain repository because there are no observations

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[7]Reamer,C.W. "U.S. Nuclear Regulatory Commission/U.S. Department of Energy Technical Exchange and Management Meeting on Igneous Activity (September 5, 2001)." Letter (September 12) to S. Brocoum, DOE. Washington, DC: NRC. 2001.

[8]Ibid.

[9]Schlueter, J. "U.S. Nuclear Regulatory Commission/U.S. Department of Energy Technical Exchange and Management Meeting on Igneous Activity (August 29–31, 2000)." Letter (October 23) to S. Brocoum, DOE. Washington, DC: NRC. 2000.

analogous to the behavior of dense high-level waste particles in eruption columns, and no appropriate analogs have been identified. There also is considerable uncertainty in how to simulate the entrainment and dispersal of high-level waste in eruption columns. Physically accurate eruption column models provide an opportunity to extend our understanding of tephra plumes to encompass the distribution and deposition of dense high-level waste particles in tephra deposits. In these circumstances, application of physically accurate models is a fundamental step in estimating risk. DOE will need to present an acceptable level of analysis that captures essential details of volcanic ash-plume dispersion and the expected dose resulting from transport of high-level waste in volcanic ash plumes. DOE recognizes this concern and has agreed to describe the methodology it will be using in its models to account for waste incorporation, including possible particle aggregation.[10]

In summary, DOE has acceptably demonstrated that the ASHPLUME code, as implemented by DOE, can reasonable replicate a natural basaltic volcanic eruption, and has agreed to provide the necessary information on high-level waste incorporation to demonstrate that the code has a sound technical basis. It is recognized that there is no natural volcanic analog that can be used to demonstrate that this part of the model abstraction is supported by objective comparisons; therefore, accurate modeling of the physical process will be necessary.

3.3.11.5 Status and Path Forward

Table 3.3.11-1 provides the status of all key technical issue subisses, referenced in Section 3.3.11.2 for the Airborne Transport of Radionuclides Integrated Subissue. The table also provides the related DOE and NRC agreements pertaining to the Airborne Transport of Radionuclides Integrated Subissue. The agreements listed in the table are associated with one or all five generic acceptance criteria discussed in Section 3.3.11.4. Note that the status and the detailed agreements (or path forward) pertaining to all the key technical issue subissues are provided in Table 1.1-2 and Appendix A.

The DOE-proposed approach, together with the DOE agreements to provide NRC with additional information (through specified testing, analysis, and the like), acceptably addresses the NRC questions so that no information beyond that provided, or agreed to, will likely be required at the time of a potential license application.

[10]Reamer, C.W. "U.S. Nuclear Regulatory Commission/U.S. Department of Energy Technical Exchange and Management Meeting on Igneous Activity (September 5, 2001)." Letter (September 12) to S. Brocoum, DOE. Washington, DC: NRC. 2001.

Table 3.3.11-1. Related Key Technical Issue Subissues and Agreements

Key Technical Issue	Subissue	Status	Related Agreements*
Igneous Activity	Subissue 2—Consequences of Igneous Activity	Closed-pending	IA.2.01 IA.2.02 IA.2.03 IA.2.04 IA.2.09 IA.2.20
Total System Performance Assessment and Integration	Subissue 1—System Description and Demonstration of Multiple Barriers	Closed-pending	None
	Subissue 2—Scenario Analysis and Event Probability	Closed-pending	TSPAI.2.02
	Subissue 3—Model Abstraction	Closed-pending	None
	Subissue 4—Demonstration of Compliance with the Postclosure Public Health and Environmental Standards	Closed-pending	None

*Related DOE and NRC agreements are associated with one or all five generic acceptance criteria.

3.3.11.6 References

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3.3.12 Representative Volume

3.3.12.1 Description of Issue

The Representative Volume Subissue addresses the effects of well pumping on the radionuclide concentrations in the extracted groundwater at the receptor location. Relationship of this integrated subissue to other integrated subissues is depicted in Figure 3.3.12-1. The overall organization and identification of all the integrated subissues are depicted in Figure 1.1-2. DOE description and technical bases for abstraction of dilution of radionuclides in groundwater due to well pumping are documented in CRWMS M&O (2000a,b). This section provides a review of the abstractions of dilution of radionuclides in groundwater due to well pumping that DOE incorporated in its total system performance assessment.

3.3.12.2 Relationship to Key Technical Issue Subissues

The Representative Volume Integrated Subissue incorporates subject matter previously captured in the following key technical issue subissues:

- Unsaturated and Saturated Flow Under Isothermal Conditions: Subissue 5—Saturated Zone Flow and Dilution Processes (NRC, 1999)
- Total System Performance Assessment and Integration: Subissue 1—System Description and Demonstration of Multiple Barriers (NRC, 2000)
- Total System Performance Assessment and Integration: Subissue 2—Scenario Analysis and Event Probability (NRC, 2000)
- Total System Performance Assessment and Integration: Subissue 3—Model Abstraction (NRC, 2000)
- Total System Performance Assessment and Integration: Subissue 4—Demonstration of Compliance with the Postclosure Public Health and Environmental Standards (NRC, 2000)

The subissues of the key technical issue formed the bases for the previous versions of the issue resolution status reports and also were the bases for technical exchanges with DOE, where agreements were reached on what additional information DOE needed to provide to resolve the subissue. The resolution status of this integrated subissue is based on the resolution status of each of the contributing key technical issue subissues. The subsequent sections incorporate applicable portions of these key technical issue subissues, however, no effort was made to explicitly identify each subissue.

3.3.12.3 Importance to Postclosure Performance

One aspect of risk-informing the NRC review was to determine how this integrated subissue is related to the DOE repository safety strategy. In the postclosure section of

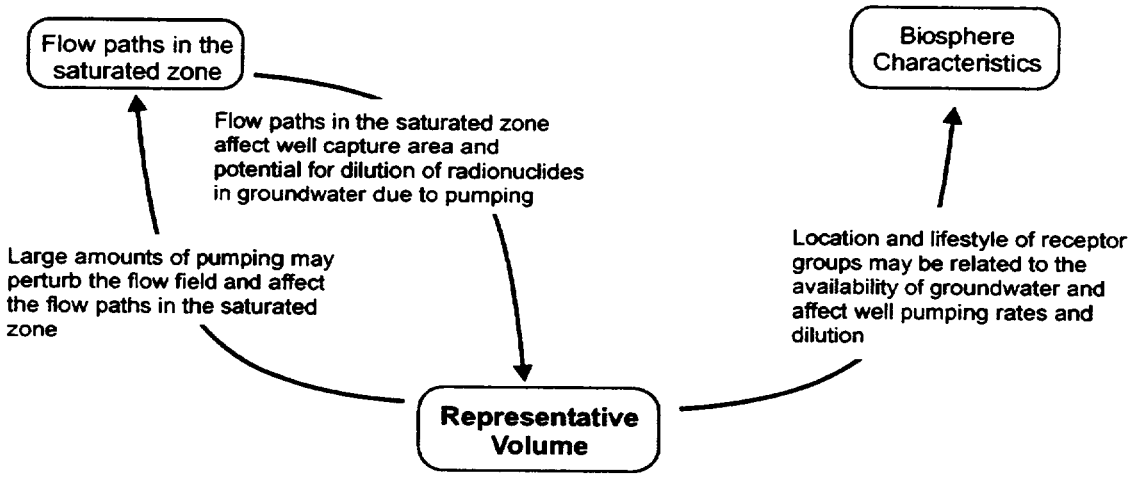

Figure 3.3.12-1. Diagram Illustrating the Relationship Between Representative Volume and Other Integrated Subissues

CRWMS M&O (2000c, Section 4.2.8), DOE concludes that its performance estimates were not very sensitive to dilution of radionuclides in groundwater due to well pumping. Based on that assessment, DOE did not consider dilution of radionuclides in groundwater due to well pumping to be a principal factor in its postclosure safety case. In the total system performance assessment model for site recommendation that DOE adopted, however, it is assumed that all radionuclides crossing the compliance boundary will be captured by pumping wells and diluted into the volume pumped (i.e., dilution volume). The sensitivity analyses DOE conducted (CRWMS M&O, 2000d, Figure 5.2-16) indicate that the calculated dose is directly affected by the pumping volume, and that increases or decreases in the pumping volume produce a proportional reduction or increase, respectively, in the calculated dose. Therefore, based on the approach DOE adopted in the total system performance assessment for site recommendation, NRC staff consider the dilution of radionuclides due to well pumping, including the pumping volume by the group containing the reasonably maximally exposed individual, important to the calculated dose.

3.3.12.4 Technical Basis

NRC developed a Yucca Mountain Review Plan (NRC, 2002) that is consistent with the acceptance criteria and review methods found in previous issue resolution status reports. A review of DOE approaches for including dilution of radionuclides in groundwater due to well pumping in total system performance assessment abstractions is provided in the following subsections. The review is organized according to the five acceptance criteria identified in Section 1.5: (i) System Description and Model Integration Are Adequate, (ii) Data Are Sufficient for Model Justification, (iii) Data Uncertainty Is Characterized and Propagated Through the Model Abstraction, (iv) Model Uncertainty Is Characterized and Propagated Through the Model Abstraction, and (v) Model Abstraction Output Is Supported by Objective Comparisons.

3.3.12.4.1 System Description and Model Integration Are Adequate

Overall, the current information, along with agreements reached between DOE and NRC (Section 3.3.12.5), is sufficient to conclude that the necessary information will be available at the time of a potential license application to assess dilution of radionuclides in groundwater due to well pumping with respect to system description and model integration.

DOE treats dilution of radionuclides in groundwater due to well pumping as an included feature, event, and process in CRWMS M&O (2001, Subsection 6.2.23). To assess dilution of radionuclides in groundwater due to well pumping, DOE assumes the future population in the Yucca Mountain area is represented by a farming community located in the Amargosa Valley region, at and beyond the compliance boundary (CRWMS M&O, 2000b, Section 6.2.4). Radionuclide concentrations in the pumped groundwater are determined by dividing the radionuclide mass delivered to the biosphere per year (i.e., the radionuclide mass arriving at the compliance boundary assuming complete capture) by the groundwater volume extracted per year to meet water demand of the farming community (CRWMS M&O, 2000a, Section 3.6.3.3.4).

DOE assumes that all the radionuclide mass reaching the compliance boundary will be captured by the pumping wells, and the radionuclide mass is distributed uniformly in the total volume of groundwater used by the farming community. Although it is reasonable to expect variations in radionuclide concentrations among spatially distributed pumping wells in the community, redistribution of radionuclides along multiple pathways in the biosphere would lead to homogenization of dose to the reasonably maximally exposed individual. This assumption implies considerable sharing of produce and resources within the farming community.

The DOE approach is consistent with the provisions for disposal of high-level waste for Yucca Mountain (10 CFR Part 63). One of the criteria provided in the regulations to characterize the reasonably maximally exposed individual is that the individual uses well water with *average* concentrations of radionuclides [10 CFR 63.312(c)]. Furthermore, the water demand of the farming community is also *specified* in the regulations at 3.7×10^6 m^3 [3,000 acre-ft] [10 CFR 63.312(c)].

In summary, available information for the saturated zone, from the saturated zone process model report and supporting analysis and model reports, is sufficient to (i) characterize the dilution of radionuclides in groundwater due to well pumping and (ii) abstract dilution of radionuclides in groundwater due to well pumping in total system performance assessment analyses.

3.3.12.4.2 Data Are Sufficient for Model Justification

Overall, the current information, along with agreements reached between DOE and NRC (Section 3.3.12.5), is sufficient to conclude that the necessary information will be available at the time of a potential license application to assess dilution of radionuclides in groundwater due to well pumping with respect to data being sufficient for model justification.

Because complete radionuclide mass capture at the compliance boundary is assumed, data to describe the spatial distribution of mass transport in the saturated zone are not used in the model abstraction for dilution by well pumping. Estimates of future groundwater pumping rates are based on a combination of data from a 1997 survey of groundwater pumping in Nye County, Nevada (State of Nevada, 1997), and 1990 census data (U.S. Census Bureau, 1999). These data were used to estimate a range of present-day, per-farm pumping rates. DOE chose the size of the hypothetical farming community assumed for the future to be reasonably consistent with 64 FR 8640, which indicates that the future farming community should be considered to contain approximately 100 people living on 15–25 farms. DOE interpreted 64 FR 8640 to mean consideration of either a farming community inhabited by 100 people or a farming community composed of 15–25 farms.

Notwithstanding that there may be variations in the calculated dose among different individual members of the farming community, the individual protection standard is based on the average water use. To the extent that the total system performance assessment will ultimately assume complete radionuclide capture, and a prespecified total water demand provided in the regulations {i.e., 3.7×10^6 m^3/yr [3,000 acre-ft/yr]}, the rates of water pumping by individual farms and the farm sizes are of no real consequence from a regulatory standpoint.

In summary, the NRC staff consider the available data adequate to support the DOE conceptual model for dilution of radionuclides in groundwater due to well pumping, and for model abstraction in performance assessment.

3.3.12.4.3 Data Uncertainty Is Characterized and Propagated Through the Model Abstraction

Overall, the current information, along with agreements reached between DOE and NRC (Section 3.3.12.5), is sufficient to conclude that the necessary information will be available at the time of a potential license application to assess dilution of radionuclides in groundwater due to pumping with respect to data uncertainty being characterized and propagated through model abstraction.

Because DOE assumes total radionuclide mass capture at the compliance boundary, the only data uncertainties are associated with two parameters that control the volume of water extracted: the number of farms and the groundwater extraction rate per farm. To account for uncertainty, lower-limit, expected, and upper-limit water use rates were calculated for scenarios of 15, 20, and 25 farms in Amargosa Valley. The lower-limit, expected, and upper-limit rates were based on the 5th percentile, mean, and 95th percentile estimates of per-farm water use rate from the State of Nevada 1997 survey. This approach produced nine discrete pumping rates that are sampled stochastically in total system performance assessment calculations (CRWMS M&O, 2000b, Table 3-28).

To the extent that the total system performance assessment will ultimately assume complete radionuclide capture, and a prespecified total water demand provided in the regulations {i.e., 3.7×10^6 m^3/yr [3,000 acre-ft/yr]}, the rates of water pumping by individual farms and the farm sizes are of no real consequence from a regulatory standpoint.

In summary, the DOE approach—incorporating data uncertainty into total system performance assessment abstractions by sampling nine discrete pumping and dilution scenarios—is sufficient to provide information in a potential license application.

3.3.12.4.4 Model Uncertainty Is Characterized and Propagated Through the Model Abstraction

Overall, the current information, along with agreements reached between DOE and NRC (Section 3.3.12.5), is sufficient to conclude that the necessary information will be available at the time of a potential license application to assess dilution of radionuclides in groundwater due to well pumping with respect to model uncertainty being characterized and propagated through model abstraction.

Groundwater data used to estimate the per-farm groundwater usage are for only a single year, 1997. A potential model uncertainty is that groundwater usage in Amargosa Valley may change (increase or decrease) considerably from that assumed for the model abstraction. Nye County representatives have stated, for example, that water demands in Amargosa Valley are expected to increase in the near future.[1] DOE did not explicitly consider changes in groundwater demand in the future in Amargosa Valley in the total system performance assessment.

NRC staff recognize that these uncertainties are potentially important and could result in doses that are different than the calculated dose. An increase in the total groundwater pumping in the Amargosa Valley area would result in a reduced expected dose, because of a greater water volume available for dilution of the radionuclide mass. A decrease in the pumping volume could lead to an increase in the dose. The NRC staff position is that the dose calculation for the safety case is based on the radionuclide capture and total groundwater pumping as defined by the regulations for the proposed high-level waste repository. As it has been stated, the total annual water demand used to evaluate the dose for individual members of the affected population is specified in the regulations to be 3.7×10^6 m^3 [3,000 acre-ft]. As for radionuclide capture, DOE assumes that all the radionuclide mass reaching the compliance boundary in the saturated zone will be captured. For a fixed water demand and radionuclide mass, the calculated dose required by the regulations is virtually unaffected by the groundwater pumping uncertainty.

In addition, it is noted that the regulations in 10 CFR Part 63 preclude projections of changes in society, biosphere (other than climate), human biology, or increases or decreases in human knowledge [10 CFR 63.305(b)].

In summary, the DOE approach is appropriate for inclusion in a potential license application.

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[1]Buqo, T. *Comments made at Nuclear Waste Technical Review Board meeting, January 31, 2001*. Amargosa Valley, Nevada. 2001.

3.3.12.4.5 Model Abstraction Output Is Supported by Objective Comparisons

Overall, the current information, along with agreements reached between DOE and NRC (Section 3.3.12.5), is sufficient to conclude that the necessary information will be available at the time of a potential license application to assess dilution of radionuclides in groundwater due to pumping with respect to model abstraction output being supported by objective comparisons.

As indicated in Section 3.3.12.4.2, estimates of groundwater pumping rates are based on a survey of groundwater pumping in Nye County and census data. In addition, the saturated zone flow model provides some support for the abstraction in the sense that the estimated groundwater withdrawal rate can be sustained by the available inflow. Specifically, estimates of the expected annual withdrawal rate for a community of 25 farms total approximately 3.08×10^6 m^3/yr [2,500 acre-ft/yr] (CRWMS M&O, 2000b, Table 3-28), whereas the saturated zone flow model calculates a total groundwater flux of approximately 23.43×10^6 m^3/yr [19,000 acre-ft/yr] into Amargosa Valley (CRWMS M&O, 2000a).

In summary, the DOE approach for treatment of dilution of radionuclides in groundwater due to well pumping in the total system performance assessment considers available geologic, hydrologic, and geochemical data.

3.3.12.5 Status and Path Forward

Table 3.3.12-1 provides the status of all key technical issue subissues, referenced in Section 3.3.12.2, for the Representative Volume Integrated Subissue. The table also provides the related DOE and NRC agreements pertaining to the Representative Volume Integrated Subissue. The agreements listed in the table are associated with one or all five generic acceptance criteria discussed in Section 3.3.12.4. Note that the status and the detailed agreements (or path forward) pertaining to all the key technical issue subissues are provided in Table 1.1-3 and Appendix A.

The DOE-proposed approach, together with the DOE agreements to provide NRC with additional information (through specified testing, analyses, and the like), acceptably addresses the NRC questions so that no information beyond that provided, or agreed to, will likely be required at the time of a potential license application.

Table 3.3.12-1. Related Key Technical Issue Subissues and Agreements

Key Technical Issue	Subissue	Status	Related Agreements*
Unsaturated and Saturated Flow Under Isothermal Conditions	Subissue 5—Saturated Zone Flow and Dilution Processes	Closed-Pending	None
Total System Performance Assessment and Integration	Subissue 1—System Description and Demonstration of Multiple Barriers	Closed-Pending	None
	Subissue 2—Scenario Analysis and Event Probability	Closed-Pending	TSPAI.2.01 TSPAI.2.02 TSPAI.2.03

Table 3.3.12-1. Related Key Technical Issue Subissues and Agreements (continued)			
Key Technical Issue	**Subissue**	**Status**	**Related Agreements***
Total System Performance Assessment and Integration	Subissue 3—Model Abstraction	Closed-Pending	None
	Subissue 4—Demonstration of Compliance with the Postclosure Public Health and Environmental Standards	Closed-Pending	None
*Related DOE and NRC agreements are associated with one or all five generic acceptance criteria.			

3.3.12.6 References

CRWMS M&O. "Saturated Zone Flow and Transport Process Model Report." TDR–NBS–HS–000001. Revision 00. Las Vegas, Nevada: CRWMS M&O. 2000a.

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3.3.13 Redistribution of Radionuclides in Soil

3.3.13.1 Description of Issue

The Redistribution of Radionuclides in Soil Integrated Subissue addresses the movement of radionuclides following deposition on the ground, either through surface application of groundwater or settling of volcanic ash following an eruption. Redistribution affects the quantity and concentrations of radionuclides accessible to receptors in the biosphere, and therefore, influences the dose from radionuclides deposited on the ground. The relationships between this integrated subissue and other integrated subissues are depicted in Figure 3.3.13-1. The overall organization and identification of all the integrated subissues are depicted in Figure 1.2-2.

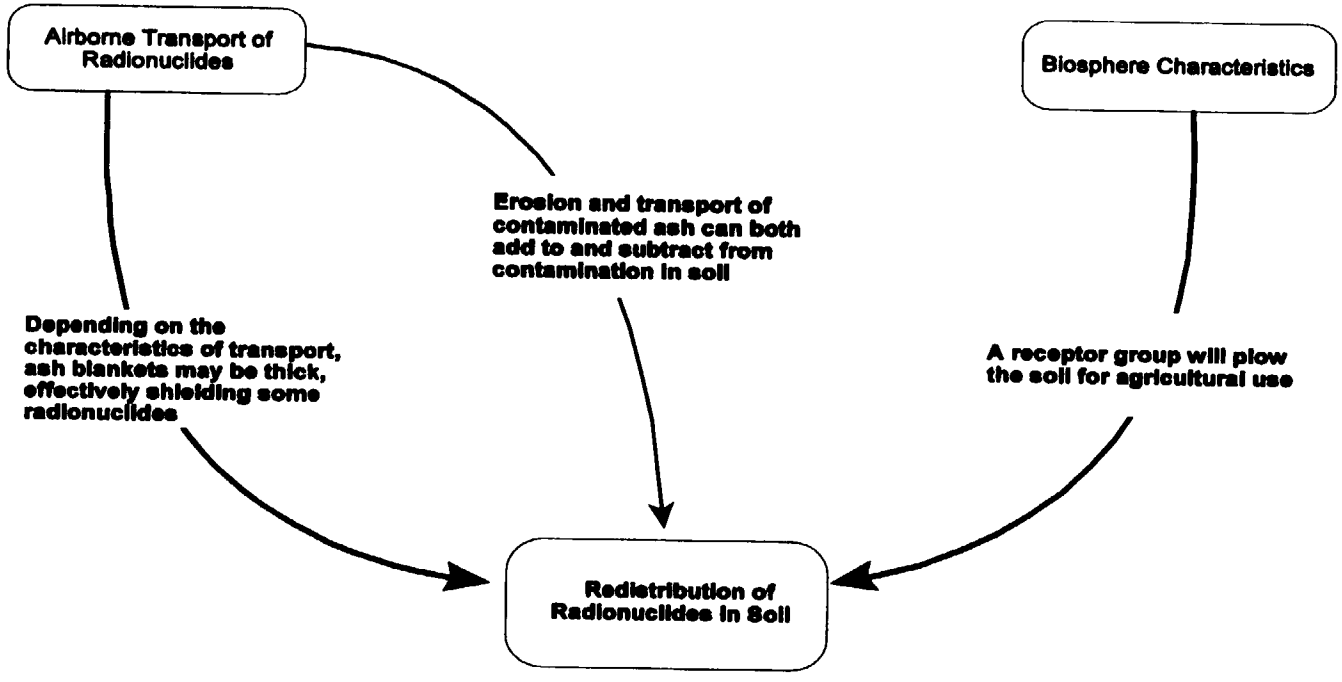
The DOE description and technical basis for the redistribution of radionuclides in soil abstractions are documented in CRWMS M&O (2000a,b), and five supporting analysis and model reports, (CRWMS M&O, 2000c–g). Portions of additional analysis and model reports are reviewed to the extent they contain data or analyses that support the proposed total system performance assessment abstractions. This section provides a review of the abstraction of redistribution of radionuclides in soil incorporated by DOE in its Total System Performance Assessment.

3.3.13.2 Relationship to Key Technical Issue Subissues

The Redistribution of Radionuclides in Soil Integrated Subissue incorporates subject matter previously captured in the following five key technical issue subissues:

- Igneous Activity: Subissue 2—Consequences of Igneous Activity (NRC, 1999)
- Total System Performance Assessment and Integration: Subissue 1—System Description and Demonstration of Multiple Barriers (NRC, 2000)
- Total System Performance Assessment and Integration: Subissue 2—Scenario Analysis and Event Probability (NRC, 2000)
- Total System Performance Assessment and Integration: Subissue 3—Model Abstraction (NRC, 2000)
- Total System Performance Assessment and Integration: Subissue 4—Demonstration of Compliance with the Postclosure Public Health and Environmental Standards (NRC, 2000)

The key technical issue subissues formed the basis for the previous versions of the issue resolution status reports and also were the basis for technical exchanges with DOE where agreements were reached on what additional information DOE needed to provide to resolve



* Relationships in bold are identified in the text

Figure 3.3.13-1. Diagram Illustrating the Relationship Between Redistribution of Radionuclides in Soil and Other Integrated Subissues

the subissue. The resolution status of this integrated subissue is based on the resolution status of each of the contributing key technical issue subissues.

The subsequent sections incorporate applicable portions of these key technical issue subissues, however, no effort was made to explicitly identify each subissue.

3.3.13.3 Importance to Postclosure Performance

The importance of appropriately assessing the effects of igneous activity on the repository system is illustrated in CRWMS M&O (2000a). This document indicates that igneous activity is the only natural process that can cause waste package failure and dose to the reasonably maximally exposed individual (called the receptor from here on) during the regulatory period of interest. Processes such as the redistribution of radionuclides in soil following an igneous event would be evaluated to ensure that models predicting the dose from igneous activity do not underestimate the risk associated with igneous activity.

Following an igneous event at the proposed repository location, a submillimeter-to-decimeter thick deposit will be deposited at the receptor location. For any future eruption through the proposed repository site, some amount of tephra will be deposited on slopes that are part of the Fortymile Wash drainage basin.

Through time, the high-level-waste-bearing tephra will be mobilized off these slopes through, and into, the Fortymile Wash drainage system. Sediment residence times in the confined channel of Fortymile Wash should be short relative to residence times on most hill slopes around Yucca Mountain. Bed-load sediments will move down the main Fortymile Wash drainage during periods of high water flow, with suspended-load sediments mobilized by relatively lower water flow. Just north of Highway 95, the main Fortymile Wash drainage changes from a steep-sided channel to a broad, braided fan system. This location represents the point below which significant long-term sediment deposition occurs within the Fortymile Wash drainage system. Sediment deposition and alluvial aggradation continue south into the Amargosa Desert and overlap the general area of the receptor location. This deposition of remobilized tephra could counteract the loss of radionuclides at the receptor location due to local erosion and lead to a net accumulation of radionuclides for some period of time following the event.

For the groundwater pathway, redistribution of radionuclides in soil affects the concentration of radionuclides in the surface soil. Irrigation of agricultural fields through multiple growing seasons can lead to a buildup of radionuclides in the soil. DOE assessments indicated that for most radionuclides, buildup of radionuclides in the soil has a minor effect on the calculated dose conversion factors (CRWMS M&O, 2000b), with the biosphere dose conversion factor increasing by less than a factor of two for most radionuclides, even for buildup times on the order of thousands of years.

3.3.13.4 Technical Basis

NRC has developed a Yucca Mountain Review Plan (NRC, 2002) that is consistent with the acceptance criteria and review methods found in the previous issue resolution status reports. A review of DOE approaches for including redistribution of radionuclides in soil in total system performance assessment abstractions is provided in the following subsections. The review is organized according to the five acceptance criteria identified in Section 1.5 as follows: (i) System Description and Model Integration Are Adequate, (ii) Data Are Sufficient for Model Justification, (iii) Data Uncertainty Is Characterized and Propagated Through the Model Abstraction, (iv) Model Uncertainty Is Characterized and Propagated Through the Model Abstraction, and (v) Model Abstraction Output Is Supported by Objective Comparisons.

In DOE (1998), analysis of redistribution of radionuclides in soil following an igneous event accounted for only the removal of radionuclides at the receptor location due to erosion, leaching, and radioactive decay of the deposited material. DOE has not developed a model to determine the effects of remobilization of radionuclides deposited upstream of the receptor following an igneous event. Instead, DOE makes several conservative assumptions about other processes and states that these conservative assumptions will bound the effects of remobilization of radionuclides.

3.3.13.4.1 System Description and Model Integration Are Adequate

Overall, the current information, along with agreements reached between DOE and NRC, (Section 3.3.13.5), is sufficient to conclude that the necessary information will be available at the time of a potential license application to assess redistribution of radionuclides in soil with respect to system description and model integration.

The features, events, and processes relevant to the Redistribution of Radionuclides in Soil Integrated Subissue (Dose 2) are listed in Section 3.2.1 of this report. The DOE technical bases for including or excluding the features, events, and processes related to redistribution of radionuclides in soil are provided in the analysis and model report (CRWMS M&O, 2000c). The following paragraphs provide a brief description of the conceptual and modeling approaches developed by DOE to integrate features, events, and processes that affect the redistribution of radionuclides in soil into the total system performance assessment abstraction.

The approach and technical basis for the methodology used to account for the effects of remobilization of radionuclides by aeolian and fluvial processes following deposition by an igneous event are documented in CRWMS M&O (2000a). DOE proposes to bound the potential effects of remobilization by (i) assuming that the wind blows toward the receptor throughout every modeled eruption; (ii) using transition-phase biosphere dose conversion factors for all time following the igneous event; and (iii) using biosphere dose conversion factors calculated for a thin [1-cm (0.39-in)] ash layer, neglecting any dilution of radionuclides in clean soil below the tephra deposit. The first assumption is considered conservative because it neglects variations in wind direction at the repository location, which could cause smaller quantities of radionuclides to be deposited initially at the receptor location. Scoping calculations in Hill and Connor (2000), however, suggest that the long-term accumulation of remobilized tephra may exceed original fallout thicknesses by a factor of 10. The second assumption

overestimates doses by maintaining the relatively high airborne particle concentrations that would be expected for a number of years following an igneous eruption for all time after the volcanic event. This conservatively neglects the processes that could decrease the amount of resuspendable ash particles in the deposit, such as wind removal and rainwater infiltration. Offsetting that conservatism is the potential for a net influx of resuspendable ash through wind and water remobilization. Finally, the third assumption is conservative because it assumes that all radionuclides are concentrated in the upper centimeter of the deposit when calculating dose from the deposited radionuclides. This increases the dose from direct exposure and inhalation pathways for thicker deposits. Furthermore, when calculating removal due to erosion from these deposits, DOE assumes that deposited radionuclides are spread throughout a 15-cm [6-in] soil layer, to reduce the quantity of radionuclides removed each year. DOE agreed to provide further justifications, including supporting data, for all of its assumptions and modeling approaches.[1]

The approach for calculating the change in concentration of radionuclides in the soil following deposition is described in the analysis and model report (CRWMS M&O, 2000d) and in the process model report (CRWMS M&O, 2000b). The dynamics of the radionuclide concentration in the top layer of soil are governed by a conservation equation where the rate of change in radionuclide concentration in a volume of soil is equal to the quantity flowing in (from either irrigation or ash fall) minus the amount being removed. Mechanisms of potential radionuclide removal from the soil include radioactive decay, plant uptake, leaching into the deeper soil layer and physical loss of soil (i.e., erosion by wind and water). Countering the removal of radionuclides from the soil in the groundwater release scenario is the continual addition of radionuclides from irrigation. The igneous scenario assumes there is no input of radioactive material into the system following the initial deposition. Buildup of radionuclides in soil was modeled using the GENII-S Version 1.485 computer code (Napier, et al., 1988). GENII-S uses a K_d approach to calculate a leaching factor based on a formula derived in Baes and Sharp (1983), which determines the fraction of a given radionuclide that leaches out of the surface soil to deeper soil depths each year. GENII-S does not account for erosion of radionuclides as a removal mechanism for radionuclides in the surface soil. GENII-S modeling predicted that the buildup of most radionuclides in the soil due to multiple years of irrigation with contaminated water would increase the biosphere dose conversion factor by less than 15 percent at equilibrium (i.e., for an infinitely long buildup time). For those radionuclides, the GENII-S prediction of the biosphere dose conversion factor for the concentration of radionuclides in the soil, once equilibrium was reached, was used in the model (CRWMS M&O, 2000b). For the remaining five radionuclides, the equilibrium concentration was calculated outside of the GENII-S code, including the erosion of the soil, and this soil buildup factor was applied to the biosphere dose conversion factor prior to fitting a distribution to the range of possible biosphere dose conversion factor outputs for sampling in the total system performance assessment. Removal of radionuclides from the tephra deposit considered the loss due to leaching for only a single year of irrigation, but included removal by erosion for all years following the eruption.

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[1]Reamer, C.W. "U.S. Nuclear Regulatory Commission/U.S. Department of Energy Technical Exchange and Management Meeting on Igneous Activity (June 21–22, 2001)." Letter (June 29) to S. Brocoum, DOE. Washington, DC: NRC. 2001.

The approach for calculating the concentration of radionuclides in the air following deposition in the soil is described in the Biosphere Process Model Report (CRWMS M&O, 2000b). The concentration of radionuclides in the air is calculated using the mass loading model in GENII-S (CRWMS M&O, 2000b). This model assumes the concentration of radionuclides on dust in the air [i.e., particle diameters $\leq 100\ \mu m$ (0.004 in)] is equivalent to the concentration of radionuclides on the ground, and all dust in the air is contaminated. This model is appropriate for situations where the contamination consists of a relatively thick deposit and is widespread such that dust that blows into the area from upwind has a similar level of contamination as dust generated locally.

Output from the DOE redistribution of radionuclides in soil is used differently in calculating dose from the groundwater pathway and air pathway. For the groundwater pathway, the redistribution of radionuclides in soil analysis is performed outside of the total system performance assessment and provides the number of years of irrigation prior to the year for which the dose is being calculated as an input value to the GENII-S code (Leigh, 1993); GENII-S then calculates the concentration of radionuclides in the soil from a unit concentration of radionuclides in the water pumped from the ground to calculate a biosphere dose conversion factor. This biosphere dose conversion factor is multiplied by the calculated time-dependent concentration of radionuclides in the water pumped from the ground to calculate the time-dependent dose. For the air pathway, the redistribution of radionuclides in soil provides the time-dependent concentration of radionuclides in the soil following an igneous event. This concentration is multiplied by a biosphere dose conversion factor derived using GENII-S with a unit concentration of radionuclides in the soil to calculate the time-dependent dose from an igneous event.

Following is a summary of staff review regarding system description and model integration. CRWMS M&O (2000b) and supporting analysis and model reports provide sufficient information about the methodology used to incorporate the effects of the redistribution of radionuclides in soil and of the couplings between models for NRC to make a regulatory decision at the time of any future license application. DOE should demonstrate that the assumptions for bounding the effects of remobilization of radionuclides following an igneous event are appropriate. The use of the K_d approach in GENII-S (Leigh, 1993) to model the leaching of radionuclides out of the surface soil is reasonable for relatively low concentrations of radionuclides in the soil, as would likely be found in the groundwater discharge scenarios. For scenarios in which higher concentrations of radionuclides may be found on the ground surface, however, a check should be performed to ensure the concentration of radionuclides leaching out of the surface soil does not exceed the solubility limit of the radionuclide (Jarzemba and Manteufel, 1997). This check does not seem to have been performed in the DOE modeling. The models used to describe the removal of radionuclides from the soil due to erosion appear to include all significant processes as long as DOE can demonstrate that the current approach to account for remobilization of tephra by wind and water is reasonable. The use of a mass-loading model to predict the concentration of radionuclides in the air is appropriate for the scenarios analyzed in the total system performance assessment. DOE agreed to provide further justifications, including supporting data, for all of its assumptions and modeling approaches, including all of the issues

above, prior to, or as part of, any potential license application.[2] NRC staff are satisfied, based on the agreements, that sufficient information will be available at the time of any potential license application review.

3.3.13.4.2 Data Are Sufficient for Model Justification

Overall, the current information, along with agreements reached between DOE and NRC (Section 3.3.13.5), is sufficient to conclude that the necessary information will be available at the time of a potential license application to assess redistribution of radionuclides in soil with respect to data being sufficient for model justification.

Detailed descriptions of the data sets used to support the models of the redistribution of radionuclides in soil are found in these analysis and model reports (CRWMS M&O, 2000d–g).

As described in CRWMS M&O (2000a), no model has been developed to describe the remobilization of radionuclides due to aeolian and fluvial processes following an igneous event. Instead, three conservative assumptions have been made to bound the effects of remobilization.

Data used to model erosion and leaching out of the surface soil following deposition are described in two analysis and model reports (CRWMS M&O, 2000d,h). The best estimates of erosion rates used in the analysis are derived from the soil loss tolerance factor, which is defined as the maximum annual rate of soil erosion that can occur while still maintaining productivity indefinitely (Troeh, et al., 1980) for the different soil types found in the vicinity of Lathrop Wells, Nevada. The soil loss tolerance factor for each soil type is taken from Brady (1984), and data on the abundance and properties of the different soils found in the proposed receptor location are from the U.S. Department of Agriculture Natural Resource Conservation Service (CRWMS M&O, 1999). A bounding value for the analysis was assumed to be zero soil loss due to the potential for improved land management techniques to minimize the loss of soil from the farm. The leaching analysis used K_d values from Sheppard and Thibault (1990) for sandy soils, which are the types of soils found in Amargosa Valley (CRWMS M&O, 1999). Estimates of precipitation at the receptor location are taken from measurements of the annual precipitation at Lathrop Wells between 1986 and 1997. Values of evapotranspiration and irrigation were based on alfalfa production in Amargosa Valley (CRWMS M&O, 2000d).

Data used to support the mass loading values are described in the analysis and model report (CRWMS M&O, 2000e). For the nominal case, average annual outdoor concentrations of PM_{10} from similar arid farming communities were used to develop a distribution of concentrations representative of the reference biosphere farming community. Analog PM_{10} concentrations were obtained from the Office of Air Quality Planning and Standards AIRSData database (EPA, 2000), which contains air quality data collected by state and local agencies and reported to EPA to monitor compliance with Federal air quality standards. Analog sites were selected

[2]Reamer, C.W. "U.S. Nuclear Regulatory Commission/U.S. Department of Energy Technical Exchange and Management Meeting on Igneous Activity (June 21–22, 2001)." Letter (June 29) to S. Brocoum, DOE. Washington, DC: NRC. 2001.

that were classified as a land use of agricultural and a location type of rural. These sites were further narrowed to limit selection to locations that had an arid climate similar to the Yucca Mountain region and little snowfall, which tends to decrease the level of airborne particulate matter. This process resulted in the selection of 5 analog sites, for which 19 measurements of annual average PM_{10} concentrations were available. The average of these measurements resulted in an annual average PM_{10} mass loading of 42 $\mu g/m^3$ [2.6×10^{-9} lb/ft^3]. This average value of PM_{10} mass loading was multiplied by the average value of the total suspended particulates to PM_{10} ratio, 2.5, which was measured in the Yucca Mountain region, to yield an annual average mass load of 105 $\mu g/m^3$ [6.5×10^{-9} lb/ft^3]. The use of this EPA database accounts for increases in airborne particulate concentration due to surface disturbing activities for time periods appropriate for a farming community. The mass load following an igneous event is higher than the nominal mass load. The annual average outdoor concentration of PM_{10} particles immediately following the eruption is assumed to be 1,000 $\mu g/m^3$ [6.2×10^{-8} lb/ft^3] based on comparison with measurements made of mass loads for different levels of disturbance (including walking/driving, outdoor play, and inside combines and farm trucks) following eruptions at Mount St. Helens and Montserrat, which had a higher concentration of fine material than would be expected from an eruption at Yucca Mountain. This mass loading value corresponds to a concentration that EPA characterizes as a level at which serious and widespread health effects occur to the general population (EPA, 1994). Data from Mount St. Helens indicate the ratio of total suspended particulates to PM_{10} is about 3.0 based on data for agricultural farming and within homes (Buist, et al., 1986). Based on data from three areas surrounding Mount St. Helens that indicated total suspended particulate values returned to preeruption values within a year of the eruption, DOE assumed that within 10 years of cessation of a volcanic eruption the concentration of resuspended particles decreases to background levels similar to that of a farming community (Bernstein, et al., 1986).

Following is a summary of staff review regarding data sufficiency and model justification. DOE needs to collect sufficient data to support the assertion that the conservative assumptions used to replace modeling of the remobilization process will bound the risk associated with igneous activity. If this assertion cannot be supported, additional data will be needed to model the remobilization process. The analysis would be strengthened by the use of site-specific K_d values instead of generic values from Sheppard and Thibault (1990) because these values can vary significantly due to variations in soil pH and other soil characteristics. Additional data are needed to support the assumption that the concentration of resuspended particles returns to background values within 10 years of cessation of an igneous event. As discussed in CRWMS M&O (2000e), data from Mount St. Helens on the rate at which particle concentrations return to nominal levels are not directly comparable to those postulated for a Yucca Mountain volcano because of (i) differences in the quantity of precipitation and snowfall between the two locations, (ii) higher concentrations of vegetation in Washington compared with the Lathrop Wells area, (iii) absence of coarser particles in the analog deposit to inhibit erosion, and (iv) lower initial mass loading values following the event at Mount St. Helens compared with estimates for Yucca Mountain and data in Hill and Connor (2000). It is not clear that increasing the observed reduction rate by a factor of 10 is sufficient to account for differences between the two locations. DOE will need to demonstrate that long-term input of fine particulates through wind and water remobilization would not significantly affect the proposed mass-load reduction factor. DOE agreed to provide further justifications, including supporting data, for all of its

assumptions and modeling approaches, including all of the issues above, prior to, or as part of, any potential license application.[3] Based on the agreements, sufficient information will be available at the time of any potential license application review.

DOE has collected sufficient and appropriate pedological, hydrological, and geochemical data to adequately define relevant parameters necessary for developing the other portions of the abstraction of redistribution of radionuclides in the soil in the total system performance assessment. DOE has adequately described how data have been used and synthesized into parameters.

3.3.13.4.3 Data Uncertainty Is Characterized and Propagated Through the Model Abstraction

Overall, the current information, along with agreements reached between DOE and NRC (Section 3.3.13.5), is sufficient to conclude that the necessary information will be available at the time of a potential license application to assess redistribution of radionuclides in soil with respect to data uncertainty being characterized and propagated through the model abstraction.

Detailed descriptions of the methodology used to characterize and propagate data uncertainty in the redistribution of radionuclides in soil abstraction are found in CRWMS M&O (2000a) and these four analysis and model reports (CRWMS M&O, 2000d–g).

DOE asserts that the conservative assumptions made in modeling the volcanism scenario bound the uncertainty associated with the process of remobilization of radionuclides deposited in areas other than the receptor location due to fluvial and aeolian processes. As such, uncertainty associated with this is not explicitly incorporated in the total system performance assessment. DOE should demonstrate that the assumptions made actually bound the effects of remobilization. DOE agreed to justify its assumptions.[4]

Uncertainty in data for the erosion and leaching of radionuclides out of the surface soil does not appear to have been appropriately incorporated into the total system performance assessment. GENII-S (Napier, et al., 1988) does not allow the user to sample the leaching factor and does not include erosion in the model. In the analysis and model report, (CRWMS M&O, 2000d), best estimate values and bounding values were developed for erosion rates and leaching factors. Best estimate values are based on the mean value of input parameters, while bounding values are based on the worst-case input values for all parameters. These values were used in two analysis and model reports (CRWMS M&O, 2000f,g), to develop a best estimate range and bounding value for the biosphere dose conversion factors. The best estimate range does not include any consideration of the variability in the K_d value, and CRWMS M&O (2000a) appears to only use this best estimate range in its modeling. Therefore, no uncertainty in the K_d value is incorporated into the results of the Total System Performance

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[3]Reamer, C.W. "U.S. Nuclear Regulatory Commission/U.S. Department of Energy Technical Exchange and Management Meeting on Igneous Activity (June 21–22, 2001)." Letter (June 29) to S. Brocoum, DOE. Washington, DC: NRC. 2001.

[4]Ibid

Assessment–Site Recommendation. Similarly, the erosion rate developed is based on the maximum erosion rate that could be maintained and allow the field to continue to be used for agriculture. It is indicated, however, that current practice in agricultural communities is to manage soil resources to maintain soil erosion losses at levels well below the established tolerable soil loss rate, making it plausible to eliminate soil erosion entirely (CRWMS M&O, 2000d). Because higher erosion rates are less conservative in the analysis, using the maximum credible erosion rate without accounting for the potential for the erosion rate to be lower in the total system performance assessment is not appropriate. DOE agreed to address this issue.[5]

Data uncertainty for the mass loading above agricultural fields and tephra deposits is explicitly incorporated in the total system performance assessment. For the nominal scenario, the uncertainty in the mass-loading factor is derived from the variation in the measured values of the annual average mass loading at the analog agricultural sites. The method used to account for the variation in the mass-loading value for the extrusive volcanism scenario in the total system performance assessment is more complex. The concentration of particulates in the air following an igneous eruption will decrease through time. As described in the previous section, DOE estimated the annual average total suspended particulates concentration in the air immediately following an igneous event to be 3,000 $\mu g/m^3$ [1.9×10^{-7} lb/ft^3] for a thick tephra deposit that will drop to nominal levels {105 $\mu g/m^3$ [6.5×10^{-9} lb/ft^3]} within 10 years. The analysis mixes temporal variability with data uncertainty by using the mean value of a loguniform distribution {864 $\mu g/m^3$ [5.3×10^{-8} lb/ft^3]} to represent the average mass loading during the first 10 years following the eruption for a thick deposit. Further, DOE argues that because thin deposits will not cause the average mass loading during 10 years to increase significantly above the nominal value, and the distribution of tephra deposit thicknesses is approximately exponential, it is reasonable to sample the value of the mass-loading parameter from a loguniform distribution between the nominal value of 105 $\mu g/m^3$ [6.5×10^{-9} lb/ft^3] and the 10-year average value above a thick deposit of 864 $\mu g/m^3$ [5.3×10^{-8} lb/ft^3] (CRWMS M&O, 2000e). Sampling from a log-uniform distribution between the nominal mass load representing a thin deposit and the average mass load for a thick deposit assumes the average mass load during the first 10 years following an event is directly proportional to the thickness of the deposit. DOE has not provided sufficient technical basis for this assumption. It seems reasonable to assert that thin deposits (i.e., less than several millimeters) will be removed relatively quickly and will not significantly influence the average mass load during the 10 years following an eruption. Once a critical thickness of deposit is reached so that the deposit is thick enough to maintain a fines-depleted shield to protect lower levels of the deposit that contain significant quantities of fines, it is likely the mass load will increase rapidly beyond this critical level, reacting more like a step function. Additional comments on the reasonableness of the range of tephra thicknesses predicted to be deposited at the receptor location are located in Section 3.2.11.4. If the minimum thickness of tephra deposit is significantly greater than currently predicted in CRWMS M&O (2000a), this methodology of sampling may not be appropriate. Finally, this methodology does not account

[5]Reamer, C.W. "U.S. Nuclear Regulatory Commission/U.S. Department of Energy Technical Exchange and Management Meeting on Igneous Activity (June 21–22, 2001)." Letter (June 29) to S. Brocoum, DOE. Washington, DC: NRC. 2001.

for the remobilization of radionuclides causing deposits at the receptor location to thicken, which would also affect whether this methodology of sampling from a range with a lower value equivalent to the nominal mass load to take credit for varying deposit thicknesses is appropriate. Demonstration that the effects of remobilization are bounded by other conservative assumptions needs to ensure that this credit for thin deposits is accounted for.

Following is a summary of staff review regarding characterization and propagation of data uncertainty. DOE needs to demonstrate that the conservative assumptions used to replace modeling of the remobilization process are appropriate. DOE has failed to explicitly incorporate the uncertainties associated with leaching and erosional rates of radionuclides into the total system performance assessment and needs to include these uncertainties in the model or demonstrate that neglecting this uncertainty will not significantly affect the results of the calculation. The mixing of temporal variability and parameter uncertainty in development of the mass loading above a tephra deposit is confusing and will only provide correct results if other time-dependent processes do not result in a significant change in the concentration of radionuclides in the soil during the 10-year period for which temporal averaging is performed. Specifically, DOE needs to demonstrate that processes to remove radionuclides from the soil (i.e., decay, erosion, and leaching) do not cause a significant change in the concentration of radionuclides in the soil during the first 10 years following the igneous eruption. DOE needs to provide further justification that its sampling from a loguniform distribution between the nominal mass load representing a thin deposit and the average mass load for a thick deposit is reasonable or conservative, accounting for the remobilization of radionuclides causing deposits at the receptor location to potentially thicken. Demonstration that the effects of remobilization are bounded by other conservative assumptions needs to ensure that this credit for thin deposits is accounted for. DOE agreed to provide further justifications, including supporting data, for all its assumptions and modeling approaches, including all of the issues above, prior to, or as part of, any potential license application.[6] Based on the agreements, sufficient information will be available at the time of any potential license application review.

3.3.13.4.4 Model Uncertainty Is Characterized and Propagated Through the Model Abstraction

Overall, the current information, along with agreements reached between DOE and NRC (Section 3.3.13.5), is sufficient to conclude that the necessary information will be available at the time of a potential license application to assess redistribution of radionuclides in soil with respect to model uncertainty being characterized and propagated through the model abstraction.

Detailed descriptions of the methodology used to characterize and propagate model uncertainty in the redistribution of radionuclides in soil abstraction are found in CRWMS M&O (2000a) and in the analysis and model report (CRWMS M&O, 2000e).

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[6]Reamer, C.W. "U.S. Nuclear Regulatory Commission/U.S. Department of Energy Technical Exchange and Management Meeting on Igneous Activity (June 21–22, 2001)." Letter (June 29) to S. Brocoum, DOE. Washington, DC: NRC. 2001.

Repository Safety After Permanent Closure

As described in CRWMS M&O (2000a), no model has been developed to describe the remobilization of radionuclides due to aeolian and fluvial processes following an igneous event. Instead, three conservative assumptions have been made to bound the effects of remobilization. DOE needs to provide justification that the methodology used to bound the effects of remobilization does not underestimate the risk from igneous activity. DOE agreed to provide the justification.[7]

The methodology used to model erosional removal of radionuclides is reasonable and sufficient, given an appropriate data set. Therefore, NRC staff agree that no alternative modeling is necessary for the erosional model. The International Atomic Energy Agency (2001) indicated that radionuclide experiments in recent years have indicated that migration of radionuclides in soil is dominated by radionuclides bound to small particles and that the sorption/desorption process only contributes to a minor extent, especially for radionuclides with a high K_d value. DOE may wish to investigate this alternative model of leaching to determine how it would affect the results of the total system performance assessment.

An alternative model was considered for modeling the resuspension process to determine the concentration of radionuclides in the air in the analysis and model report (CRWMS M&O, 2000e). This report considered the use of a resuspension model, which correlates the concentration of radionuclides in the air to concentration of radionuclides on the ground through use of a resuspension factor. For the widespread area of contamination and the relatively thick deposits of contamination associated with an igneous event, DOE argued that a mass-loading model is more appropriate. Additionally, data supporting mass-loading values are more readily available to support the model than the resuspension factor needed for the resuspension model. This approach to assessing model uncertainty is sufficient for inclusion in a potential license application.

Following is a summary of staff review regarding characterization and propagation of model uncertainty. DOE needs to provide justification that the methodology used to bound the effects of remobilization does not underestimate the risk from igneous activity. The DOE has agreed to provide further justifications, including supporting data, for all of its assumptions and modeling approaches, including all of the issues above, prior to, or as part of, any potential license application.[8] NRC staff are satisfied, based on the agreements, that sufficient information will be available at the time of any potential license application review. DOE has adequately considered appropriate alternative conceptual models for other processes in the redistribution of radionuclides in soil abstraction and has provided sufficient justification for the selection of preferred models.

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[7]Reamer, C.W. "U.S. Nuclear Regulatory Commission/U.S. Department of Energy Technical Exchange and Management Meeting on Igneous Activity (June 21–22, 2001)." Letter (June 29) to S. Brocoum, DOE. Washington, DC: NRC. 2001.

[8]Ibid

3.3.13.4.5 Model Abstraction Output Is Supported by Objective Comparisons

Overall, the current information, along with agreements reached between DOE and NRC (Section 3.3.13.5), is sufficient to conclude that the necessary information will be available at the time of a potential license application to assess redistribution of radionuclides in soil with respect to model abstraction output being supported by objective comparisons.

As described in CRWMS M&O (2000a), no model has been developed to describe the remobilization of radionuclides due to aeolian and fluvial processes following an igneous event. Instead, three conservative assumptions have been made to bound the effects of remobilization. Therefore, verification of the accuracy of the model is not possible. DOE needs to provide justification that the methodology used to bound the effects of remobilization does not underestimate the risk from igneous activity.

The model for tracking concentration of radionuclides in soil, which includes processes such as deposition by irrigation and losses by erosion, leaching, and decay, is a simple box model for which the input data control the results. Provided that the computer code is verified to be performing the mathematics correctly and the input data are determined to be appropriate for the materials and activities being modeled, support for the model used is not necessary.

The mass-loading model that estimates the concentration of radioactive material in the air relies on the assumption that the concentration of radioactive material in the air is the same as the concentration of radioactive material on the ground. No attempt has been made in the DOE analysis and model reports to compare the results of this model with field data.

Following is a summary of staff review regarding verification of the redistribution of radionuclides in soil abstraction. DOE needs to provide justification that the methodology used to bound the effects of remobilization does not underestimate the risk from igneous activity. DOE should compare the results of the mass-loading model to field data to demonstrate that use of the mass-loading model does not underestimate the concentration of radionuclides in the air compared with the concentration of radionuclides on the ground. DOE agreed to provide further justifications, including supporting data, for all of its assumptions and modeling approaches, including all of the issues above, prior to, or as part of, any potential license application.[9] NRC staff are satisfied, based on the agreements, that sufficient information will be available at the time of any potential license application review.

3.3.13.5 Status and Path Forward

Table 3.3.13-1 provides the status of all key technical issue subissues, referenced in Section 3.3.13.2, for the Redistribution of Radionuclides in Soil. The table also provides the related DOE and NRC agreements to the Redistribution of Radionuclides in Soil. The agreements listed in the table are associated with one or all five generic acceptance criteria

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[9]Reamer, C.W. "U.S. Nuclear Regulatory Commission/U.S. Department of Energy Technical Exchange and Management Meeting on Igneous Activity (June 21–22, 2001)." Letter (June 29) to S. Brocoum, DOE. Washington, DC: NRC. 2001.

discussed in Section 3.3.13.4. Note that the status and the detailed agreements (or path forward) pertaining to all the key technical issue subissues are provided in Table 1.1-3 and Appendix A.

The DOE-proposed approach, together with the DOE agreements to provide NRC with additional information (through specified testing, analyses, and the like), acceptably addresses the NRC questions so that no information beyond that provided, or agreed to, will likely be required at the time of a potential license application.

Table 3.3.13-1. Related Key Technical Issue Subissues and Agreements

Key Technical Issue	Subissue	Status	Related Agreement*
Igneous Activity	Subissue 2—Consequences of Igneous Activity	Closed-Pending	IA.2.06 IA.2.07 IA.2.08 IA.2.11 through IA.2.17
Total System Performance Assessment and Integration	Subissue 1—System Description and Demonstration of Multiple Barriers	Closed-Pending	None
	Subissue 2—Scenario Analysis and Event Probability	Closed-Pending	TSPAI.2.01 TSPAI.2.02 TSPAI.2.03
	Subissue 3—Model Abstraction	Closed-Pending	TSPAI.3.33
	Subissue 4—Demonstration of Compliance with the Postclosure Public Health and Environmental Standards	Closed-Pending	None

*Related DOE and NRC agreements are associated with one or all five generic acceptance criteria.

3.3.13.6 References

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3.3.14 Biosphere Characteristics

3.3.14.1 Description of Issue

The Biosphere Characteristics Integrated Subissue encompasses technical and regulatory issues regarding development and implementation of total system performance assessment models to convert concentration estimates of radionuclides in soil and groundwater to human dose estimates that can be used to assess compliance with 10 CFR Part 63 dose limits. Model development is based on a combination of site-specific and relevant technical information and scientific principles applied within the regulatory policy framework established in 10 CFR Part 63. The Biosphere Characteristic Integrated Subissue includes the features, events, and processes that impact fate and transport of radioactive contamination in the biosphere and subsequent exposure of the dose receptor (i.e., the reasonably maximally exposed individual). The dose receptor is a hypothetical individual defined by regulation (for dose modeling) in 10 CFR Part 63 to be protective of the vast majority of the potentially exposed population (i.e., an individual based on characteristics derived from local populations that live in the accessible environment directly above the area of highest radionuclide concentration in the groundwater plume). The reference biosphere is defined also by regulation in 10 CFR Part 63 and represents (for dose modeling) the local environment of the dose receptor. Radioactive releases from a potential repository can enter the biosphere through transport processes, such as saturated zone flow, following a postulated groundwater release and airborne fallout resulting from a postulated volcanic event. The DOE description and technical basis for biosphere dose modeling are documented in CRWMS M&O (2000a) and various supporting analysis and model reports. Only Revision 00 reports were reviewed to support this status report. Revisions to CRWMS M&O (2000a) or any of the analysis and model reports will be reviewed as they become available, and results will be documented in future reports or meetings.

3.3.14.2 Relationship to Key Technical Issue Subissues

The Biosphere Characteristic Integrated Subissue is derived from the dose calculation component of the biosphere subsystem (Figure 1.1-2). The relationships between biosphere characteristic and other integrated subissues are illustrated in Figure 3.3.14-1. The overall organization and identification of all the integrated subissues are depicted in Figure 1.1-2. The Biosphere Characteristics Integrated Subissue incorporates subject matter previously captured in the following key technical subissues:

- Radionuclide Transport: Subissue 3—Radionuclide Transport Through Fractured Rock (NRC, 2000a)
- Igneous Activity: Subissue 2—Consequences of Igneous Activity (NRC, 1999a)
- Unsaturated and Saturated Flow Under Isothermal Conditions: Subissue 1—Climate Change (NRC, 1999b)

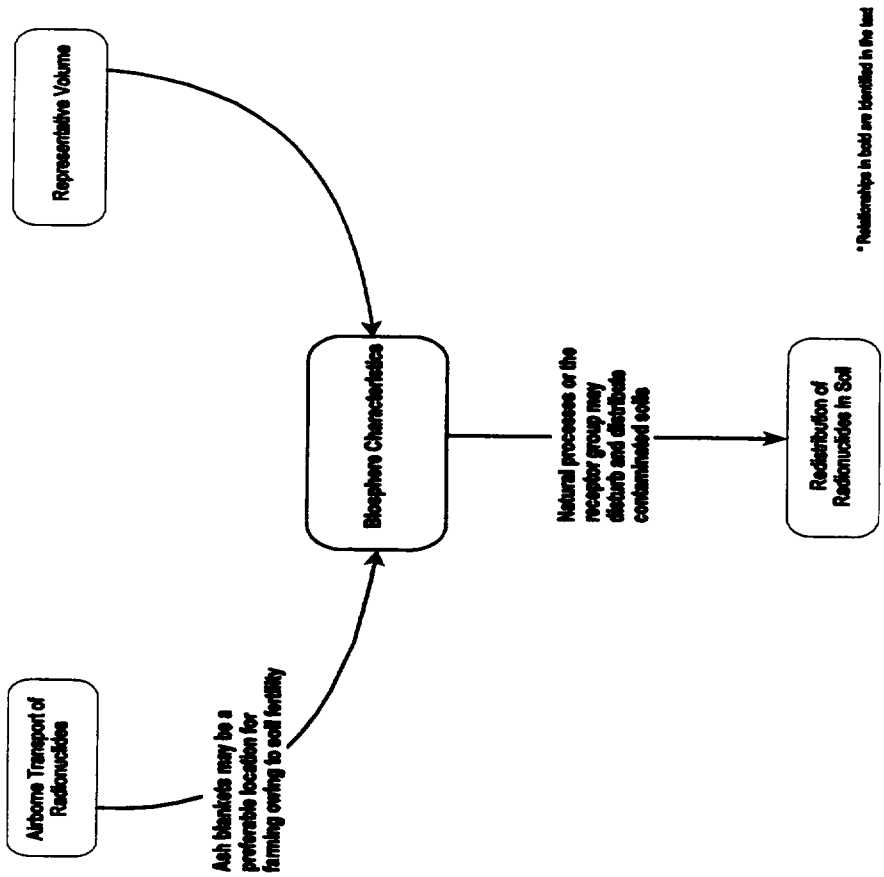

Figure 3.3.14-1. Diagram Illustrating the Relationship Between Biosphere Characteristics and Other Integrated Subissues

- Unsaturated and Saturated Flow Under Isothermal Conditions: Subissue 2—Hydrologic Effects of Climate Change (NRC, 1999b)
- Unsaturated and Saturated Flow Under Isothermal Conditions: Subissue 3—Present Day Shallow Groundwater Infiltration (NRC, 1999b)
- Unsaturated and Saturated Flow Under Isothermal Conditions: Subissue 5—Saturated Zone Ambient Flow Conditions and Dilution Processes (NRC, 1999b)
- Total System Performance Assessment and Integration: Subissue 1—System Description and Demonstration of Multiple Barriers (NRC, 2000b)
- Total System Performance Assessment and Integration: Subissue 2—Scenario Analysis and Event Probability (NRC, 2000b)
- Total System Performance Assessment and Integration: Subissue 3—Model Abstraction (NRC, 2000b)
- Total System Performance Assessment and Integration: Subissue 4—Demonstration of Compliance with the Postclosure Public Health and Environmental Standards (NRC, 2000b)

The key technical issue subissues formed the bases for the previous versions of the issue resolution status reports and were also the bases for technical exchanges with DOE where agreements were reached on what additional information DOE needed to provide to resolve the subissue. The resolution status of this integrated subissue is based on the resolution status of each of the contributing key technical issue subissues. The subsequent sections incorporate applicable portions of these key technical issue subissues.

3.3.14.3 Importance to Postclosure Performance

One aspect of risk informing the NRC review was to determine how this integrated subissue is related to the DOE repository safety strategy. DOE initially determined that the biosphere dose conversion factors were important parameters in the total system performance assessment calculations (DOE, 1998), but later demonstrated diminished importance of the biosphere in sensitivity studies in CRWMS M&O (2000b). This change in significance was attributed to the small variation DOE propagated in the biosphere dose conversion factor distributions after parameter changes to mean values for parameters now specified by regulation. Staff propagate a slightly larger, yet relatively small, amount of variation in biosphere dose conversion factors in the TPA Version 4.0 code (Mohanty, et al., 2002) calculations for radionuclides important to performance. Nonetheless, staff sensitivity analyses have identified a few important biosphere parameters in system-level sensitivity analyses. Staff expect the small amount of variation in the biosphere dose conversion factors places the biosphere at a borderline level of importance. Furthermore, staff sensitivity analyses are based on the total amount of uncertainty and variation propagated in biosphere dose conversion factors, whereas DOE sensitivity analyses truncated the distribution at the 5th and 95th percentiles. Because stochastic biosphere dose conversion factor results for important radionuclides approximate lognormal distributions

(CRWMS M&O, 2000a), DOE truncation at the 95th percentile significantly reduces the range of values. This truncation directly impacts the results of the DOE perturbation type of sensitivity analysis because that analysis method is sensitive to the range of the parameter being analyzed. If DOE changes parameter ranges in the process of resolving existing agreements, or if the magnitude of radionuclide concentrations change in the total system performance assessment calculations, the importance of biosphere dose conversion factor distributions could change, and the sensitivity analyses may need to be updated. As a result, staff will continue to monitor DOE updates of the biosphere dose modeling abstraction.

3.3.14.4 Technical Basis

NRC developed a plan (2002) consistent with the acceptance criteria and review methods found in previous issue resolution status reports. A review of DOE approaches for including biosphere characteristics in total system performance assessment abstractions is provided in the following subsections. The review is organized according to the five acceptance criteria identified in Section 1.5: (i) System Description and Model Integration Are Adequate, (ii) Data Are Sufficient for Model Justification, (iii) Data Uncertainty Is Characterized and Propagated Through the Model Abstraction, (iv) Model Uncertainty Is Characterized and Propagated Through the Model Abstraction, and (v) Model Abstraction Output Is Supported by Objective Comparisons. Review methods have been formulated to focus on those aspects of the abstraction that prior sensitivity studies have shown are important to performance (LaPlante, et al., 1995; LaPlante and Poor, 1997) and relevant to the NRC requirements for 10 CFR Part 63. A review of the DOE approach to biosphere characteristics for each acceptance criterion is contained in the sections that follow.

3.3.14.4.1 System Description and Model Integration Are Adequate

Overall, the current information, along with agreements reached between DOE and NRC (Section 3.3.14.5), is sufficient to conclude that the necessary information will be available at the time of a potential license application to assess the biosphere characteristics with respect to system description and model integration.

The system description for biosphere characteristics supports identification, screening, and integration of features, events, and processes to aid development, selection, and integration of conceptual and mathematical models. Identification and screening of features, events, and processes related to the biosphere are included in Section 3.2.1 of this report. Therefore, this section will concentrate on the adequacy of the DOE overall system description supporting conceptual model development, selection, and integration.

The reference biosphere and dose receptor must be developed and implemented within the regulatory framework provided by the 10 CFR Part 63 requirements. Some important characteristics of the biosphere and dose receptor have been explicitly defined in 10 CFR Part 63 requirements to avoid unnecessary speculation. Although DOE is not required to justify characteristics of the biosphere and dose receptor explicitly defined in the regulation (e.g., drinking water consumption rate, and location of the dose receptor), supporting information is needed to define characteristics not explicitly defined in 10 CFR Part 63 (e.g., irrigation rates, food consumption, and outdoor activity).

DOE developed various documents that describe the biosphere and dose receptor at various levels of detail. A general description of the biosphere and dose receptor is provided in CRWMS M&O (2000b). More detailed technical information is provided in a series of analysis and model reports that cover specific aspects of the biosphere and dose receptor. In general, these reports provide a system description that is adequate for understanding the bases for selection of exposure scenarios, identification of exposure pathways, and selection or development of models for biosphere dose modeling. Staff concerns were identified during the review; however, most of the concerns relate to transparency and traceability which are covered by existing agreements.

The following discussion will focus on the status of various important aspects of the biosphere system description and model integration that staff reviewed. For discussion purposes, these aspects include the general system description that supports the overall conceptual dose model exposure scenarios and pathway information. A more detailed discussion of specific technical areas, including support for establishing the habits of the dose receptor, support for modeling processes related to fate and transport of radioactive materials in the biosphere, and documentation of the bases for the implementation of biosphere dose modeling in total system performance assessment calculations, is also included.

In defining the dose receptor, 10 CFR 63.312(b) requires the diet and living style to be representative of the people who now reside in the town of Amargosa Valley, Nevada. The regulation also requires DOE to use projections based on surveys of the people residing in the town of Amargosa Valley, Nevada, to determine living styles and use mean values for the performance assessment calculations. Staff review of DOE documentation (CRWMS M&O, 2000a,b) indicates demographic surveys of Amargosa Valley have been completed and documented, and the results are incorporated as mean value parameters into the biosphere dose modeling. 10 CFR 63.312(e) also requires the dose receptor to be an adult with metabolic and physiological considerations consistent with present knowledge of adults. In CRWMS M&O (1999), DOE documents the use of adult dosimetry in its application of dose coefficients from existing EPA Federal Guidance reports (1988, 1993) that NRC commonly uses and accepts for dose modeling. DOE also indicates the location of the dose receptor will be 18 km [11 mi] south of Yucca Mountain as required by 10 CFR Part 63.

The general description of the biosphere dose modeling provided in CRWMS M&O (2000b) includes a dose receptor and biosphere intended to be consistent with regulations proposed by EPA and NRC. The receptor is described as a member of a hypothetical farming community presumed to be exposed to radionuclide releases to groundwater (nominal scenario) and air (for the disruptive volcanic event scenario). The reference biosphere is based on characteristics of Amargosa Valley which includes a climate characterized as arid to semiarid (considering potential future climate evolution). Alfalfa production and dairy farming are noted as primary agricultural activities in the area. Water for all uses in the area comes predominantly from local wells. Census data and results of a survey of local residents provide information on the lifestyle characteristics of people in the region. Information on biosphere characteristics is adequate for inclusion in a potential license application.

The DOE conceptual model of the biosphere includes a scenario (i.e., nominal case) where radionuclides presumed to leach from the repository are transported to the location of the dose

receptor where wells pump the contaminated water to the surface. The community where the dose receptor resides then uses the pumped water. The nominal scenario provides one mechanism for transporting radioactive materials to the biosphere. A separate disruptive event scenario involves a volcanic eruption that transports airborne particles of ash contaminated with radionuclides to the biosphere location for deposition and contamination of surface soil. DOE used its understanding of these mechanisms of biosphere contamination, along with a detailed analysis of biosphere features, events, and processes, to refine the conceptual model of the biosphere and identify potential exposure pathways that should be included in the biosphere dose modeling.

The biosphere conceptual model emphasizes aspects of the biosphere that can directly contribute to exposure of the human dose receptor. This model includes transfer of radionuclides to soil, the atmosphere, and flora and fauna (CRWMS M&O, 2000b). The conceptual model for movement of material within the biosphere is consistent with commonly known fate and transport models including deposition of radionuclides from water to soil through irrigation, from soil to air through resuspension, and from air to soil through deposition. Subsequent movement of material occurs from air and soil to plants and from water and plants to livestock. Human exposure to radioactive material from inhalation, ingestion, and external exposure pathways result from contact with contaminated air, water, food products (both plant and animal), and soil. Staff identified an additional transport mechanism for the volcanic scenario involving redistribution of contaminated ash deposits during a review of the DOE model. Redistribution in the biosphere is covered by another integrated subissue (Redistribution of Radionuclides in Soil) and is addressed by an existing agreement (Section 3.3.13), which may result in collection of additional information to support the conceptual model. The remainder of the DOE biosphere conceptual model appears to be well supported by the existing information. Results of the staff review of the DOE features, events, and processes analysis for the biosphere have identified concerns predominantly related to transparency and traceability, which have been incorporated into existing agreements.[1]

Integration with related integrated subissues was evident from reviews of the DOE biosphere abstraction. A number of biosphere modeling issues related to the igneous activity scenario are receiving technical input from the Igneous Activity Subissue 2 (e.g., redistribution and mass-loading). DOE conducted analyses into the effects of natural climate change on biosphere dose conversion factors in Bechtel SAIC Company, LLC (2001), but decided not to use the revised biosphere dose conversion factors because climate had the effect of lowering the dose (nonconservative). DOE has also developed biosphere dose conversion factors for those radionuclides expected to transport through the saturated zone (or be transported by an igneous event). The issues regarding transport of radioactive material in the saturated zone and the atmosphere (from igneous events) are sufficiently understood to translate the relevant modeling concepts to dose calculations. Resolutions of some issues from the Igneous Activity Integrated Subissue will provide input to further improve the technical bases for biosphere dose modeling in the future (e.g., redistribution and mass-loading). Overall, the staff did not identify

[1]Reamer, C.W. "U.S. Nuclear Regulatory Commission/U.S. Department of Energy Technical Exchange and Management Meeting on Total System Performance Assessment and Integration (August 6–10, 2001)." Letter (August 23) to S. Brocoum, DOE. Washington, DC: NRC. 2001.

any major integrated subissue integration issues impacting the biosphere dose modeling when they reviewed the DOE reports.

In summary, the system description DOE provided is based on local surveys and other available information appropriate for supporting the conceptual model of the biosphere and receptor group. The DOE conceptual model is consistent with a detailed features, events, and processes analysis that is found to be generally comprehensive for the biosphere, which DOE is updating to address a current agreement regarding transparency and traceability issues.[2] At the general conceptual model level, it is unlikely that any additional features, events, or processes significant to the dose calculation will be identified after resolution of existing agreements. Resolving agreements related to including redistribution of volcanic ash may add complexity to the present conceptual model. At a more detailed submodel level, some models may be optimized or updated, but these modifications are not expected to significantly change the overall conceptual model of the biosphere.

3.3.14.4.2 Data Are Sufficient for Model Justification

Overall, the current information, along with agreements reached between DOE and NRC (Section 3.3.14.5), is sufficient to conclude that the necessary information will be available at the time of a potential license application to assess the biosphere dose modeling with respect to data being sufficient for model justification.

DOE selected a series of mathematical models for the biosphere dose modeling consistent with the needs of the biosphere conceptual model. The mathematical models are contained within the GENII-S dose modeling software program (Leigh, et al., 1993). DOE selected GENII-S because it has the flexibility to model the features, events, and processes that have been included in the biosphere conceptual model for Yucca Mountain. NRC has not identified any major problems with the code selection or justification; however, the DOE resolution of some existing agreements may result in the use of additional models for specific biosphere processes (e.g., redistribution and leaching) (Section 3.3.13.5).

The DOE implementation of the biosphere dose modeling in total system performance assessment calculations uses lookup tables of biosphere dose conversion factors that convert groundwater and soil concentrations into human doses. DOE uses the GENII-S modeling to generate the tables for the total system performance assessment calculations. Insufficient justification was provided for this implementation approach in the DOE documents. As a result, an existing agreement[3] requests DOE to provide further justification for the selection of this implementation approach to demonstrate it does not significantly bias the original GENII-S results.

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[2]Reamer, C.W. "U.S. Nuclear Regulatory Commission/U.S. Department of Energy Technical Exchange and Management Meeting on Total System Performance Assessment and Integration (August 6–10, 2001)." Letter (August 23) to S. Brocoum, DOE. Washington, DC: NRC. 2001.

[3]Ibid.

The DOE biosphere dose conversion factor calculations using GENII-S require a large number of parameter selections. The input parameters for the biosphere dose conversion factor calculations are documented in various analysis and model reports that the NRC staff has reviewed. The review effort focused on those parameters found to be important for the GENII-S dose modeling. Both DOE (CRWMS M&O, 2000c,d) and staff (LaPlante and Poor, 1997) conducted sensitivity analyses at the process model level that identified a similar set of important input parameters. These parameters include consumption rates (e.g., water, vegetables, and milk), animal and plant uptake factors, a resuspension factor, and crop interception fraction.

Both DOE (CRWMS M&O, 2000c) and staff (LaPlante and Poor, 1997) have shown that consumption rates, which have a direct impact on the magnitude of modeled doses, are important at the process model level. Because 10 CFR 63.312(b) requires behavioral input parameters to be based on mean values (e.g., no variation propagated in the performance calculation), the parameter cannot be included in system-level sensitivity analyses without violating the requirement. Nonetheless, importance at the process level suggests the magnitude of the selected mean values used for total system performance assessment calculations can directly impact dose results, and the mean values should, therefore, be adequately justified. Furthermore, 10 CFR 63.312(b) requires the consumption rates to be based on local survey, data and such survey data will serve to address the regulatory requirement as well as address the technical need for justification.

The DOE mean value consumption rates are supported by results of a stratified random sample survey of the local population that the University of Las Vegas Cannon Center for Survey Research conducted (CRWMS M&O, 2000e). The survey included the population residing within 84 km [52 mi] of Yucca Mountain including the communities of Amargosa Valley, Beatty, Indian Springs, and Pahrump. Information was collected on the frequency of locally produced food and water consumption, which was then converted into amounts consumed by applying average intake information from a national survey. Intakes were not measured directly because recall of specific intake amounts is less reliable than frequency information. Staff found descriptions of the survey methodology, execution, and analysis of results in CRWMS M&O (2000e) provide sound bases for the consumption rate parameter information. Staff continue to await DOE publication of the detailed documentation for the Amargosa Valley survey.

Animal and plant uptake factors are important parameters for the process-level biosphere modeling (CRWMS M&O, 2000c; LaPlante and Poor, 1997). Preliminary system-level sensitivity results conducted by staff suggest plant uptake can be important in the total system performance calculations. These factors are used in the plant and animal uptake models to transfer contaminants from soil to plants and from feed to livestock (Napier, et al., 1988). The DOE technical basis for selection of plant and animal uptake factors is provided in CRWMS M&O (2000f). Because DOE indicates no site-specific information is available, it has used available information from the technical literature to select values for Yucca Mountain. Although this is likely to be the case, staff informed DOE of radionuclide transfer studies EPA conducted at the Nevada Test Site that could be applicable to Yucca Mountain. DOE agreed to

investigate the information and provide a technical basis for transfer factor information.[4] The staff also questioned the DOE method for selecting values from the available technical literature. The selection method is partially based on the frequency of occurrence of the same parameter values in the literature rather than the applicability of the values to conditions at Yucca Mountain. Because transfer coefficient research is limited, some references in the technical documents that DOE reviewed refer to the same source data. Although staff do not have technical concerns with the source data, DOE has been encouraged to use original references to source data and to consider using a more technically sound basis for selecting transfer coefficients relevant to the site conditions at Yucca Mountain (rather than selecting data because they are most frequently used by others). Again, DOE agreed to provide a technical basis for radionuclide specific parameters important to biosphere dose conversion factors including transfer coefficients.[5]

Crop interception fraction is the fraction of the contaminants in irrigation water deposited on the plant surface. DOE (CRWMS M&O, 2000c) and the NRC staff indicate that the crop interception fraction (LaPlante and Poor, 1997) is important to dose modeling at the process level. The parameter has been found to be moderately important in some staff system-level sensitivity checks. The importance of the parameter in dose calculations is influenced by the width of the parameter probability distribution. DOE discusses the crop interception fraction in CRWMS M&O (2000g). DOE adopts a calculation for the interception fraction from Hoffman (1989) that is based on comparisons with experimental data from two radionuclides. DOE calculations result in a normal distribution for the parameter from approximately 0.044 to 0.47 at the 99.9 percent confidence interval, with a mean of 0.26. For comparison, prior staff biosphere calculations used a triangular distribution with a conservative range (0.06 to 1.0) and mode of 0.40 based on a technical expert calculation after a review of 20 studies (of varying applicability and quality) in the technical literature by Anspaugh (1987). The studies reviewed by Anspaugh (1987) involve 10 radionuclides; however, neither DOE nor staff identified any of the radionuclides considered as important contributions.

Staff raised a concern that the two radionuclides forming the basis for the DOE approach may not be representative of the entire suite of radionuclides considered important in the total system performance assessment calculation, and DOE has agreed to conduct an analysis of the applicability of the assumed crop interception fraction to all important radionuclides in the total system performance assessment. The following discussion provides further justification for the original comment[6] regarding the applicability of the DOE crop interception fraction values to other radionuclides.

Anspaugh (1987) considered a variety of studies conducted in controlled laboratory conditions with fine sprays as well as field studies involving natural rainfall and radioactive fallout. The

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[4]Reamer, C.W. "U.S. Nuclear Regulatory Commission/U.S. Department of Energy Technical Exchange and Management Meeting on Total System Performance Assessment and Integration (August 6–10, 2001)." Letter (August 23) to S. Brocoum, DOE. Washington, DC: NRC. 2001.

[5]Ibid.

[6]Ibid.

majority of values presented in Anspaugh (1987) fall within the DOE range. Some values are higher than the DOE upper limit value, but DOE indicates the studies are based on fine sprays of small amounts of water not applicable to agricultural field irrigation conditions at Yucca Mountain (e.g., where large amounts of water must reach the soil) (CRWMS M&O, 2000g). Staff review of the data also found that many of the elevated results reported in field studies are compromised by the potential effects of atmospheric deposition on rain collectors and imprecision leading to values much greater than one. Because the overall weight of the evidence reviewed suggests values within the DOE range, and the calculation appears technically sound, staff do not have major concerns that would invalidate the present DOE approach. Nonetheless, there are field results outside the DOE range not explained by the fine spray or low-volume argument used in the analysis and model report. Values have been recorded between 0.65 and 0.80 for individual rainfall events of 0.5 to 2 cm [0.2 to 0.8 in] volume that is consistent with the DOE stated daily irrigation application rate of 1 cm [0.4 in]. Staff did agree with DOE that the prior total system performance assessment value with a maximum of 1.0 is probably an overestimate for an irrigation scenario where the objective is to water the crop roots in soil. As a result, staff will continue to conduct confirmatory calculations and sensitivity studies using a range wider than the DOE range [i.e., consistent with the Anspaugh (1987) data] but narrower than the previously used range (e.g., 0.06 to 0.80) until DOE provides additional information to address the agreement regarding the applicability of the crop interception fraction to all important radionuclides.

The mass-loading factor combines several biosphere processes into a coefficient used to determine the concentration of radionuclides in air from known soil concentrations. Resuspension is important for the inhalation pathway that dominates the biosphere dose calculations for the igneous activity disruptive event scenario (CRWMS M&O, 2000d). The staff has raised various issues (leading to agreements) regarding the DOE basis for the mass-loading factor. Although the mass-loading factor is used in the biosphere dose modeling, the issues are discussed in the Redistribution of Radionuclides in Soil Integrated Subissue (Section 3.3.13).

Specific agreements were developed for issues where initial DOE responses to staff concerns were incomplete. Some initial DOE responses to staff concerns that were initially adequate included DOE action items to be completed in the future. These action items include (i) update the radionuclide inventory analysis and model report to account for biological transport in radionuclide screening, (ii) improve documentation of the assumptions in a future revision to the environmental transport analysis and model report, (iii) update the analysis and model report entitled Transfer Coefficient Analysis to include methods for combining data based on individual crops to food groups and a clarified definition of conservatism, and (iv) complete additional model validation for the GENII-S code (Leigh, et al., 1993). These items will be checked by staff when the revised analysis and model reports are available.

In summary, DOE parameter choices for biosphere dose conversion factor calculations to support the biosphere dose modeling abstraction are, in general, consistent with available data and adequately justified except for a few exceptions where DOE agreed to provide additional information to resolve issues. Consumption rates are adequately documented. Other parameters, such as transfer coefficients, the crop interception fraction, and the mass-loading factor need additional justification.

3.3.14.4.3 Data Uncertainty Is Characterized and Propagated Through the Model Abstraction

Overall, the current information, along with agreements reached between DOE and NRC (Section 3.3.14.5), is sufficient to conclude that the necessary information will be available at the time of a potential license application to assess the biosphere characteristics with respect to data uncertainty characterization and propagation through the model abstraction.

This section discusses the status of issues related to uncertainty propagation in the GENII-S (Leigh, et al., 1993) biosphere dose conversion factor calculations as well as in the implementation of the abstraction. As described in CRWMS M&O (2000b), DOE propagates biosphere dose modeling input parameter uncertainty by executing the GENII-S code stochastically using input parameter distributions to generate a biosphere dose conversion factor distribution for each radionuclide. The parameter uncertainty is propagated through the biosphere abstraction by sampling from the biosphere dose conversion factor distributions for each realization of the total system performance assessment code. Uncertainty propagation of biosphere dose conversion factors is potentially important because of the impact on sensitivity results. DOE concluded the biosphere dose conversion factors are not important in the total system performance assessment whereas staff analyses suggest the importance of a few biosphere parameters at the total system level. Staff believe the limited range of biosphere dose conversion factors used in the total system performance assessment calculations produce a borderline level of importance. Changes to the total system performance assessment to resolve existing agreements, however, could impact the level of importance of biosphere parameters, and, therefore, staff will continue to monitor biosphere uncertainty propagation in future reviews.

As noted before, the NRC regulations in 10 CFR Part 63 limit the propagation of parameter uncertainty by requiring the use of mean values for behavioral input parameters (i.e., diet and living style) such as consumption rates and exposure times. Consumption rates have been shown to be important parameters in process model level sensitivity analyses conducted by both DOE (CRWMS M&O, 2000c) and staff (LaPlante and Poor, 1997). Fixing consumption rates at the mean values eliminates a substantial portion of the uncertainty propagated to the biosphere dose conversion factors as DOE indicated in CRWMS M&O (2000b); however, nonbehavioral parameters contribute variability to the biosphere dose conversion factors to the extent that the total range for most biosphere dose conversion factor distributions are approximately order of magnitude.

Propagated uncertainty and variation in DOE biosphere dose conversion factors for most radionuclides are similar to staff-generated results, when geometric means and standard deviations are compared. Staff-generated distributions are somewhat wider, but the magnitude is not considered significant (possible impacts on sensitivity analysis conclusions are discussed in Section 3.3.14.3). The difference can be explained partly by differences in the ranges used for the crop interception fraction (Section 3.3.14.2). The difference in total system performance assessment results using both the DOE and NRC ranges for crop interception fraction produces similar geometric mean biosphere dose conversion factors with only moderate differences in geometric standard deviations.

Regarding the DOE implementation of the biosphere dose modeling abstraction, an issue was raised about the need for DOE to address the potential for the abstraction to introduce bias into the original GENII-S modeling results. Because DOE samples from radionuclide-specific biosphere dose conversion factor distributions created by the GENII-S code, the resulting suite of selected biosphere dose conversion factors for any particular realization of the total system performance assessment is unlikely to be based on the same set of input parameters for all radionuclides (i.e., the original GENII-S output vectors have been disrupted by the sampling). It is more likely that each radionuclide-specific biosphere dose conversion factor would be based on a suite of sampled input parameters different from any other radionuclide-specific biosphere dose conversion factor sampled for that realization. Such conditions are physically impossible when the conceptual model suggests the radionuclides exist in the same biosphere at the same time. DOE has also correlated the sampling of biosphere dose conversion factor distributions for all radionuclides to the sampling for one radionuclide (Np-237). This method of sampling is inconsistent with the GENII-S modeling results that indicate the magnitude of each biosphere dose conversion factor is affected by radionuclide-dependent factors that vary in effect on dose. For example, a high plant transfer coefficient scale factor may greatly increase the magnitude of biosphere dose conversion factors for radionuclides where plant uptake is high but have little impact on the biosphere dose conversion factor for radionuclides with low plant transfer coefficients. To ensure such deviations from the original process level modeling do not impact results, DOE agreed to conduct a quantitative analysis to demonstrate its selected abstraction approach does not significantly bias the total system performance assessment results.[7]

In summary, propagation of uncertainty is limited in biosphere dose modeling by regulations specifying the use of mean values for behavioral parameters. This regulatory specification reduces propagated uncertainty to levels that lead to low or borderline significance of the biosphere in sensitivity studies. The range of uncertainty propagated in the biosphere, however, could be impacted by resolution of existing agreements; therefore, staff will continue to monitor the issues. In general, the range of biosphere dose conversion factor distributions span no more than one order of magnitude, which is low relative to the uncertainty propagated in other total system performance assessment abstractions. The DOE implementation of the biosphere dose modeling involves correlated sampling of process model output that may generate results different from the original process modeling. DOE agreed to conduct a quantitative analysis to test the potential for the approach to bias results.

[7]Reamer, C.W. "U.S. Nuclear Regulatory Commission/U.S. Department of Energy Technical Exchange and Management Meeting on Total System Performance Assessment and Integration (August 6–10, 2001)." Letter (August 23) to S. Brocoum, DOE. Washington, DC: NRC. 2001.

3.3.14.4.4 Model Uncertainty Is Characterized and Propagated Through the Model Abstraction

Overall, the current information is sufficient to conclude that the necessary information will be available at the time of a potential license application to assess the biosphere dose modeling with respect to characterization and propagation of model uncertainty through the model abstraction.

Biosphere dose modeling is a highly abstracted and idealized type of modeling that lacks precision. Many available models for biosphere dose calculations are based on similar conceptual models and mathematical representations. Available models, such as those in the GENII-S code (Leigh, et al., 1993) are designed to be inherently conservative to avoid underestimation of doses. Furthermore, many of the conceptual models, and some mathematical models (e.g., dosimetry) are sufficiently (and intentionally) constrained by regulation such that DOE is not free to choose alternative models under the present regulation. As a result, staff believe the characterization and propagation of model uncertainty are unnecessary for biosphere dose modeling. The emphasis on propagation of parameter uncertainty is more appropriate for the type of modeling conducted for the biosphere. Nonetheless, because the biosphere dose model represents a compilation of a variety of submodels that represent specific features, events, or processes in the biosphere, some of these submodels may have specific, known limitations that could benefit by a comparison with alternative modeling approaches. Such modeling approaches could be integrated into the biosphere dose modeling in the future, if necessary. Examples include special submodels to account for redistribution of radionuclides in the biosphere, mass-loading (Section 3.3.13), and inhalation calculations. Other than those issues addressed by related integrated subissues, staff have not identified any parts of the biosphere dose modeling where model uncertainty comparisons would help inform the review of the DOE safety case.

In summary, staff believe the abstracted nature of biosphere models precludes the usefulness of model uncertainty comparisons.

3.3.14.4.5 Model Abstraction Output Is Supported by Objective Comparisons

Overall, the current information, along with agreements reached between DOE and NRC (Section 3.3.14.5), is sufficient to conclude that the necessary information will be available at the time of a potential license application to assess the biosphere dose modeling with respect to system description and model integration.

The DOE biosphere dose modeling abstraction consists of the biosphere dose conversion factor distributions, the approach for sampling these factors for each realization, and the routine that multiplies estimated soil and groundwater radionuclide concentrations by the sampled factors to calculate dose. The biosphere dose conversion factor distributions are generated from process modeling using the GENII-S code (Leigh, et al., 1993). DOE has made comparisons to improve confidence that the modeling in the abstraction is being performed correctly, the biosphere dose conversion factor distributions can be verified against the GENII-S modeling results easily with a simple check. DOE has also compared its GENII-S results with other results from the same process model to provide confidence that the code was executed

correctly (CRWMS M&O, 2000a). A DOE-sponsored independent technical review of the conceptual model of the biosphere and its implementation using GENII-S also has been completed (CRWMS M&O, 2000a). In response to a concern regarding the potential for the abstraction approach to bias original process model results, DOE agreed to conduct an additional quantitative analysis to check for bias (TSPAI.3.37) as discussed in the previous section. Staff also expect additional documentation to be provided from DOE to resolve a general comment regarding the validation of codes used in the total system performance assessment.

In summary, the nature of the abstraction (look-up table of code results) provides a basis for simple comparisons with process model results. DOE conducted some reasonable comparisons; however, additional comparisons likely will be done to resolve existing agreements regarding potential for bias in the abstraction approach and model validation.

3.3.14.5 Status and Path Forward

Table 3.3.14-1 provides the status of all key technical issue subissues referenced in Section 3.3.14.2 for the Biosphere Characteristics Subissue. The table also provides the related DOE and NRC agreements pertaining to the biosphere dose modeling subissue. The agreements listed in the table are associated with one or all five generic acceptance criteria discussed in Section 3.3.14.4. Note that the status and the detailed agreements (or path forward) pertaining to all the key technical issue subissues are provided in Table 1.1-3 and Appendix A.

The DOE-proposed approach, together with the DOE agreements to provide NRC with additional information (through specified testing, analyses, and the like), acceptably addresses the NRC questions so that no information beyond that provided, or agreed to, will likely be required at the time of a potential license application.

Table 3.3.14-1. Related Key Technical Issue Subissues and Agreements

Key Technical Issue	Subissue	Status	Related Agreements*
Radionuclide Transport	Subissue 3—Radionuclide Transport Through Fractured Rock	Closed-Pending	None
Igneous Activity	Subissue 2—Consequences of Igneous Activity	Closed-Pending	IA.2.06 IA.2.07 IA.2.08 IA.2.11 through IA.2.17
Unsaturated and Saturated Flow Under Isothermal Conditions	Subissue 1—Climate Change	Closed-Pending	None

Table 3.3.14-1. Related Key Technical Issue Subissues and Agreements (continued)

Key Technical Issue	Subissue	Status	Related Agreements*
Unsaturated and Saturated Flow Under Isothermal Conditions	Subissue 2—Hydrologic Effects of Climate Change	Closed-Pending	None
	Subissue 3—Shallow Infiltration	Closed-Pending	None
	Subissue 5—Saturated Zone	Closed-Pending	None
Total System Performance Assessment and Integration	Subissue 1—System Description and Demonstration of Multiple Barriers	Closed-pending	None
	Subissue 2—Scenario Analysis and Event Probability	Closed-Pending	TSPAI.2.01 through TSPAI.2.04
	Subissue 3—Model Abstraction	Closed-Pending	TSPAI.3.34 through TSPAI.3.37
	Subissue 4—Demonstration of Compliance with the Postclosure Public Health and Environmental Standards	Closed-Pending	None

*Related DOE and NRC agreements are associated with one or all five generic acceptance criteria.

3.3.14.6 References

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3.4 Demonstration of Compliance with the Postclosure Public Health and Environmental Standards

3.4.1 Demonstration of Compliance with the Postclosure Individual Protection Standard

3.4.1.1 Description of Issue

The analysis of repository performance that demonstrates compliance with the postclosure individual protection standard at 10 CFR 63.311 is necessary to ensure DOE has presented an acceptable analysis demonstrating the safety of the repository system. The analysis of repository performance that demonstrates compliance with the postclosure individual protection standard includes the following parts: (i) appropriate incorporation of scenarios into the DOE total system performance assessment results, (ii) calculation of the annual total effective dose equivalent from the repository system, and (iii) credibility of the DOE total system performance assessment results.

This section provides a review of the methodologies used by DOE to demonstrate that the repository system will meet the postclosure individual protection standard requirements in 10 CFR 63.113(b). The DOE description and technical basis for the analysis of repository performance that demonstrates compliance with the postclosure individual protection standard are documented in CRWMS M&O (1999, 2000a,b)

3.4.1.2 Relationship to Key Technical Issue Subissues

The analysis of repository performance that demonstrates compliance with the postclosure individual protection standard is related to appropriately incorporating scenarios into the total system performance assessment, demonstrating that the DOE total system performance assessment has been conducted correctly, and the results have been appropriately combined for comparison with regulatory limits. This subissue is related to all key technical issue subissues because proper conduct of the DOE total system performance assessment requires identification and incorporation of scenarios and data analysis for conceptual model development and validation, which are the focal points of these key technical issues. The reviews in the past were previously captured (NRC, 2000) within the framework of the following nine key technical issues:

- Igneous Activity
- Structural Deformation and Seismicity
- Evolution of the Near-Field Environment
- Container Life and Source Term
- Thermal Effects on Flow

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- Repository Design and Thermal-Mechanical Effects
- Total System Performance Assessment and Integration
- Unsaturated and Saturated Flow Under Isothermal Conditions
- Radionuclide Transport

The key technical issue subissues formed the bases for the previous versions of the issue resolution status report and also were the bases for technical exchanges with DOE where agreements were reached about the additional information DOE needed to provide to resolve the subissue.

3.4.1.3 Importance to Postclosure Performance

This issue relates to the methodology used to calculate the performance of the proposed Yucca Mountain repository system and to compare the results of the DOE total system performance assessment with the regulatory requirements. Therefore, this issue is directly related to the determination of postclosure safety of the repository.

In addition to calculating the performance at Yucca Mountain during the most likely scenarios, it is important to ensure DOE is appropriately including the consequences of disruptive events in calculating total effective dose equivalent from the repository for comparison against the 0.15 mSv/yr [15 mrem/yr] all pathways dose standard in 10 CFR Part 63. 10 CFR 63.2 indicates in the definition of performance assessment that estimates of dose from disruptive events should be weighted by their probability of occurrence when included in the calculation of dose to the reasonably maximally exposed individual.

3.4.1.4 Technical Basis

NRC developed a plan (2002) consistent with the acceptance criteria and review methods found in previous issue resolution status reports. A review of DOE approaches for analyzing repository performance that demonstrates compliance with the postclosure individual protection standard is provided in the following subsections.

3.4.1.4.1 Appropriate Incorporation of Scenarios into the Total System Performance Assessment Results

Overall, the current information, along with agreements reached between DOE and NRC, is sufficient to conclude that the necessary information will be available at the time of a potential license application to assess the incorporation of scenarios into the DOE total system performance assessment results.

The approach and technical basis for the appropriate incorporation of scenarios into the DOE total system performance assessment results are documented by DOE in CRWMS M&O (2000a). Based on the results of the features, events, and processes analysis, DOE concludes

there are two disruptive event classes that could significantly affect the repository performance, igneous activity, and seismically induced cladding failure. The probability of extrusive volcanism is incorporated into the DOE total system performance assessment results by multiplying the sampled annual probability of occurrence of extrusive volcanism by the timestep size and the dose from the igneous event assuming an eruptive igneous event occurred before that time for each timestep in the realization. The mean value of these probability-weighted realizations is then calculated for each timestep. The probability of intrusive volcanism is incorporated into the DOE total system performance assessment results by multiplying the sampled probability that an intrusive igneous event has occurred at any time during the simulation by the dose from the event at all timesteps in the realization. The mean value of these probability-weighted realizations is then calculated for each timestep. Both methodologies are acceptable and result in an appropriate estimate of the probability-weighted dose to be compared with the 0.15 mSv/yr [15 mrem/yr] all pathways dose standard in 10 CFR Part 63. DOE does not calculate the nominal dose from the unaffected parts of the repository after an igneous event. The calculation of dose from the nominal case, however, is not weighted by the probability of the nominal scenario class, which is slightly less than one, because the volcanism event class is excluded. The mean probability-weighted dose curve from the disruptive events is added to the conditional nominal case dose to calculate the total effective dose equivalent from the repository. The only concern with combining the results of the nominal case and the igneous scenario is that the same waste packages involved in the igneous event are also counted in the nominal case; however, double counting is acceptable because it increases the doses, a conservative outcome.

The current approach adopted by DOE for incorporating seismically induced cladding failure into its total system performance assessment may not adequately characterize the variability of the consequences. To address this concern, DOE agreed[1] to modify the approach used in its total system performance assessment to estimate the risk caused by seismically induced cladding failure so that the full range of variability in the consequence is accounted for.

3.4.1.4.2 Calculation of the Total Effective Dose Equivalent from the Repository System

Overall, the current information, along with agreements reached between DOE and NRC, is sufficient to conclude that the necessary information will be available at the time of a potential license application to assess calculation of the total effective dose equivalent from the repository system.

The approach and technical basis for the calculation of the total effective dose equivalent from the repository system are documented by DOE in CRWMS M&O (2000a). DOE demonstrates the stability of its total system performance assessment results by plotting the results of the time history of the dose curve from the repository system for different numbers of realizations. NRC staff have concerns that this approach is too qualitative and difficult to conclude that the results are stable, especially when the dose histories are plotted on a logarithmic scale. NRC

[1]Schlueter, J.R. "U.S. Nuclear Regulatory Commission/U.S. Department of Energy Technical Exchange and Management Meeting on Structural Deformation and Seismicity (October 11–12, 2000)." Letter (October 27) to S. Brocoum, DOE. Washington, DC: NRC. 2000.

staff found no indication that similar tests were performed for models that provided results to the total system performance assessment. For example, the biosphere model provides distributions of biosphere dose conversion factors to the total system performance assessment model, but stability checks for these results were not documented. Another example is the saturated zone transport model, which provides 100 transfer functions to be used in the total system performance assessment model. Additional realizations of the total system performance assessment model will not increase the variance in the results of the saturated zone transport model. Again, no stability check was included to show that 100 transfer functions were sufficient to properly represent uncertainty in the saturated zone transport model. To address these concerns, DOE agreed[2] to document the method to be used to demonstrate that the overall results of its total system performance assessment are stable. NRC staff also had concerns that DOE did not provide a methodology to demonstrate the results of its total system performance assessment were stable with respect to discretization of the model in Total System Performance Assessment–Site Recommendation (CRWMS M&O, 2000a). To address this concern, DOE agreed[3] to conduct analyses and provide documentation demonstrating that the results of the performance assessment are stable with respect to discretization. The documentation will include a description of the statistical measures that will be used to support the argument of stability.

Based on the intermediate outputs available in CRWMS M&O (2000c), it appears that sufficient information about intermediate outputs in the DOE total system performance assessment will be available to allow NRC staff to understand how individual components or subsystems contribute to system performance. Concerns about the consistency between the modeling of individual components or subsystems have been documented in all 14 subsections of Section 3.3.0 of this Integrated Issue Resolution Status Report. The results of the analysis in CRWMS M&O (2000a) seem to be consistent with the performance of individual subsystems or components.

3.4.1.4.3 Credibility of the Total System Performance Assessment Results

Overall, the current information, along with agreements reached between DOE and NRC, is sufficient to conclude that the necessary information will be available at the time of a potential license application to assess credibility of the DOE total system performance assessment results.

The approach and technical basis for credibility of the DOE total system performance assessment results are documented by DOE in CRWMS M&O (1999, 2000a,b). Concerns about the consistency between assumptions in different individual modules of the performance assessment code have been documented in all 14 subsections of Section 3.3.0 of this

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[2]Schlueter, J.R. "U.S. Nuclear Regulatory Commission/U.S. Department of Energy Technical Exchange and Management Meeting on Structural Deformation and Seismicity (October 11–12, 2000)." Letter (October 27) to S. Brocoum, DOE. Washington, DC: NRC. 2000.

[3]Reamer, C.W. "U.S. Nuclear Regulatory Commission/U.S. Department of Energy Technical Exchange and Management Meeting on Total System Performance Assessment and Integration (August 6–10, 2001)." Letter (August 23) to S. Brocoum, DOE. Washington, DC: NRC. 2001.

Integrated Issue Resolution Status Report. DOE indicated that its TSPA Code will be verified using a two-phase process. The first phase will assure the input construction is in complete accord with the conceptual models of the different processes as developed in a series of relevant and applicable analysis and model reports. This verification will be accomplished by using an independent review process to check a tabular form that lists the different elements of the conceptual models and records their manner of incorporation in the DOE total system performance assessment. The second phase of verification is designed to ensure the GoldSim model (Golder Associates, 2000) provides the correct output for a given input model embodying the full-scale complexity of the Yucca Mountain site. This verification is beyond what has been conducted by Golder Associates for GoldSim and is specifically related to the Yucca Mountain model. This phase consists of three stages. The first stage consists of performing hand calculations at selected times to verify the results of models that rely on the output from another model to produce results. These hand calculations use the output from the upstream model to verify the results of the dependent model. The second stage verifies all the inputs, including both data files and GoldSim arguments, and stand-alone codes that are incorporated into GoldSim as a dynamically linked library. The third stage consists of verifying that transfers of information between dynamically linked libraries are performed correctly when the full-scale Total System Performance Assessment–Site Recommendation model is implemented. This verification includes writing the time-dependent inputs to a dynamically linked library to an output file and comparing these inputs to the correct values as output from the upstream dynamically linked library.

NRC staff have concerns about the validation performed on the DOE TSPA Code. The verification process should demonstrate that (i) the models used have been adequately tested for calculational correctness with all relevant data together with associated uncertainties, (ii) a well-defined and rational assessment procedure has been followed, and (iii) results have been fully disclosed and subjected to quality assurance and review procedures. The verification process should encompass both tests that provide evidence of correct and successful implementation of algorithms and bench-marking or comparative testing against results from other software for cases where accuracy of the code cannot be judged otherwise. DOE has the elements of verification in its Total System Performance Assessment–Site Recommendation and supporting documents. Rigorous verification of the modules and the full code, however, was either not conducted or was not adequately reported. A specific verification plan was not found, and the verification was not uniform across Total System Performance Assessment–Site Recommendation (CRWMS M&O, 2000a). NRC review of CRWMS M&O (2000c) found errors in verification of hand calculations and abstractions in the performance assessment that were operating outside of their intended ranges.[4] Verification was performed only on a median input value run without rationale to justify that this verification was sufficient for a probabilistic model. Verification of CRWMS M&O (2000c) included various levels of analyses to demonstrate the verification of selected aspects of the performance assessment model but did not carry the calculations forward to step through different parts of the model in larger segments. DOE

[4]Reamer, C.W. "U.S. Nuclear Regulatory Commission/U.S. Department of Energy Conference Call Regarding Quality Assurance and Performance Assessment Issues." Letter (May 17) to S. Brocoum, DOE. Washington, DC: NRC. 2001.

agreed[5] to document the process used to develop confidence in the total system performance assessment models, such as described in NRC (1999) and to document compliance with the improved process in the verification documentation required by AP-SI.1Q (DOE, 2001).

DOE indicated that models used within the total system performance assessment will be validated in accordance with AP-3.10Q (CRWMS M&O, 2000c). This procedure requires comparing analysis results against data acquired from the laboratory, field experiments, natural and humanmade analog studies, or other relevant observations to validate models used in the total system performance assessment. It also requires that existing engineering-type models be validated using accepted engineering practices. The criteria used to evaluate the appropriateness and adequacy of the model for its intended use may be qualitative or quantitative but must be justified in the model documentation. If data are not available to support validation of the model, DOE AP-3.10Q requires the use and documentation of an alternative approach. Alternative approaches may include one or more of the following activities: (i) peer review or review by international collaborations; (ii) technical review through publication in the open literature; (iii) review of model calibration parameters for reasonableness, or consistency in explanation of all relevant data; (iv) comparison of analysis results with the results from alternative conceptual models, including supporting information to establish a basis for confidence in the selected model; (v) calibration and corroboration within experimental data sets; or (vi) comparison of analysis results with data attained during performance confirmation studies.

NRC staff have concerns about the steps DOE performed to build confidence in its total system performance assessment models. Confidence building in models should include demonstrating that (i) the processes are properly formulated mathematically and correctly parameterized following accepted theories (or tested theories if a new theory is used), (ii) numerical schemes used have acceptable convergence properties, and (iii) space and time dimensionality is appropriate. DOE has the elements of model validation in its documents supporting Total System Performance Assessment–Site Recommendation (CRWMS M&O, 2000a). A model validation plan does not appear to exist, however. Rigorous model validation at the system level has either not been conducted or has not been adequately reported. For example, the discussion of validation of the mathematical model of the biosphere (GENII-S) (Leigh, et al., 1993) includes only aspects of software verification. DOE has collected field and laboratory data to support detailed hydrologic calculations from which abstractions were made when representing the data in tabular form. This document does not consistently document whether the data that support the original model also support the abstracted model (in the form of tabular data). Also, objective comparisons have not been made for all the constituent models, such as validating the colloidal transport model with data from the C-Wells Testing Complex. DOE audits of the Total System Performance Assessment Program have identified problems with the validation of models, and DOE has issued Corrective Action Report BSC–01–C–001

[5]Reamer, C.W. "U.S. Nuclear Regulatory Commission/U.S. Department of Energy Technical Exchange and Management Meeting on Total System Performance Assessment and Integration (August 6–10, 2001)." Letter (August 23) to S. Brocoum, DOE. Washington, DC: NRC. 2001.

(Bechtel SAIC Company, LLC, 2001) to address these problems. DOE has also agreed[6] to document the implementation of the process for model confidence building and demonstrate compliance with model confidence criteria in accordance with the applicable procedures.

The treatment of scenario and parameter uncertainty described in CRWMS M&O (2000a) appears to be appropriate. The approach outlined in CRWMS M&O (2000b) for determining the effect of alternative conceptual models on performance using sensitivity studies by weighting the results of the alternative conceptual models, based on the probability of the model being correct, or by demonstrating that one model is more conservative and using that one in the analysis is acceptable to NRC staff. NRC staff have concerns, however, that DOE has weighted the results of the alternative conceptual models based on the probability of the model being correct in Total System Performance Assessment–Site Recommendation (CRWMS M&O, 2000a) without an appropriate technical basis for assigning the weights to the alternative conceptual models. Additionally, it is not clear to NRC staff if DOE will analyze the effect of alternative conceptual models for more than one process at a time that may interact with each other and potentially have a greater effect on the results than either alternative conceptual model individually. The aforementioned approach (completing essentially a one-off replacement of conceptual model with an alternative model) leads to difficulties in determining which alternative conceptual models significantly impact risk and which ones do not. When many alternative conceptual models exist, the number of permutations for combinations of alternative conceptual models becomes large. To address these concerns, DOE agreed[7] to document the methodology used to incorporate alternative conceptual models into the performance assessment in such a manner that risk is not underestimated including the guidance given to process-level experts for treating alternative models.

The methodology outlined by DOE in CRWMS M&O (1999) for sampling parameter uncertainty seems to be reasonable. This use of Latin hypercube sampling permits parameters to be sampled across their ranges of uncertainty. This sampling is acceptable as long as a sufficient number of realizations is conducted to ensure the intervals, in which the range of uncertainty is divided, are not excessively large.

3.4.1.5 Status and Path Forward

Table 3.4.1-1 provides related DOE and NRC agreements pertaining to the analysis of the repository performance that demonstrate compliance with the postclosure individual protection standard. The status and the detailed agreements (or path forward) pertaining to all the key technical issue subissues are provided in Table 1.1-3 and Appendix A.

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[6]Reamer, C.W. "U.S. Nuclear Regulatory Commission/U.S. Department of Energy Technical Exchange and Management Meeting on Total System Performance Assessment and Integration (August 6–10, 2001)." Letter (August 23) to S. Brocoum, DOE. Washington, DC: NRC. 2001.

[7]Ibid.

Repository Safety After Permanent Closure

The Total System Performance Assessment and Integration Key Technical Issue Subissue pertaining to the demonstration of the postclosure individual protection standard is considered closed-pending. Following is a summary of issues that DOE needs to resolve before this subissue can be closed.

Table 3.4.1-1. Related Key Technical Issue Subissues and Agreements

Key Technical Issue	Subissue	Status	Related Agreements*
Igneous Activity	—	—	All Agreements
Structural Deformation and Seismicity	—	—	All Agreements
Evolution of Near-Field Environment	—	—	All Agreements
Container Life and Source Term	—	—	All Agreements
Thermal Effects on Flow	—	—	All Agreements
Repository Design and Thermal-Mechanical Effects	—	—	All Agreements
Unsaturated and Saturated Flow Under Isothermal Conditions	—	—	All Agreements
Radionuclide Transport	—	—	All Agreements
Total System Performance Assessment and Integration	Subissue 4—Demonstration of Compliance with the Postclosure Public Health and Environmental Standards	Closed-Pending	TSPAI.4.01 TSPAI.4.03 through TSPAI.4.07

*Related DOE and NRC agreements are associated with one or all five generic acceptance criteria.

3.4.1.6 References

Bechtel SAIC Company, LLC. "Root Cause Analysis Report for CAR BSC–01–C–001 and CAR BSC–01–C–002." Revision 1. Las Vegas, Nevada: Bechtel SAIC Company, LLC. 2001.

CRWMS M&O. "Total System Performance Assessment–Site Recommendation Methods and Assumptions." TDR–MGR–MD–000001. Revision 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. 1999.

———. "Total System Performance Assessment for the Site Recommendation." TDR–WIS–PA–000001. Revision 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. 2000a.

———. "Repository Safety Strategy: Plan to Prepare the Postclosure Safety Case to Support Yucca Mountain Site Recommendation and Licensing Considerations." TDR–WIS–RL–000001. Revision 03. North Las Vegas, Nevada: DOE, Yucca Mountain Site Characterization Office. 2000b.

———. "Total System Performance Assessment Model for Site Recommendation." MDL–WIS–PA–000002. Revision 00. Las Vegas, Nevada: CRWMS M&O. 2000c.

DOE. "Software Management." Procedure AP-SI.1Q. Revision 03 ICN 01. Las Vegas, Nevada: DOE, Office of Civilian Radioactive Waste Management. 2001.

Golder Associates. "Software Code: GoldSim." 6.04.007. Redmond, Washington: Golder Associates. 2000.

Leigh, C.D., B.M. Thompson, J.E. Campbell, D.E. Longsine, R.A. Kennedy, and B.A. Napier. "User's Guide for GENII-S: A Code for Statistical and Deterministic Simulation of Radiation Doses to Humans from Radionuclides in the Environment." SAND91–056. Albuquerque, New Mexico: Sandia National Laboratories. 1993.

NRC. NUREG–1636, "Regulatory Perspectives on Model Validation in High-Level Radioactive Waste Management Programs: A Joint NRC/SKI White Paper." Washington, DC: NRC. March 1999.

———. "Issue Resolution Status Report, Key Technical Issue: Total System Performance Assessment and Integration." Washington, DC: NRC. 2000.

———. "NUREG–1804, "Yucca Mountain Review Plan—Draft Report for Comment." Revision 2. Washington, DC: NRC. March 2002.

3.4.2 Demonstration of Compliance with the Human Intrusion Standard

3.4.2.1 Description of Issue

The Demonstration of Compliance with the Human Intrusion Standard section addresses the DOE approach for conducting a total system performance assessment of the effects of limited human intrusion on the repository system and, if necessary, demonstrates that the repository system is not substantially degraded as a result. Limited human intrusion, as detailed in 10 CFR 63.322, describes an event for which (i) a single groundwater exploration borehole is drilled through a degraded waste package and continues to the saturated zone, (ii) the borehole is not properly sealed and is assumed to degrade naturally, (iii) no waste material falls into the borehole, (iv) only exposure to radionuclides transported to the saturated zone by water is considered, and (v) unlikely natural processes and events are not considered. The overall organization and identification of all the integrated subissues are depicted in Figure 1.1-2. The DOE description and technical basis for analyzing performance in case of limited human intrusion are documented in the total system performance assessment and model reports for the site recommendation (CRWMS M&O, 2000a,b) and numerous supporting analysis and model reports. This chapter reviews the analysis of performance, in case of limited human intrusion, DOE incorporated in its total system performance assessment.

3.4.2.2 Relationship to Key Technical Issue Subissues

The Demonstration of Compliance with the Human Intrusion Standard section incorporates subject matter previously captured in the following key technical issue subissues:

- Total System Performance Assessment and Integration: Subissue 3—Model Abstraction (NRC, 2000)
- Total System Performance Assessment and Integration: Subissue 4—Demonstration of Compliance with the Postclosure Public Health and Environmental Standards (NRC, 2000)

These key technical issue subissues formed the bases for the previous versions of the issue resolution status reports and also were the bases for technical exchanges with DOE where agreements were reached on the additional information DOE needed to provide to resolve the subissue. The resolution status of this integrated subissue is based on the resolution status of each of the contributing key technical issue subissues. The subsequent sections incorporate applicable portions of these key technical issue subissues, however, no effort was made to explicitly identify each subissue.

3.4.2.3 Importance to Postclosure Performance

One aspect of risk-informing the NRC review was to determine how this issue is related to the DOE repository safety strategy. Repository performance in case of limited human intrusion at Yucca Mountain is directly related to three of the principal factors DOE identified in the repository safety strategy (CRWMS M&O, 2000c)—seepage into emplacement drifts,

radionuclide concentration limits in water, and radionuclide delay through the saturated zone. The DOE analyses indicate that the peak dose rate for human intrusion is most affected by the amount of seepage contacting the waste intersected by the borehole, radionuclide concentrations in this seepage, delay of radionuclide migration through the saturated zone, dilution of the radionuclide concentrations during pumping, and biosphere dose conversion factors for the groundwater related pathway (CRWMS M&O, 2000c). Note that 10 CFR 63.332 specifies the amount of water that can be pumped per year and, therefore, fixes the dilution rate of radionuclides.

3.4.2.4 Technical Basis

NRC used the acceptance criteria and review methods found in previous issue resolution status reports to develop the Yucca Mountain Review Plan (NRC, 2002). This section documents the review of DOE approaches for including analysis of performance in case of limited human intrusion in total system performance assessment abstractions. The review is organized according to three acceptance criteria: (i) Time of the Earliest Intrusion Event Is Technically Supported, (ii) Evaluation of an Intrusion Event Demonstrates the Annual Dose to the Reasonably Maximally Exposed Individual in Any Year During the Compliance Period Is Acceptable, and (iii) The Total System Performance Assessment Code Provides a Credible Representation of the Intrusion Event.

3.4.2.4.1 Time of the Earliest Intrusion Event Is Technically Supported

Overall, the current information is sufficient to conclude that the necessary information will be available at the time of a potential license application to evaluate the earliest time of an intrusion event.

Staff found the method for estimating the time of earliest intrusion presented in CRWMS M&O, (2000a) was generally satisfactory. The individual protection standard for human intrusion in 10 CFR 63.321 is a two-step process. The first step requires DOE to provide the analyses and technical bases used to determine the earliest time after disposal that the waste package would degrade sufficiently that a human intrusion could occur without recognition by the drillers. The second step, which will be covered in more detail in Section 3.4.2.4.2, requires that an assessment be performed if a waste package is projected to be penetrated at or before 10,000 years after disposal. The DOE approach presented in the Total System Performance Assessment–Site Recommendation assumed that the human intrusion occurred 100 years after closure of the repository. DOE stated that 100 years was used " because it was considered to be conservative and because it was difficult to defensibly quantify a later intrusion time ." Staff found that assuming the human intrusion event occurs 100 years after closure of the repository is conservative and acceptable. It should be noted, however, if DOE elects to modify this approach by using a different time of occurrence for the human intrusion event, DOE must provide, as required by 10 CFR 63.321, the analyses and technical bases used to justify the new time of occurrence.

3.4.2.4.2 Evaluation of an Intrusion Event Demonstrates the Annual Dose to the Reasonably Maximally Exposed Individual in Any Year During the Compliance Period Is Acceptable

Overall, the current information is sufficient to conclude that the necessary information will be available at the time of a potential license application to assess the adequacy of DOE demonstration that the annual dose to the reasonably maximally exposed individual in any year during the compliance period because of a human intrusion event is acceptable.

The methods presented in CRWMS M&O (2000a) for evaluating the annual dose to the reasonably maximally exposed individual in any year during the compliance period resulting from human intrusion were generally acceptable to allow information in a potential license application. DOE assumed the human intrusion event occurs 100 years after closure of the repository. Because the event is assumed to occur at or before 10,000 years after disposal, DOE is required by 10 CFR 63.321 to demonstrate there is a reasonable expectation that the reasonably maximally exposed individual receives no more than an annual dose of 0.15 mSv [15 mrem] as a result of human intrusion during the 10,000-year compliance period. DOE used its TSPA Code for this demonstration in CRWMS M&O (2000a).

3.4.2.4.3 The Total System Performance Assessment Code Provides a Credible Representation of the Intrusion Event

Overall, the current information, along with agreements reached between DOE and NRC, is sufficient to conclude that the necessary information will be available at the time of a potential license application to assess whether the DOE TSPA Code provides a credible representation of the intrusion event. The methods presented in CRWMS M&O (2000b) for performing a total system performance assessment should provide a credible representation of the human intrusion event.

Any parameter and scenario description choices DOE made in developing an approach for human intrusion analysis must be justified. A few examples of scenario specifications that still must be justified include, but are not limited to water infiltration rates in the borehole, assumption of no gain or loss of water from or to the unsaturated zone, borehole dimensions, treatment of early-time vaporization, in-package temperature and chemistry, and credit for sorption in the unsaturated fault pathway. Other examples of where assumptions made in the analysis of the effects of human intrusion do not appear to be justified or appropriate, based on 10 CFR Part 63, were raised at the Total System Performance Assessment and Integration Technical Exchange[1] and follow:

- Volume and chemistry of drilling fluids are ignored in analysis.
- Rate of infiltration is unaffected by the presence of the borehole.

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[1]Reamer, C.W. "U.S. Nuclear Regulatory Commission/U.S. Department of Energy Technical Exchange and Management Meeting on Total System Performance Assessment and Integration (August 6–10, 2001)." Letter (August 23) to S. Brocoum, DOE. Washington, DC: NRC. 2001.

- Cladding in the penetrated waste package is perforated because of the event, but not completely failed.

- The properties of the rubblized borehole (porosity, fluid saturation, and dispersivity) are represented by the matrix properties of an unsaturated zone fault.

DOE responded that human intrusion inputs will be reevaluated after promulgation of final EPA, DOE, and NRC rules. This response is acceptable, and NRC expects the approach DOE selects for analysis of the limited human intrusion scenario will conform to 10 CFR Part 63. No specific agreement was generated for this comment.

DOE should ensure the results of the human intrusion analyses are consistent with other models in the DOE TSPA Code. The following apparent inconsistency was raised at the Total System Performance Assessment and Integration Technical Exchange.[2]

The peak expected dose resulting from human intrusion is shown to occur approximately 200 years after the single waste package is breached by drilling. This result suggests that the travel time in the saturated zone is extraordinarily short. Elsewhere in the Total System Performance Assessment–Site Recommendation technical document, it appears the three-dimensional saturated zone model predicts a median travel time for unretarded C-14 of approximately 600 years, whereas for slightly retarded Tc-99, the median travel time is around 1,000 to 1,500 years. These findings seem inconsistent.

DOE responded that the apparent inconsistency may be caused by comparison of time for mean peak dose from the calculation of human intrusion from the DOE TSPA Code in CRWMS M&O (2000a, Figure 4.4-11) to breakthrough times calculated using median inputs to the three-dimensional saturated zone model in CRWMS M&O (2000a, Figure 3.8-18). DOE noted the mean human intrusion dose is strongly dominated by the early breakthroughs, and the DOE TSPA Code median human intrusion dose peaks after 10,000 years, consistent with retardation of neptunium and plutonium. This response is acceptable, and NRC expects results of the human intrusion analyses are consistent with other models in the DOE TSPA Code. NRC further recommends that explanations be provided for cases where results do not appear consistent. No specific agreement was generated for this comment.

DOE should ensure human intrusion calculations are stable with respect to the number of realizations and timestepping used. This comment was raised at the Total System Performance Assessment and Integration Technical Exchange, August 6–10, 2001.[3] DOE responded that 300 realizations have been conducted for human intrusion calculations. The calculations result in lower peak dose during the 10,000-year timeframe when compared with results using 100 realizations. Results using both 300 and 100 realizations are well below the current regulatory limit of 0.15 mSv [15 mrem]. DOE agreed the supporting

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[2]Reamer, C.W. "U.S. Nuclear Regulatory Commission/U.S. Department of Energy Technical Exchange and Management Meeting on Total System Performance Assessment and Integration (August 6–10, 2001)." Letter (August 23) to S. Brocoum, DOE. Washington, DC: NRC. 2001.

[3]Ibid

basis for the number of realizations will be documented in the Total System Performance Assessment–License Application Technical Report and the rationale for timestepping in the Total System Performance Assessment–License Application Model Report. This response is acceptable, and NRC expects that technical bases will be provided to demonstrate the results are stable for the number of realizations and timestepping used. This comment is addressed by agreements TSPAI.4.03 and TSPAI.4.04, which deal with stability for the number of realizations and spatial and temporal discretization.

3.4.2.5 Status and Path Forward

Table 3.4.2-1 provides the status of all key technical issue subissues referenced in Section 3.4.2.2 for analysis of performance in case of limited human intrusion. The table also provides the related DOE and NRC agreements. The agreements listed in the table are associated with one or all of the acceptance criteria discussed in Section 3.4.2.4. Note that the status and the detailed agreements (or path forward) pertaining to all the key technical issue subissues are provided in Table 1.1-3 and Appendix A.

The DOE-proposed approach, together with the DOE agreements to provide NRC with additional information (through specified testing, analyses, and the like), acceptably addresses the NRC questions so that no information beyond that provided, or agreed to, will likely be required at the time of a potential license application.

The final approach DOE selected for analysis of the limited human intrusion scenario must conform to 10 CFR Part 63, and all scenario-specific assumptions will be justified. To meet the acceptance criteria, the DOE human intrusion analysis must (i) adequately support the selection of time of occurrence of the earliest human intrusion; (ii) be performed separately from the overall code used to conduct a total system performance assessment but be generally consistent with the code used to conduct a total system performance assessment; (iii) demonstrate that the calculations are stable; (iv) use calculations based on appropriate conceptual models and produce results that are reasonable and consistent with the available conceptual models and data; (v) show that the repository system meets NRC performance objectives; and (vi) ensure the code used to conduct a total system performance assessment provides a credible representation of the intrusion event with respect to consistent assumptions, code verification, estimate of uncertainty, and proper sampling methods.

Table 3.4.2-1. Related Key Technical Issue Subissues and Agreements

Key Technical Issue	Subissue	Status	Related Agreements*
Total System Performance Assessment and Integration	Subissue 3—Model Abstraction	Closed-Pending	None
	Subissue 4—Demonstration of Compliance with the Postclosure Public Health and Environmental Standards	Closed-Pending	TSPAI.4.03 TSPAI.4.04

*Related DOE and NRC agreements are associated with one or all acceptance criteria.

3.4.2.6 References

CRWMS M&O. "Total System Performance Assessment for the Site Recommendation." TDR–WIS–PA–000001. Revision 00. Las Vegas, Nevada: TRW Environmental Safety Systems, Inc. 2000a.

———. "Total System Performance Assessment Model for Site Recommendation." MDL–WIS–PA–000002. Revision 00. Las Vegas, Nevada: TRW Environmental Safety Systems, Inc. 2000b.

———. "Repository Safety Strategy: Plan to Prepare the Safety Case to Support Yucca Mountain Site Recommendation and Licensing Considerations." TDR–WIS–RL–000001. Revision 04. Las Vegas, Nevada: TRW Environmental Safety Systems, Inc. 2000c.

NRC. "Issue Resolution Status Report, Key Technical Issue: Total System Performance Assessment and Integration, Revision 3." Washington, DC: NRC. 2000.

———. NUREG–1804, "Yucca Mountain Review Plan—Draft Report for Comments." Revision 2. Washington, DC: NRC. March 2002.

3.4.3 Analysis of Repository Performance That Demonstrates Compliance with Separate Groundwater Protection Standards

Text in this section will be provided at a later date.

3.5 Status of Postclosure Issue Resolution and Path Forward

This section summarizes the status of postclosure issue resolution at the staff level. These results do not constitute a licensing review, and none of the agreements summarized here should be used to draw conclusions about whether the proposed Yucca Mountain site is likely to meet applicable NRC regulatory requirements for postclosure performance. The DOE and NRC agreements describe the information DOE agreed to provide and is needed to support an NRC licensing review. As previously noted, if DOE were to adopt a lower temperature operating mode or the approach used in Bechtel SAIC Company, LLC (2001a,b), NRC believes that more information would be needed for a potential license application.

The organization of the postclosure section follows the report structure previously used in NRC (2000), which consists of four parts: (i) System Description and Demonstration of Multiple Barriers, (ii) Scenario Analysis and Event Probability, (iii) Model Abstraction, and (iv) Demonstration of Compliance with the Postclosure Public Health and Environmental Standards. As described in Chapter 1, this approach was adopted to streamline the postclosure performance assessment review process and focus on those areas important to repository performance after permanent closure. The total repository system is divided into 14 integrated subissues or model abstractions (Figure 1.1-2), each of which is evaluated against 5 generic acceptance criteria. Historically, issue resolution activities have been conducted and documented on the basis of nine key technical issues.

In the issue resolution status reports for individual key technical issues, issue resolution was documented subissue by subissue. The nine key technical issues represent major processes and related staff concerns regarding the postclosure safety of a geologic repository. Some processes were shared among key technical issues, making discussion and resolution cumbersome. As the NRC and the CNWRA staffs conducted independent performance assessment exercises over the years and reviewed similar exercises by the U.S. Department of Energy Yucca Mountain Project, Electric Power Research Institute, the U.S. Department of Energy Waste Isolation Pilot Project, and other international programs, it became clear that a more integrated and transparent issue structure was needed.

To clarify the issue structure, charts were constructed to depict the components of a safety review (Figure 1.1-1) and the relationships among various components of a postclosure performance assessment for the proposed repository at Yucca Mountain (Figure 1.1-2). These charts showed that an efficient way to review the DOE postclosure safety case and its associated performance assessment is to follow the partitioning depicted in Figure 1.1-2. This partitioning is primarily based on the natural progress of potential radionuclide release and transport to a receptor group at the Yucca Mountain site. The topics at the most detailed level of decomposition (14 in all) in Figure 1.1-2 are called integrated subissues or model abstractions, mainly because each integrated subissue draws information from multiple key technical issues. The integrated subissues represent an interdisciplinary and logical approach to reviewing the DOE total system performance assessment. The integrated subissue format and the interdisciplinary questions posed for each of the integrated subissues assist the staff in more formally integrating the contribution of the key technical issue subissues. Therefore, it was decided to adopt this structure in developing the postclosure portions of the Yucca

Mountain Review Plan (NRC, 2002). NRC (2002) documents guidance to the staff for the review of any license application submitted by DOE. To create traceability and transparency through better correlation of current reviews with future reviews of the potential license application, the same structure is also followed for the postclosure portion of this document.

System Description and Demonstration of Multiple Barriers

The Total System Performance Assessment and Integration Key Technical Issue Subissue pertaining to System Description and Demonstration of Multiple Barriers was categorized as closed-pending at the staff level as a result of agreements[1] reached at the August 2001 technical exchange. When information identified in the agreements is adequate, DOE will have provided sufficient information for the staff to conduct a detailed review of the DOE license application with respect to its demonstration that the repository has multiple barriers. DOE has to provide information in response to two multiple-barrier-related agreements. DOE agreed to enhance the description of its approach for presenting and describing the capabilities of barriers, which NRC anticipates will include how DOE will use its performance assessment model to support assertions of barrier performance. The eventual approach that DOE decides to use when describing the capabilities of particular barriers will influence the amount of effort used to complete the multiple-barrier-related agreements. Satisfying the agreements would not require DOE to conduct further site studies, however. The staff understanding is that DOE will be extending its Total System Performance Assessment–Site Recommendation analyses to address these agreements and, consequently, the staff anticipate that fulfilling these agreements may involve a minor level of effort.

Scenario Analysis and Event Probability

The Total System Performance Assessment and Integration Key Technical Issue Subissue pertaining to Scenario Analysis and Event Probability was categorized as closed-pending at the staff level as a result of agreements[2] reached at the August 2001 technical exchange between DOE and NRC. Presently, it appears DOE will have sufficient information on (i) the features, events, and processes considered for the total system performance assessment; (ii) the technical basis for including or excluding each feature, event, or process in the dose assessment; (iii) the formation and screening of scenario classes; and (iv) the treatment of events with a probability greater than one chance in 10,000 in 10,000 years for NRC to make a regulatory decision on receipt of any potential license application. DOE agreed to revise its process of defining, describing, and screening features, events, and processes to ensure that the process is comprehensive and that NRC can audit it. DOE has flexibility in how it addresses the NRC staff questions raised during the May and August 2001 technical exchanges. The effort that may be needed to provide the information described in the agreements will depend on the DOE approach. Changes in the scope of a feature, event, or process could affect the documentation of the technical basis used to include or exclude it from

[1] Reamer, C.W. "U.S. Nuclear Regulatory Commission/U.S. Department of Energy Technical Exchange and Management Meeting on Total System Performance Assessment and Integration (August 6–10, 2001)." Letter (August 23) to S. Brocoum, DOE. Washington, DC: NRC. 2001.

[2] Ibid.

the dose assessment. In some instances, additional analyses or data may be necessary to provide a technical basis for excluding a feature, event, or process from the dose assessment. In addition, information and analyses used to support these technical bases will be developed in response to other, linked, agreements. Consequently, the staff anticipate a moderate level of effort will be needed for DOE to provide the information necessary to fulfill the scenario-analysis-related agreements.

Model Abstraction

The Total System Performance Assessment and Integration Key Technical Issue Subissue pertaining to Model Abstraction was categorized as closed-pending at the staff level as a result of agreements[3] on performance assessment methods reached at the August 2001 technical exchange, as well as agreements reached at previous technical exchanges related to the other key technical issues. Presently, it appears DOE will have sufficient information to demonstrate (i) each model abstraction is adequately described and properly integrated with other model abstractions, (ii) the data are sufficient to justify each model abstraction, (iii) data uncertainty is properly characterized and propagated through each model abstraction, (iv) model uncertainty is properly characterized and propagated through each model abstraction, and (v) the output from each model abstraction is supported by objective comparison to confirmatory data. The information DOE agreed to provide to meet criteria (i)–(v) for each model abstraction is described in Sections 3.3.1–3.3.14.

Demonstration of Compliance with the Postclosure Public Health and Environmental Standards

The Total System Performance Assessment and Integration Key Technical Issue Subissue pertaining to Demonstration of Compliance with the Postclosure Public Health and Environmental Standards was categorized as closed-pending at the staff level as a result of agreements[4] reached at the August 2001 technical exchange. Presently, it appears DOE will have enough information about the methods to compute an accurate and stable estimate of the peak mean dose for 10,000 years, thus enabling NRC to make a regulatory decision on receipt of any potential license application. DOE must satisfy the terms of seven agreements to completely close this subissue. Although none of these seven agreements explicitly requires DOE to collect additional data, fulfilling the terms of the requirements, which include conducting new stability analysis, should require a moderate level of effort.

[3] Reamer, C.W. "U.S. Nuclear Regulatory Commission/U.S. Department of Energy Technical Exchange and Management Meeting on Total System Performance Assessment and Integration (August 6–10, 2001)." Letter (August 23) to S. Brocoum, DOE. Washington, DC: NRC. 2001.

[4] Ibid.

3.5.1 References

Bechtel SAIC Company, LLC. "FY01 Supplemental Science and Performance Analyses." Vol. 1: Scientific Bases and Analyses. TDR–MGR–MD–000007. Revision 00 ICN 01. Las Vegas, Nevada: Bechtel SAIC Company, LLC. 2001a.

Bechtel SAIC Company, LLC. "FY01 Supplemental Science and Performance Analyses." Vol. 2: Performance Analyses. TDR–MGR–PA–000001. Revision 00. Las Vegas, Nevada: Bechtel SAIC Company, LLC. 2001b.

NRC. "Issue Resolution Status Report, Key Technical Issue: Total System Performance Assessment and Integration." Revision 3. Washington, DC: NRC. 2000.

———. NUREG–1804, "Yucca Mountain Review Plan—Draft Report for Comment." Revision 2. Washington, DC: NRC. March 2002.

4 PERFORMANCE CONFIRMATION

4.1 Research and Development Program to Resolve Safety Questions

4.1.1 Description of Issue

Requirements for the content of the license application at 10 CFR 63.21(c)(10) specify that DOE identifies those structures, systems, and components of the geologic repository, both surface and subsurface, that require research and development to confirm the adequacy of design. This requirement also specifies that for structures, systems, and components important to safety and for the engineered and natural barriers important to waste isolation, DOE shall provide a detailed description of the programs designed to resolve safety questions, including a schedule indicating when these questions would be resolved.

DOE cannot provide schedules and detailed descriptions of research and development programs to resolve safety questions for either structures, systems, and components important to safety or engineered and natural barriers important to waste isolation until the safety questions have been identified. Unresolved safety questions are likely to be associated with other topics discussed in this Integrated Issue Resolution Status Report. It is premature to identify these questions until DOE has presented its safety case in a license application for construction authorization.

NRC staff will evaluate any safety questions, and the schedules and descriptions of the research and development programs to resolve them, using review methods and acceptance criteria in NRC (2002. This review, and staff knowledge of the status of open item issue resolution, could result in identification of additional safety questions. These additional safety questions would require DOE to define additional acceptable research and development programs before NRC could approve a construction authorization.

Because assessment of safety questions is premature as of the writing of this report, no specific concerns have been defined.

4.1.2 Relationship to Key Technical Issue Subissues

Specific topics for the research and development programs to resolve safety questions will not be identified until DOE has completed its safety case to support the license application for construction authorization. NRC staff expect that any such safety issues are likely to derive from existing integrated subissues that may not be adequately resolved at the time of a license application. It is also possible that safety questions that have not yet been identified will evolve before submission of a license application.

4.1.3 Importance to Safety and Postclosure Performance

Any safety question, by definition, is important to safety or to waste isolation. The degree of significance of any specific safety question will be evaluated on the basis of risk insights and information gained throughout the prelicensing consultation period. The degree of safety significance also will be considered in determining the adequacy of any proposed research and

development program. The integrated safety significance of all safety questions must be taken into account when the staff decide whether it is appropriate to approve a construction authorization.

4.1.4 Technical Basis

Because safety questions and their associated research and development programs have not yet been presented in a license application, there is no technical basis to evaluate. A generic approach for the review of any such concerns and programs will be provided in NRC (2002).

4.1.5 Status and Path Forward

No safety questions have yet been identified. Consequently, the associated research and development programs have not been developed.

When the license application for construction authorization is submitted, the NRC staff will evaluate the research and development programs for any safety questions using an approach that will be included in NRC (2002).

4.1.6 Reference

NRC. NUREG–1804, "Yucca Mountain Review Plan—Draft Report for Comment." Revision 2. Washington, DC: NRC. March 2002.

4.2 Performance Confirmation Program

4.2.1 Description of Issue

Performance confirmation is the program of tests, experiments, and analyses to evaluate the adequacy of the information used to determine that the performance objectives for the facility will be met. The Performance Confirmation Program begins during site characterization and continues until permanent closure of the repository. DOE will conduct a Performance Confirmation Program to confirm the assumptions, data, and analyses that support the performance assessment and any findings, based thereon, that permitted construction of the repository and subsequent emplacement of the wastes. Key geologic, hydrologic, geomechanical, and other physical parameters will be monitored to detect any significant changes in the conditions assumed in the performance assessment that may affect compliance with the performance objectives.

4.2.2 Importance to Safety and Postclosure Performance

The DOE Performance Confirmation Program is intended to address the full range of safety issues described elsewhere in this report. Many of those safety issues have substantial uncertainties, especially those issues related to meeting long-term system performance objectives. The responses of the engineered and natural system barriers to activities conducted during waste emplacement and as a result of waste emplacement are to be evaluated using the Performance Confirmation Program, during an extended operating period, to discover any negative effects on the safety of the repository. Conduct of the Performance Confirmation Program is therefore an important part of the DOE repository safety case. Specifically, performance confirmation is identified in Revision 4 of the DOE Repository Safety Strategy as one of five elements of the planned DOE postclosure safety case (CRWMS M&O, 2000a).

4.2.3 Status and Path Forward

DOE published CRWMS M&O (2000b), presenting its current plans for test and evaluation activities, including predicting test outcomes, conducting *in-situ* and laboratory tests, analyzing test data, and modeling and evaluating test results. The staff understand that DOE will update this Performance Confirmation Plan when new information becomes available. DOE activities conducted to date as part of site characterization have begun to establish baseline information against which future repository performance can be evaluated. DOE anticipates that the transition from baseline development to monitoring and modeling the performance effects of changes from baseline conditions will occur after submittal of the site recommendation report and before emplacement of waste in the repository. The staff will review in detail the DOE Performance Confirmation Plan subsequent to the DOE completion of its planned revision of the Performance Confirmation Plan.

Performance Confirmation

DOE plans these steps to accomplish the Performance Confirmation Program (CRWMS M&O, 2000b):

(1) Identify performance confirmation factors and parameters: Identify the factors (processes) and related parameters important to postclosure safety that should be monitored as part of performance confirmation.

(2) Establish the performance confirmation database and predict performance: Establish the database from site characterization efforts and identify the analytical process models and performance assessment models to be used to predict and evaluate performance. Using this basis, predict the expected preclosure values and variations of these values.

(3) Establish tolerances and bounds: Establish tolerances or acceptable limits (screening levels) of deviations from predicted performance, including acceptable ranges of key parameter values, regulatory limits, and model validity or credibility limits. Analyses are to address expected changes as a result of construction, operations, and waste emplacement.

(4) Establish completion criteria and guidelines for corrective actions: Establish criteria and guidelines for completing an activity and for evaluating conditions outside of tolerance, as well as identify and recommend corrective actions to be taken in these cases.

(5) Plan and set up the performance confirmation test and monitoring program: Conduct detailed planning, construct the test/monitoring facilities, and set up instrumentation necessary for the Performance Confirmation Program, including establishment of the ambient baseline, if necessary.

(6) Monitor, test, and collect data: Perform the testing and monitoring activities necessary to collect data in accordance with applicable regulations and quality assurance requirements.

(7) Analyze, evaluate, and assess data: Analyze and evaluate performance confirmation data against the performance confirmation baseline, including conducting statistical tests and trend analyses. When changes occur in the predicted construction and operation sequencing, total system performance assessments will be conducted as necessary to assess the impact of these changes on the activity baseline.

(8) Recommend and implement corrective actions (if required): Identify, recommend, and (if necessary) implement corrective action if data or data trends exceed (or are expected to exceed) the prescribed bounds. If data stay within prescribed bounds, continue to perform periodic evaluations against completion criteria to determine whether to continue the test operation or stop the monitoring.

The current version of CRWMS M&O (2000b) is based on Revision 3 of CRWMS M&O (2000c). DOE is expected to update the principal safety factors for CRWMS M&O (2000b) when future versions of the CRWMS M&O (2000c) are produced.

4.2.4 References

CRWMS M&O. "Repository Safety Strategy: Plan to Prepare the Safety Case to Support Yucca Mountain Site Recommendation and Licensing Considerations." DRL–WIS–RL–000001. Revision 04. Las Vegas, Nevada: CRWMS M&O. 2000a.

———. "Performance Confirmation Plan." TDR–PCS–SE–000001. Revision 01 ICN 01. Las Vegas, Nevada: CRWMS M&O. 2000b.

———. "Repository Safety Strategy: Plan to Prepare the Postclosure Safety Case to Support Yucca Mountain Site Recommendation and Licensing Considerations." TDR–WIS–RL–000001. Revision 03. Las Vegas, Nevada: CRWMS M&O. 2000c.

5 ADMINISTRATIVE AND PROGRAMMATIC REQUIREMENTS

5.1 Quality Assurance Program

The following is based on the status of the DOE quality assurance program.

5.1.1 Background

In late 1998 and early 1999, DOE identified significant deficiencies in the implementation of its quality assurance program in the following areas: (i) procurement (qualification of suppliers and the use of unqualified sources), (ii) model development (inadequate technical review and collection of data and documentation of data collection in scientific notebooks), and (iii) software development (inadequate identification and implementation of software controls). As a result of these deficiencies, DOE implemented a corrective action plan. The two major elements of this corrective action plan required that the quality of all data and software developed before June 1999 be reverified and that procedures controlling the areas where deficiencies were identified be revised to provide adequate controls to ensure the quality assurance program is effectively implemented. Further, all personnel supporting site characterization activities received extensive training in the regulatory and licensing processes.

During fiscal years 2000 and 2001, staff reviewed the implementation of the DOE corrective action plan, including data and software qualification, by (i) observing several DOE performance-based audits; (ii) using daily overviews performed by the NRC onsite representatives assigned to the Yucca Mountain Project Office in Las Vegas, Nevada; and (iii) addressing concerns and progress with DOE during technical exchanges and management meetings.

DOE also stated that it will submit a comprehensive corrective action plan to address the causes of problems. This plan will consider and address items such as (i) results of DOE reviews of the documents supporting the site recommendation and a potential license application; (ii) root cause analysis for the various quality assurance problems; (iii) lessons learned from past corrective action plans; (iv) accountability; (v) performance measures; (vi) upgrading and enhancing procedures; and (vii) audits, surveillances, self assessments, and management oversight to confirm that the corrective actions are being implemented and are effective.

NRC reviewed DOE (2002), which is intended to address the items described in the previous paragraph. This document did not meet NRC expectations and the DOE committed to revise the document to address NRC concerns.

The following paragraphs provide additional information on the progress DOE has made in implementing its corrective action plan and addressing quality assurance issues relating to DOE documentation supporting the site recommendation and a potential license application.

5.1.2 Staff Oversight of the DOE Quality Assurance Program

Before May 2000, the staff observed several DOE performance-based audits of analysis and model reports and related process model reports. In February 2000, the DOE Office of Quality

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Assurance suspended audits of analysis and model reports and process model reports because (i) deficiencies were repeatedly identified in the areas of procedure compliance and software control, (ii) recommendations and lessons learned from the audits were not being effectively communicated to and implemented by the preparers of the analysis and model reports, and (iii) scheduled completion dates for some of the analysis and model reports were being postponed. Staff considered the actions of the DOE Office of Quality Assurance to delay the remaining audits appropriate.

In July 2000, DOE resumed auditing of analysis and model reports and process model reports. Some of the audits yielded no significant findings and indicated improvement in the technical quality and completeness of analysis and model reports and process model reports. Other audits, however, revealed that problems continued in the area of procedure compliance and some analysis and model reports and process model reports contained insufficient detail for documenting the bases for certain assumptions, inputs, and equations. During the April 17, 2001, DOE and NRC Quarterly Quality Assurance Breakout Session Meeting, DOE reported that it was evaluating the results of the recurring problems identified during the audits and determined that improvements were needed to clearly document model validation and the qualification of software routines and macros.[1,2] Further, DOE stated that it was investigating whether there was a significant condition adverse to quality regarding traceability and transparency of documentation supporting analysis and model reports and process model reports.

During prelicensing interactions in 2001, DOE discussed the results of its reviews to verify the quality of the documents supporting the site recommendation, including the Yucca Mountain Science and Engineering Report, the Total System Performance Assessment for the Site Recommendation, and the FY01 Supplemental Science and Performance Analyses. DOE performed vertical, horizontal, and technical reviews of these documents using, in some cases, personnel independent of the Yucca Mountain project. DOE also used independent personnel to perform an analysis for determining the root causes of the errors found in these documents. Although the NRC staff have not independently verified them, the staff believes that the performance of the reviews by DOE was necessary and appropriate to verify the quality of the documents supporting the site recommendation. It appears to the NRC staff that the reviews did not reveal any significant errors or problems that would impact the conclusions in the Total System Performance Assessment for the Site Recommendation portion of the site recommendation.

Although DOE has not yet fully qualified data and software used in the CRWMS M&O (2000) portion of the site recommendation, it has a reasonable approach to do so. Further, DOE indicated that if the information contained in Bechtel SAIC Company, LLC (2001a,b) is used to support or be a part of a potential license application, the information would be fully qualified and subjected to the same qualification controls as used for CRWMS M&O (2000). The staff

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[1]Reamer, C.W. "Minutes of the April 17, 2001, Quality Assurance and Key Technical Issue Status Management Meeting." Letter (August 20) to R. Clark, DOE. Washington, DC: NRC. 2001.

[2]Reamer, C.W. "Minutes of the April 18, 2001, Management Meeting." Letter (June 20) to S. Brocoum, DOE. Washington, DC: NRC. 2001.

accept the DOE commitment to fully qualify all data, software, and models if used in a potential license application.

5.1.3 Implementation of Corrective Action

DOE has made significant progress in implementing appropriate corrective action to address its quality assurance problems. DOE responded to and completed the required corrective action requests documenting the 1998 and 1999 significant conditions adverse to quality except for the corrective action to confirm the adequacy of data and software qualified before June 1999.

In September 1999, DOE notified NRC of its goal to have 80 percent of all data fully qualified by mid-January 2001. To meet this goal, a graded approach was applied to the reverification of data collected before June 1999. This graded approach was based on the risk significance of the data. At that time, DOE also committed to have 100 percent of all data and software fully qualified by the time of a potential license application. DOE met its mid-January 2001 data qualification goal of 80 percent. As of September 6, 2001, DOE had qualified 94 percent of the data and 98 percent of the software supporting a potential license application. During the April 17, 2001, DOE and NRC Quarterly Quality Assurance Breakout Session Meeting, DOE reported that its goal was to have all data fully qualified by the time of the site recommendation and all software fully qualified by the time of a potential license application.

The staff will continue to observe DOE audits and discuss quality assurance problems and corrective actions with DOE. Also, the NRC onsite representatives will continue to routinely interact with DOE and its management and operating contractor to increase confidence that DOE is satisfactorily implementing the required corrective actions to address past and present quality assurance problems.

5.1.4 Conclusions

The DOE corrective action plan elements and approach appear reasonable. Although DOE has had problems implementing previous corrective action plans, DOE has made progress in implementing appropriate corrective actions to address identified quality assurance problems. Problems that have arisen since January 2001, however, indicate DOE needs to improve the implementation of its quality assurance program, especially in the areas of software control, model validation, and accuracy of information provided in DOE reports [e.g., CRWMS M&O (2000)]. Adherence to procedures and attention to detail in the preparation, independent review, and issuance of DOE documents continue to require improvement.

DOE has not yet fully qualified all the data and software needed for a potential license application, but appears to have a reasonable approach to do so by the time of a potential license application. If the data and software supporting a potential license application are fully qualified before any such license application, as agreed, there will be sufficient basis for NRC to conduct its licensing review. Taking into consideration the progress made to date and the current DOE schedule, DOE should be able to complete the qualification of data and software by the time of a potential license application.

5.1.5 References

Bechtel SAIC Company, LLC. "FY01 Supplemental Science and Performance Analyses." Vol. 1: Scientific Bases and Analyses. TDR–MGR–MD–000007. Revision 00 ICN 01. Las Vegas, Nevada: Bechtel SAIC Company, LLC. 2001a.

———. "FY01 Supplemental Science and Performance Analyses." Vol. 2: Performance Analyses. TDR–MGR–PA–000001. Revision 00. Las Vegas, Nevada: Bechtel SAIC Company, LLC. 2001b.

CRWMS M&O. "Total System Performance Assessment for the Site Recommendation." TDR–WIS–PA–000001. Revision 00 ICN 01. Las Vegas, Nevada: TRW Environmental Safety Systems, Inc. 2000.

DOE. "Office of Civilian Radioactive Waste Management (OCRWM) Management Improvement Initiatives." Revision 00. Las Vegas, Nevada: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. 2002.

5.2 Records, Reports, Tests, and Inspections

Text in this section will be provided at a later date.

5.3 Training and Certification of Personnel

Text in this section will be provided at a later date.

5.4 Expert Elicitation

5.4.1 Description of Issue

Nearly every aspect of site characterization, design, and performance assessment will involve significant uncertainties. The primary method to evaluate and, to the extent practical, reduce these uncertainties should be through collection of sufficient data and information during site characterization. Factors such as temporal and spatial variations in the data, the possibility for multiple interpretations of the same data, and the absence of validated theories for predicting the performance of a repository for thousands of years, however, will result in some residual uncertainty. Consequently, the staff anticipate it will be necessary to complement and supplement the data obtained during site characterization with the interpretations and subjective judgments of technical experts (i.e., expert elicitation) as well as to conduct confirmatory testing and analyses during and after construction, should NRC authorize construction.

In the review process, NRC traditionally accepted expert elicitation to evaluate and interpret the factual bases of license applications. Thus, NRC is to give appropriate consideration to the judgments of DOE experts on a possible geologic repository at Yucca Mountain. Such consideration, however, envisions DOE using expert elicitation to complement and supplement more objective sources of scientific and technical information, such as data collection, analyses, and experimentation. The NRC staff believe formal elicitation procedures, used prudently and appropriately, can help ensure the expert elicitations are well documented, and the technical reasoning used to reach those judgments is open and traceable for independent review. If conducted optimally, formal elicitation can reveal a wide range of scientific and technical interpretations, thereby exposing (and possibly quantifying) the uncertainties in estimates concerning repository siting, design, and performance attributable to limitations in the state of technical knowledge. Formal procedures may also help groups of experts resolve differences in their estimates by providing a common scale of measurement and a common vocabulary for expressing their judgments.

5.4.2 Background

Recognizing that DOE intended to use expert elicitation in its geologic repository program, the NRC completed work, in late 1996, on its Branch Technical Position on the Use of Expert Elicitation in the High-Level Waste Program. This document, designated NUREG–1563 (NRC, 1996), provides general guidelines on those circumstances that may warrant the use of a formal process for obtaining the judgments of more than one expert (i.e., expert elicitation) and describes acceptable procedures for conducting expert elicitation, when formally elicited judgments are used to support a demonstration of compliance with NRC geologic repository disposal regulation. At the time, DOE was independently developing its own internal guidance on the use of expert elicitation. As part of the public comment process, however, DOE reviewed the Branch Technical Position and noted that it is in substantial agreement with staff

technical positions. Moreover, DOE committed[1,2,3] to modify its internal procedures to be consistent with the Branch Technical Position and to follow this document in any formal elicitations DOE conducts for Yucca Mountain.

There are no precise criteria for determining when an expert elicitation should be undertaken. To implement the risk-informed performance-based approach, the language in 10 CFR Part 63 is intentionally nonprescriptive; that is, it leaves to DOE the opportunity and responsibility to determine how best to design any potential geologic repository at Yucca Mountain. Typically, programmatic concerns (timing, cost, and compliance demonstration requirements) will have a major influence on when the repository developer (DOE) uses an expert elicitation or gathers additional objective information. For example, programmatic concerns dominate the choices of (i) gathering additional field or laboratory data, (ii) undertaking additional theoretical analyses, (iii) using expert elicitation, or (iv) altering the compliance demonstration strategy, to lessen or eliminate the need to resolve a particular issue. Thus, DOE is responsible for determining a data-information-gathering approach, as long as an effective demonstration of compliance with the regulations can be made.

Consequently, DOE has the flexibility to determine if the costs and benefits of performing an expert elicitation are advantageous when compared with the costs and benefits of performing theoretical analyses, gathering additional field and experimental data, or both. As noted in NUREG–1563 (NRC, 1996), "... the use of expert elicitation should not be considered as an acceptable substitute for traditional analyses based on adequate field or experimental data, when such data are reasonably available or obtainable, or the analyses are practicable to perform .... ." Moreover, the guidance also states that adherence to the Branch Technical Position does not guarantee the specific technical conclusions will be accepted and adopted by the staff, an independent Licensing Board, NRC itself, or any other party to a potential high-level waste licensing proceeding. Rigid adherence to a sound elicitation process, in and of itself, does not guarantee the resulting judgments will be sufficient to satisfy the applicant burden of proof regarding the substantive issues addressed by the elicitation. Conversely, expert elicitation obtained through an evidently flawed or poorly documented process will not be adequate to support demonstrations of compliance.

5.4.3 Staff Oversight of DOE Use of Expert Elicitation

For years, the use of expert elicitation supported DOE incremental (DOE, 1998) decisionmaking related to determining the suitability of the Yucca Mountain site. DOE used expert elicitation to

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[1]Austin, J.H. "Issue Resolution for Site Characterization Analysis Comment 3 and Other Open Items Related to the Use of Expert Judgment." Letter (December 26) to R.A. Milner, DOE, Office of Civilian Radioactive Waste Management. Washington, DC: NRC, Division of Waste Management. 1996.

[2]Brocoum, S.J. "Resolution of U.S. Nuclear Regulatory Commission Site Characterization Analysis Comment 3 and Other Comments Related to the Use of Expert Elicitations in the High-Level Waste Program." Letter (August 6) to M. Bell, NRC. Washington DC: NRC. 1997.

[3]Bell, M.J. "U.S. Department of Energy Proposals to Implement Appendix E to NUREG–1563—Resolution of Site Characterization Analysis Comment 3." Letter (February 12) to S. Brocoum, DOE. Washington, DC: NRC. 1998.

resolve important performance issues, such as volcanism, and to select parameter distribution for the Total System Performance Assessment–Viability Assessment (TRW Environmental Safety Systems, Inc., 1996) [i.e., understanding unsaturated/saturated flow, defining waste form degradation and radionuclide mobilization modes, explaining near-field/altered-zone coupled effects, and determining sorption coefficient (k_d)].

NRC and CNWRA staffs have observed most DOE-sponsored formal elicitations. Furthermore, the Branch Technical Position was under development at the time DOE began elicitations on volcanism and seismic hazard. DOE now only relies on the use of expert elicitation in the areas noted in the next sections.

5.4.3.1 Probabilistic Volcanic Hazards Analysis

Major silicic volcanic eruptions have not occurred in southern Nevada in the last 10 million years. There is evidence, however, of lesser-magnitude basaltic volcanic activity in the Yucca Mountain area during this period, with activity at the Lathrop Wells cone—approximately 15 km [9.3 mi] southwest of the proposed repository site—possibly occurring as recently as 80,000 years ago. Because of the potentially undesirable consequences of a low-probability disruptive event, volcanism has been intensely investigated and debated for the last two decades. The uncertainties include

- Age of the most recent volcanism
- Mode of volcanic activity
- Structural control of past and future volcanic activity
- Adequacy of probabilistic models of volcanic activity
- Sufficiency of existing data for reliable probabilistic estimates of the volcanic hazard

There are no generally accepted methodologies for calculating the probability of future igneous activity during the regulatory period of interest. In addition, more than one conceptual model can be applied to this problem, resulting in a wide range of probability values. In an attempt to address the areas of controversy as well as to establish a credible basis for probabilistic calculations that could be used to assess the potential impact of volcanism on repository performance, DOE assembled 10 experts and conducted expert elicitations between 1995 and 1997. The elicitation process consisted of four workshops and two field trips to the Yucca Mountain site. The resulting elicitation, documented in Geomatrix Consultants (1996), evaluated a range of probability models, estimated uncertainties in model results caused by reasonable variations in model parameters, and determined a probability distribution for use in performance assessment models for Yucca Mountain. NRC and CNWRA staffs observed the expert elicitation workshops and reviewed the information developed through the documentation process and found it generally sufficient to use in a potential Yucca Mountain license application. Overall, DOE adequately justified the need for the elicitation and generally conducted the elicitation in accordance with the guidance set forth in NUREG–1563 (NRC, 1996).

Nevertheless, as explained in Section 3.2.2.4.1 of this document, the staff performed a technical review of the Geomatrix Consultants (1996) and have several technical concerns regarding these results and their application in the Yucca Mountain program.

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As a result of the various concerns, NRC reached two agreements with DOE.[4] Hence, the probability subissue is considered closed-pending. In the first agreement, DOE will include, in any possible site recommendation and possible license application, for information purposes, the results of a single-point sensitivity analysis for extrusive and intrusive igneous processes at a probability of 10^{-7}/yr—a value supported by the NRC staff. This analysis has been previously presented in such documents as Bechtel SAIC Company LLC (2001a Figure 4.3-1). In addition, at the August 2000 Igneous Activity Technical Exchange,[5] it was indicated that a new aeromagnetic survey had been undertaken for the site area. In the second agreement, DOE agreed to examine the results of this new survey for potential unrecognized buried igneous features and to evaluate the effect of these features on the Geomatrix Consultants (1996) probability estimates.

5.4.3.2 Probabilistic Seismic Hazards Analysis

DOE developed comprehensive probabilistic seismic and faulting hazard assessments necessary to characterize the potential seismic and faulting hazards at Yucca Mountain. The approach was similar to that suggested for a Level 4 Probabilistic Seismic Hazard Assessment, as defined in Budnitz, et al. (1997). The Level 4 Probabilistic Seismic Hazard Assessment includes the use of expert elicitation. Because of the limited availability of sufficient strong motion data and uncertainties in the seismologic characteristics of the Yucca Mountain site and region, DOE convened two expert panels. One panel was to evaluate the seismic source characterization. The other panel was to develop probabilistic models for ground-motion attenuation specific to the regional conditions of the western Basin and Range in proximity to Yucca Mountain. In the context of these circumstances, the use of an expert elicitation process was reasonable and appropriate.

Development of Budnitz, et al. (1997) followed a methodology first proposed by Cornell (1986) and McGuire (1976) and used a modified version of the FRISK88 computer code (Risk Engineering Inc., 1998). Within this approach, uncertainties were propagated through the analyses, and the results were presented as mean, median, and fractile hazard curves that incorporate uncertainties in the input parameters.

5.4.3.2.1 Seismic Source and Fault Displacement Characterization

For this elicitation, DOE assembled 18 experts, divided into 6 expert teams, and held 6 elicitation workshops between 1995 and 1998 (CRWMS M&O, 1998a). In addition to developing earthquake and ground-motion hazard assessments, the seismic source zone characterization experts also were to develop fault-specific probabilistic fault displacement hazards. These fault displacement hazard assessments used an approach similar to the one used in the seismic source zone characterization. Technical details of aspects of the seismic

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[4]Schlueter, J. "U.S. Nuclear Regulatory Commission/U.S. Department of Energy Technical Exchange and Management Meeting on Igneous Activity (August 29–31, 2000)." Letter (October 23) to S. Brocoum, DOE. Washington DC: NRC. 2000.

[5]Ibid.

and fault displacement hazard results are provided in Section 3.3.2.4.2, Faulting, and Section 3.3.2.4.3, Seismicity, of this Integrated Resolution Status Report.

The staff reviewed the information developed by DOE through the documentation process on fault displacement and seismic source zone characterization (CRWMS M&O, 1998a) and found it sufficient to use in a potential Yucca Mountain license application. DOE adequately justified the need for the elicitation and conducted the elicitation in accordance with the guidance set forth in NUREG–1563 (NRC, 1996).

5.4.3.2.2 Ground-Motion Attenuation

DOE assembled seven experts for the ground-motion elicitation, and the elicitation process was conducted in parallel with that of the seismic source zone elicitation. The ground-motion experts were to provide input (e.g., data, scientific interpretations, and estimates of parameter uncertainties) for developing the probabilistic ground-motion attenuation model (i.e., mathematical relationships between ground-motion and earthquake magnitude, distance, site conditions, and style of faulting). Unlike seismic source characterization, experts for this elicitation team were asked to provide intermediary results that were then used to develop the final Probabilistic Seismic Hazard Assessment (Budnitz, et al., 1997) ground-motion relationships. The seven experts each developed a probabilistic ground-motion attenuation model. These models were subsequently aggregated to (probabilistically) represent the current state of knowledge with regard to ground motions possible at the Yucca Mountain site due to earthquake phenomena. Technical details of aspects of the ground-motion attenuation results are provided in Section 3.3.2.4.3, Seismicity, of this Integrated Resolution Status Report.

The staff reviewed the information developed by DOE through the documentation process on ground-motion attenuation (CRWMS M&O, 1998b) and found it insufficient to use in a potential Yucca Mountain license application (subject to the agreement described in Section 5.4.5, Status and Path Forward of this report). The staff review concluded that, although DOE adequately justified the need for elicitation in this area, DOE did not conduct the elicitation in accordance with the guidance set forth in NUREG–1563 (NRC, 1996), particularly as it relates to the documentation provision of the elicitation process itself. Specifically, DOE has not provided documentation demonstrating that the ground-motion experts clearly understood the implications of their ground-motion parameter inputs, (part of postelicitation feedback) which are necessary to the ground-motion model development process. This postelicitation feedback information is necessary to verify the technical integrity of the elicitation process as well as the traceability of the assessment itself. Consequently, the absence of post-elicitation feedback documentation diminishes the acceptability and credibility of the elicitation results themselves because the process at present does not appear to be transparent and traceable.

For example, the staff independent review of the elicited ground-motion models for Yucca Mountain raised questions about the scientific basis for several of the individual expert ground-motion assessments as well as completeness of the elicitation feedback process itself. In particular, examination of several of the ground-motion models illustrated that a large range of unexplained differences exists between the experts inputs regarding predicted ground-motions and epistemic and aleatory uncertainties. In some instances, the staff noted wide differences between experts and large variability within individual expert models. The issues of

proper feedback and documentation are especially crucial to the ground-motion part of Budnitz, et al. (1997) because the nature of this elicitation is the expectation that the experts will support the Probabilistic Seismic Hazard Assessment results. In the ground-motion elicitation, the experts provided intermediate results that were subsequently used by the technical facilitator/integrator to develop seven ground-motion attenuation models. The seven ground-motion attenuation models were then used to develop the curves for use in Probabilistic Seismic Hazard Assessment.

Although comparable to the generalist typically used to conduct an expert elicitation (Meyer and Booker, 1990), the role of the technical facilitator or integrator, as defined by the Senior Seismic Hazard Analysis Committee methodology (Budnitz, et al., 1997, pp. 29–48), has greater authority with the elicitation process and results. The NRC staff have expressed concerns to DOE about the potential overreaching authority of the technical facilitator or integrator in the elicitation process.[6] NRC staff concerns remain despite DOE assurances to the contrary.[7]

The staff independently examined the basis for the elicited ground-motion attenuation models and results and identified several questions about the DOE postelicitation feedback/ documentation process (CRWMS M&O, 1998b). At the October 2000 Technical Exchange on Structural Deformation and Seismicity,[8] DOE provided a brief summary of the elicitation approach used in the ground-motion portion of the Probabilistic Seismic Hazard Assessment. As a result of the staff questions after this presentation, DOE agreed[9] to provide additional documentation describing the process used to elicit the ground-motion attenuation models. In a letter dated December 21, 2000, DOE provided information it believed was responsive to the agreement made with the staff in October 2000.[10] After a review of this new submittal, staff concluded that most of the information provided was already available and, therefore, did not materially contribute to the closure of this particular issue. Nevertheless, based on the October 2000 technical exchange and follow-on discussion, it appears DOE will provide the requested and necessary documentation before submission of a potential license application for the proposed Yucca Mountain repository. Thus, this issue between DOE and NRC in this area is considered closed-pending.

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[6]Austin, J.H. "Implementation of NUREG–1563 in Elicitations for the Yucca Mountain Site Characterization Program." Letter (December 31) to R.A. Milner, DOE, Office of Civilian Radioactive Waste Management. Washington, DC: NRC. Division of Waste Management. 1996.

[7]Brocoum, S.J. "Resolution of U.S. Nuclear Regulatory Commission Site Characterization Analysis Comment 3 and Other Comments Related to the Use of Expert Elicitations in the High-Level Waste Program." Letter (August 6) to M. Bell, NRC. Washington, DC: DOE. 1997.

[8]Schlueter, J.R. "U.S. Nuclear Regulatory Commission/U.S. Department of Energy Technical Exchange and Management Meeting on Structural Deformation and Seismicity (October 11–12, 2000)." Letter (October 27) to S. Brocoum, DOE. Washington, DC: NRC. 2000.

[9]Ibid.

[10]Ibid.

5.4.3.3 Groundwater-Specific Discharge

The transport time of radionuclides in the saturated zone is important to estimate potential repository performance. Uncertainty and variability of the groundwater flow system are accounted for in the DOE total system performance assessment through the probability distributions for three hydrologic input parameters: (i) groundwater-specific discharge, (ii) effective porosity, and (iii) horizontal anisotropy. In 1997, DOE conducted formal expert elicitations [hereafter referred to as the Saturated Zone Flow and Transport Expert Elicitation (CRWMS M&O, 1998a)] to better understand the state of knowledge and uncertainties regarding these key input parameters to any DOE total system performance assessment for Yucca Mountain. The panel of five experts addressed a variety of technical issues related to the saturated zone beneath Yucca Mountain and the region downgradient, including groundwater-specific discharge (flux). NRC and CNWRA staffs observed the expert elicitation workshops and reviewed the information developed through the documentation process (DOE, 1998) and found it sufficient to use in a potential license application for Yucca Mountain. Overall, DOE adequately justified the need for the elicitation and conducted the elicitation in accordance with the guidance set forth in NUREG–1563 (NRC, 1996). The broader technical details of saturated zone modeling are provided in Section 3.3.8 of this report.

In the Total System Performance Assessment–Site Recommendation, specific discharge in the site-scale saturated zone flow and transport model is represented using one of three discrete cases: (i) high, (ii) medium, or (iii) low. Only the medium-specific discharge is calculated directly in the three-dimensional saturated zone model. The value for the low-specific discharge case was one-tenth the value for the medium-specific discharge case, and the value for the high-specific discharge case was 10 times that of the medium case. To arrive at these values, four Saturated Zone Flow and Transport Expert Elicitation (CRWMS M&O, 1998a) panel members evaluated the uncertainty in hydraulic conductivity separately and subsequently propagated the results into a range of uncertainty for specific discharge.

For the Supplemental Science and Performance Analyses (Bechtel SAIC Company, LLC, 2001a) (a document DOE identified as also supporting the Yucca Mountain site recommendation), rather than relying on the original Saturated Zone Flow and Transport Expert Elicitation (CRWMS M&O, 1998a) estimates, DOE alternatively selected a factor of 3 above and below the medium-specific discharge case, such that specific discharge for the low-specific case is increased from one-tenth to one-third of the medium value, and is decreased for the high-specific case from 10 times to 3 times the medium value. Volume 1 (Part 2) of the Supplemental Science and Performance Analyses (Bechtel SAIC Company, LLC, 2001a) includes the results of an unquantified uncertainty analysis used to evaluate the treatment of uncertainty in the site-scale saturated zone flow and transport model. Uncertainty in the probability distribution for specific discharge was reevaluated because the previous range of values was based on the Saturated Zone Flow and Transport Expert Elicitation (CRWMS M&O, 1998a) available data and the literature. Specifically, the principal DOE investigators developing the saturated zone model concluded that the range for specific discharge used for the DOE Total System Performance Assessment–Site Recommendation is overly conservative. In particular, the investigators believe the maximum value of the parameter range is unreasonably large. Darcy's law states that the specific discharge is the product of hydraulic conductivity and hydraulic gradient, which are best characterized for Yucca Mountain in the

vicinity of the C-Wells Complex. During the Saturated Zone Flow and Transport Expert Elicitation (CRWMS M&O, 1998a), it was recognized that, although the hydraulic gradient beneath Yucca Mountain is subject to uncertainty, its relative contribution to the uncertainty in specific discharge in the area of the C-Wells Complex is small. In general, the experts believed that the data from the multiple-hole pumping tests at the C-Wells Complex constituted the most reliable source for hydraulic conductivity estimates. In most cases, the experts provided a range of hydraulic conductivity values wider than that obtained from the C-Well Complex studies, reflecting uncertainty in the range of hydraulic conductivities that might characterize the units at other locations within the region. DOE also uses the same data from the multiple-hole pumping tests at the C-Wells Complex to decrease the range of values for specific discharge, arguing that the new reduced range better represents the data from the C-Wells Complex. Unlike the Saturated Zone Flow and Transport Expert Elicitation (CRWMS M&O, 1998a), DOE excludes the uncertainty in the hydraulic conductivity for locations not influenced by pumping tests at the C-Wells Complex. DOE also argued that the scale effects do not cause single-hole tests to underestimate the hydraulic conductivity of unfaulted regions as was previously thought. Therefore, it was concluded that the single-hole hydraulic conductivities reflect the true hydraulic conductivities of the hydrologic units in unfaulted areas and can be used to represent the hydraulic conductivities of the hydrogeologic units in numerical models, provided the effects of faults are accounted for in the same manner. DOE cites the recent work by Vesselinov, et al. (2001) at the Apache Leap test site as support for its reduced range of groundwater-specific discharge.

DOE is not required to strictly adhere to the recommendations of elicitations it sponsors. Where it departs from those recommendations, however, DOE should document any additional data, analyses, or other information, not considered by the expert panel, that factored into its departure decision. The Saturated Zone Flow and Transport Expert Elicitation (CRWMS M&O, 1998a) established the uncertainty range to include hydraulic conductivity uncertainty for locations not influenced by pumping tests at the C-Well Complex. No new data or analyses have been presented that would replace the technical basis for establishing the uncertainty range. The only new information cited [Section 12.3.1.4.1, Supplemental Science and Performance Analyses (Bechtel SAIC Company LLC, 2001a)] is a reference to an analysis by Vesselinov, et al. (2001) published in proceedings of a conference on fractured rock in Canada. It is not clear however, that the conclusions reached by Vesselinov, et al. (2001) have gained general acceptance within the broader technical/scientific community. It is also not clear that the conclusions, that reached for air-injection tests in a relatively small area at the Apache Leap site are applicable to groundwater pumping testing on a much larger scale at Yucca Mountain.

Air-permeability tests are used as an additional line of evidence, showing permeability can be enhanced near fault zones. The logic is then extended to argue that the cross-hole tests at the C-Wells Complex indicate higher permeability because faults are included in the relatively large scale of the aquifer tested. It is, therefore, reasoned that, because the DOE saturated zone flow model explicitly includes major faults, the permeability assigned to the hydrostratigraphic layer properties should reflect unfaulted (but still fractured) rock, which is reflected in the smaller-scale results of single-hole tests. Because the range in variability from the population of single-hole tests alone is less than the variability among both single- and cross-hole tests, DOE reasons that the range of uncertainty considered for total system performance assessment need only consider the range of permeability from the single-hole tests.

This logic may be sound as it applies to data uncertainty, however, it fails to consider and propagate model uncertainty into the DOE total system performance assessment.

To illustrate this point, it is helpful to look at the plot of permeability data shown in Figure 14 of the Calibration of the Site-Scale Saturated Zone Flow Model (CRWMS & MO, 2000a). Within any of the relatively permeable units, the range of permeability estimates from single-hole tests spans approximately one order of magnitude. This range can be considered data uncertainty, and a factor of three above or below the mean (as DOE proposes for the total system performance assessment uncertainty) adequately captures this data uncertainty. In several instances (i.e., for the Prow, Bullfrog, and Tram Tuffs), however, the final calibrated permeabilities for the saturated zone flow model are more than one order of magnitude outside the range of permeabilities measured in the single-hole tests. The difference between the calibrated permeability and the single-hole test permeability can be considered model uncertainty because the reason for the discrepancy is not clear. To account for the additional model uncertainty, a larger range of saturated-zone-specific discharges should be considered in the DOE total system performance assessment analyses. The factor of 10 above and below the calibrated model permeability that was previously used would account for the additional model uncertainty.

5.4.3.4 Sorption Coefficient Parameter Distributions

Sorption coefficient (k_d) parameter distributions are important to understand radionuclide transport phenomena in both the unsaturated and saturated zones (see Chapters 3.3.7 and 3.3.9 of this report). Although a significant amount of laboratory work and theoretical research concerning k_d values exists in the literature, there is little information on what the respective distributions may be for the various rock types present at Yucca Mountain. Despite the importance of k_d value, it is unlikely that any technically defensible distributions for sorption modeling, which are necessary to support the DOE total system performance assessment model abstractions of radionuclide transport, would be developed at the time of any potential license application submittal. Consequently, the staff view is that DOE was justified in its decision to estimate k_d parameter distributions for Yucca Mountain sorption modeling using the judgment of experts.

In determining k_d distributions, DOE relied on its own in-house experts (Los Alamos National Laboratory staff) which, although unusual, is permissible according to the guidance in NUREG–1563 (NRC, 1996), so long as any possible conflicts of interest are recognized and minimized to the extent practical to enhance credibility.[11] In this case, all three experts had an existing relationship with DOE and the Yucca Mountain program. After its completion, the results of the k_d distribution elicitation were initially documented in Barnard, et al. (1992). In reviewing this document, however, the technical basis for the expert-selected k_d distribution(s) is not clear because of inadequate documentation reflecting how the elicitation was conducted.

[11]Austin, J.H. "Documenting and Disclosing Potential Conflict of Interest in Expert Elicitations for the Geologic Repository Program." Letter (January 7) to R.A. Milner, DOE, Office of Civilian Radioactive Waste Management. Washington, DC: NRC, Division of Waste Management. 1997.

Administrative and Programmatic Requirements

The analytical methods used to arrive at the k_d probability distribution functions are described in general terms in Barnard, et al. (1992), but the specific process for conducting the k_d elicitation procedure itself is not described. Specifically, there is no documentation that describes how the expect elicitation itself was conducted, as outlined in NUREG–1563 (NRC, 1996). In general, this information is needed to understand how the experts arrived at their conclusions (including what initial data were used that formed a basis for the elicitation) and, in particular, how the k_d probability distribution functions themselves were arrived at using this data. For example, Wilson, et al. (1994) noted that one of the experts believed that elemental lead (Pb) should be assigned a k_d of 0, but a consensus value of 0 to 500 [subsequently adjusted in DOE (1998) from 100 to 500] was adopted during the elicitation process. This information is necessary to verify the technical integrity of the elicitation process as well as the traceability of the assessment itself. Consequently, the absence of this documentation diminishes the acceptability and credibility of the elicitation results themselves because the process at present does not appear to be transparent and traceable. This is particularly important because, in subsequent reports [Wilson, et al. (1994); Triay, et al. (1997); and CRWMS M&O (2000b)], DOE continued to make modifications to the parameter distributions without explanation. To improve the transparency and traceability of DOE decisionmaking in this area, DOE agreed[12] to provide the requisite documentation supporting this elicitation, including documentation on differing opinions regarding how the k_d probability distributions were reconciled. Thus, this issue is considered closed-pending.

5.4.4 Summary

The staff continued to monitor DOE implementation of the guidance found in NUREG–1563 (NRC, 1996). Thus far, NRC observation of the DOE-sponsored elicitations revealed few, if any, significant deviations between DOE implementation and NRC guidance. Although some elicitations may have potential weaknesses, as previously discussed with DOE,[13,14,15,16] such weaknesses do not appear to fundamentally change the conclusion or outcome of total system performance assessment presented by DOE to date. Because there are weaknesses in the

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[12]Reamer, C.W. "U.S. Nuclear Regulatory Commission/U.S. Department of Energy Technical Exchange and Management Meeting on Radionuclide Transport (December 5–7, 2000)." Letter (December 12) to S. Brocoum, DOE. Washington, DC: NRC. 2000.

[13]Austin, J.H. "Implementation of NUREG–1563 in Expert Elicitations for the Yucca Mountain Site Characterization Program." Letter (December 31) to R.A. Milner, DOE, Office Civilian Radioactive Waste Management. Washington, DC: NRC, Division of Waste Management. 1996.

[14]Austin, J.H. "Documenting and Disclosing Potential Conflict of Interest in Expert Elicitations for the Geologic Repository Program." Letter (January 7) to R.A. Milner, DOE, Office of Civilian Radioactive Waste Management. Washington, DC: NRC, Division of Waste Management. 1997.

[15]Bell, M.J. "Summary of U.S. Nuclear Regulatory Commission/U.S. Department of Energy Technical Exchange on the Total-System Performance Assessment (July 21–22, 1997)." Letter (December 17) to R.A. Milner, DOE. Washington, DC: NRC. 1997.

[16]Bell, M.J. "Summary of U.S. Nuclear Regulatory Commission/U.S. Department of Energy Technical Exchange on the Total-System Performance Assessment (November 5–6, 1997)." Letter (June 24) to S. Rousso, DOE. Washington, DC: NRC. 1998.

respective elicitations, the staff obtained detailed agreements from DOE to provide new information that can resolve the specific NRC concerns, as noted in Section 5.4.5 of this Integrated Resolution Status Report.

Lastly, NRC regulation requires any potential license application be as complete as possible at the time of docketing. For potential updating of elicitation results, the staff will continue to monitor DOE decisionmaking as it relates to the reexamination of elicitation results and the potential need for updating when new site characterization, design, and performance assessment information become available. In this regard, DOE had an agreement to provide the staff with its administrative procedure describing when and how new data would be treated after completion of an elicitation.[17] Staff are currently reviewing Section 5.14, Reassessment of the procedure in question (DOE, 1999) to determine how it comports with NRC guidance found in NUREG–1563 (NRC, 1996).

5.4.5 Status and Path Forward

5.4.5.1 Probabilistic Volcanic Hazards Analysis

DOE conducted the preliminary analysis of the aeromagnetic anomalies. As shown in Bechtel SAIC Company, LLC (2001b, Table 1), the new aeromagnetic data show 20 anomalies that can be interpreted as buried basalt. This increase in potential buried basalt bodies is well outside the average hidden event factor used in the 1996 Probabilistic Volcanic Hazards Analysis (Geomatrix Consultants, 1996). As stated in Bechtel SAIC Company, LLC (2001b), a determination of the Plio-Pleistocene volcanic inventory was one of the interpretations made by the volcanism experts. The increase in anomalies from 7 to 20 and the increase in quality of data to be evaluated by the experts strongly suggest that the probability of the volcanic event needs to be reviewed and updated. At present, DOE is scheduled to furnish staff with evaluation results of the aeromagnetic maps as part of a U.S. Geological Survey Open-File Report scheduled for publication in January 2002 and meet with NRC in March 2002 to discuss how the information on the anomalies will be factored into the probability estimates.

5.4.5.2 Probabilistic Seismic Hazards Analysis

5.4.5.2.1 Seismic Source and Fault Displacement Characterization

No further action in this area is required at this time.

5.4.5.2.2 Ground-Motion Attenuation

To close this issue at the staff level, DOE needs to provide the documentation originally requested by NRC during the October 2000 Structural Deformation and Seismicity Technical

[17] Bell, M.J. "Summary of U.S. Department of Energy/U.S. Nuclear Regulatory Commission Technical Exchange on the Total-System Performance Assessment (July 21–22, 1997)." Letter (December 17) to R.A. Milner, DOE. Washington, DC: NRC. 1998.

Exchange.[18] The staff seek DOE documentation of the extent to which each of the seven ground-motion experts understood the probabilistic modeling concepts associated with the respective inputs to the attenuation models as well as the subsequent implementation of the model in the broader Probabilistic Seismic Hazard Assessment.

5.4.5.3 Groundwater-Specific Discharge

Results of the unquantified uncertainty analysis were documented in the Supplemental Science and Performance Analyses (Bechtel SAIC Company, LLC 2001a) for the first time. Consequently, the NRC staff will wait for DOE to choose which of the two alternative methods is to be applied in the DOE total system performance assessment. If DOE decides to depart from the original Saturated Zone Expert Elicitation (CRWMS M&O, 1998a) panel recommendations, the NRC staff will then review the documentation to determine if a new technical basis needs to be provided to support a new range of uncertainty values for specific discharge.

5.4.5.4 Sorption Coefficient Parameter Distributions

The informality of this elicitation could jeopardize acceptability of the DOE k_d probability distribution functions. To close this issue at the staff level, DOE needs to provide the documentation originally requested by NRC during the December 5–7, 2000, Technical Exchange on the Radionuclide Transport Key Technical Issue.[19]

5.4.6 References

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[18]Schlueter, J.R. "U.S. Nuclear Regulatory Commission/U.S. Department of Energy Technical Exchange and Management Meeting on Structural Deformation and Seismicity (October 11–12, 2000)." Letter (October 27) to S. Brocoum, DOE. Washington, DC: NRC. 2000.

[19]Reamer, C.W. "U.S. Nuclear Regulatory Commission/U.S. Department of Energy Technical Exchange and Management Meeting on Radionuclide Transport (December 5–7, 2000)." Letter (December 12) to S. Brocoum, DOE. Washington, DC: NRC. 2000.

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———. "Unsaturated Zone and Saturated Zone Transport Properties." ANL–NBS–HS–000019. Revision 00. Las Vegas, Nevada: CRWMS M&O. 2000b.

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5.5 Status and Path Forward

Text in this section will be provided at a later date.

6 SUMMARY AND CONCLUSIONS

This report provides the status of resolution of technical issues at the staff level to all parties that may have an interest in the proposed geologic repository at Yucca Mountain. Prelicensing consultations between DOE and NRC are called for in the Nuclear Waste Policy Act of 1982 (1982). DOE and NRC use these consultations, including document reviews and technical exchanges, to resolve technical issues. Resolution of technical issues before DOE submits any license application increases the likelihood that the license application will contain the information required for an efficient and effective regulatory review. Technical issues are considered resolved at the staff level when the NRC staff considers the information gathered by DOE sufficient for the staff to conduct their review. Resolution, however, does not imply any conclusions regarding the end result of such a review. Moreover, any issue can be reopened if new information becomes available.

Starting in August 2000, various technical exchanges were conducted between the DOE and NRC staffs with the specific objective of issue resolution. These technical exchanges were held as open public meetings. Available information was evaluated for its sufficiency for inclusion in any license application. Where such information was judged to be insufficient, NRC reached agreements with DOE, which specify the additional information DOE will collect, a schedule for obtaining such information, and a mechanism for providing the information to the NRC staff. This report incorporates the results of the technical exchanges completed before October 31, 2001. This version also includes regulatory information, such as 10 CFR Part 63, 10 CFR Part 963, and the Yucca Mountain Review Plan (NRC, 2002), through March 2002. Technical exchanges on all the preclosure topics have not been completed to date. Therefore, some of the sections in Chapter 2 are not complete. Additional information on preclosure, as well as other key areas within NRC (2002) will be included in the next update of this report.

Overall, there are 9 postclosure key technical issues partitioned into 37 subissues. As indicated in Table 1.1-3, 5 of these subissues are classified as closed and 32 as closed-pending. The majority of the subissues are classified as closed-pending. Two hundred and ninety-three agreements were reached with DOE for these subissues to gain the closed-pending classification. The full text of these agreements is provided in Appendix A.

As a part of its risk-informed approach, NRC regulatory reviews will focus on technical items significant to repository performance preclosure and postclosure safety. Chapter 3 of this report is structured according to these integrated subissues.

NRC staff will review the information received from DOE in response to DOE and NRC agreements to determine if the information is sufficient and, if not, what additional information is needed. These reviews will be provided to DOE and other interested parties via formal letters and will be documented, as appropriate, in the next revision of this report.

6.1 References

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KTI Agreement - ISI Crosswalk

Agreement	Related ISIs or	NRC/DOE Agreement	Status
CLST.1.01	ENG1	Provide the documentation for Alloy 22 and titanium for the path forward items listed on slide 8. [establish credible range of brine water chemistry; evaluate effect of introduced materials on water chemistry; determine likely concentrations and chemical form of minor constituents in YM waters; characterize YM waters with respect to the parameters which define the type of brine which would evolve; evaluate periodic water drip evaporation] DOE will provide the documentation in a revision to AMR "Environment on the Surfaces of the Drip Shield and Waste Package Outer Barrier" by LA.	Not Received
CLST.1.02	ENG1	Provide the documentation for the path forward items listed on slide 12. [surface elemental analysis of alloy test specimens is necessary for determination of selective dissolution; surface analysis of welded specimens for evidence of dealloying; continue testing including simulated saturated repository environment to confirm enhancement factor] DOE will provide the documentation in a revision to AMR "General and Localized Corrosion of Waste Package Outer Barrier" by LA.	Not Received
CLST.1.03	ENG1	Provide documentation that confirms the linear polarization resistance measurements with corrosion rate measurements using other techniques. DOE will provide the documentation in a revision to AMR "General and Localized Corrosion of Waste Package Outer Barrier" by LA.	Not Received
CLST.1.04	ENG1	Provide the documentation for Alloy 22 and titanium for the path forward items listed on slide 14. [continue testing in the LTCTF; add new bounding water test environments to LTCTF (SSW & BSW); install thinner coupons in LTCTF with larger surface area/volume rations; install high sensitivity probes of Alloy 22 in some of the LTCTF vessels; materials testing continues during performance confirmation] DOE will provide the documentation in a revision to AMR "ANL-EBS-MD-000003 and ANL-EBS-MD-000004" by LA.	Not Received
CLST.1.05	ENG1	Provide additional details on sensitivities, resolution of measurements, limitations, and deposition of silica for the high sensitivity probes. DOE will document the results of the sensitivity probes including limitation and resolution of measurements as affected by silica deposition in the Alloy 22 AMR and Ti Corrosion AMR (ANL-EBS-MD-000003 and ANL-EBS-MD-000004) prior to LA.	Not Received
CLST.1.06	ENG1	Provide the documentation on testing showing corrosion rates in the absence of silica deposition. DOE will document the results of testing in the absence of silica deposits in the revision of Alloy 22 AMR (ANL-EBS-MD-000003) prior to LA.	Not Received
CLST.1.07	ENG1	Provide the documentation for the alternative methods to measure the corrosion rate of the waste package material (e.g., ASTM G-102 testing) or provide justification for the current approach. DOE will document the alternative methods of corrosion measurement in the revision of Alloy 22 AMR (ANL-EBS-MD-000003), prior to LA.	Not Received
CLST.1.08	ENG1	Provide the documentation for Alloy 22 and titanium for the path forward items listed on slide 16 and 17. [calculate potential-pH diagrams for multi-component Alloy 22; grow oxide films at higher temperatures in autoclaves, in air and/or electrochemically to accelerate film growth for compositional and structural studies below; resolve kinetics of film growth: parabolic or higher order, whether film growth becomes linear, and if, as film grows it becomes mechanically brittle and spalls off; determine chemical, structural, and mechanical properties of films, including thicken films; correlate changes in Ecorr measured in LTCTF with compositional changes in passive film over time; perform analyses on cold-worked materials to determine changes in film structural properties; perform examination of films formed on naturally occurring Josephinite; compare films formed on Alloy 22 with other similar passive film Alloys with longer industrial experience] DOE will provide the documentation in the revision to AMRs (ANL-EBS-MD-000003 and ANL-EBS-MD-000004) prior to LA.	Not Received
CLST.1.09	ENG1	Provide the data that characterizes the passive film stability, including the welded and thermally aged specimens. DOE will provide the documentation in a revision to AMRs (ANL-EBS-MD-000003 and ANL-EBS-MD-000004) prior to LA.	Not Received

Agreement	Related ISIs or	NRC/DOE Agreement	Status
CLST.1.10	ENG1	Provide the documentation for Alloy 22 and titanium for the path forward items listed on slide 21 and 22. [measure corrosion potentials in the LTCTF to determine any shift of potential with time toward the critical potentials for LC; determine critical potentials on welded and welded and aged coupons of Alloy 22 vs those for base metal - particularly important if precipitation or severe segregation of alloying elements occurs in the welds; separate effects of ionic mix of specimens in YM waters on critical potentials - damaging species from potentially beneficial species; determine critical potentials in environments containing heavy metal concentrations] DOE will provide the documentation in a revision to AMRs (ANL-EBS-MD-000003 and ANL-EBS-MD-000004) prior to LA.	Not Received
CLST.1.11	ENG1	Provide the technical basis for the selection of the critical potentials as bounding parameters for localized corrosion, taking into account MIC. DOE will provide the documentation in a revision to AMRs (ANL-EBS-MD-000003 and ANL-EBS-MD-000004) prior to LA.	Not Received
CLST.1.12	ENG1	Provide the documentation for Alloy 22 and titanium for the path forward items listed on slides 34 and 35. [qualify and optimize mitigation processes; generate SCC data for mitigated material over full range of metallurgical conditions; new vessels for LTCTF will house many of the SCC specimens; continue SSRT in same types of environments as above, specimens in the same range of metallurgical conditions; determine repassivation constants needed for film rupture SCC model to obtain value for the model parameter 'n'; continue reversing direct current potential drop crack propagation rate determinations in same types of environments and same metallurgical conditions as for SSRT and LTCTF tests; evaluate SCC resistance of welded and laser peened material vs non-welded unpeened material; evaluate SCC resistance in induction annealed material; evaluate SCC resistance of full thickness material obtained from the demonstration prototype cylinder of Alloy 22] DOE will provide the documentation in a revision to AMRs (ANL-EBS-MD-000005 and ANL-EBS-MD-000006) prior to LA.	Not Received
CLST.1.13	ENG1 ENG2 PRE	Provide the data that characterizes the distribution of stresses due to laser peening and induction annealing of Alloy 22. DOE will provide the documentation in a revision to AMR (ANL-EBS-MD-000005) prior to LA.	Not Received
CLST.1.14	ENG2 PRE,	Provide the justification for not including the rockfall effect and deadload from drift collapse on SCC of the waste package and drip shield. DOE will provide the documentation for the rockfall and dead-weight effects in the next revision of the SCC AMR (ANL-EBS-MD-000005) prior to LA.	Not Received
CLST.1.15	ENG1	Provide the documentation for Alloy 22 and titanium for the path forward items listed on slide 39. [install specimens cut from welds of SR design mock-up in LTCTF and in other SCC test environments - determine which specimen geometry is most feasible to complement SCC evaluation; evaluate scaling and weld process factors between thin coupons and dimensions in actual welded waste package containers - including thermal/metallurgical structural effects of multi-pass weld processes; provide representative weld test specimens for MIC work, thermal aging and localized corrosion evaluations] DOE will provide documentation for Alloy 22 and Ti path forward items on slide 39 in a revision to the SCC and general and localized corrosion AMRs (ANL-EBS-MD-000003, ANL-EBS-MD-000004, ANL-EBS-MD-000005) by LA.	Not Received
CLST.1.16	ENG1 ENG2 PRE	Provide the documentation on the measured thermal profile of the waste package material due to induction annealing. DOE stated that the thermal profiles will be measured during induction annealing, and the results will be reported in the next SCC AMR (ANL-EBS-MD-000005) prior to LA.	Not Received
CLST.1.17	ENG1 ENG2 PRE	Provide additional detail on quality assurance acceptance testing. DOE stated that it would provide guidance and criteria in the next revision of the Technical Guidance Document (TGD) for LA. The development of the LA sections and associated programs and process controls for the procurement and fabrication of waste package materials and components will be included. This will include consideration of the controls for compositional variations in Alloy 22. The TGD revision will be issued by June 2001, contingent upon NRC publication of the final 10 CFR 63 and the Yucca Mountain Review Plan.	Not Received

Agreement	Related ISIs or	NRC/DOE Agreement	Status
CLST.2.01	ENG2 PRE	Either provide documentation using solid element formulation, or provide justification for not using it, for the drip shield - rockfall analysis. DOE stated that shell elements include normal stresses and transverse stresses in the calculations and provide more accurate results for thin plates and use far fewer elements. Therefore, shell elements will be used instead of solid elements. This justification will be documented in the next revision of AMR ANL-XCS-ME-000001, Design Analysis for the Ex-Container Components, prior to LA.	Not Received
CLST.2.02	ENG2 PRE	Provide the documentation for the point loading rockfall analysis. DOE stated that point loading rock fall calculations will be documented in the next revisions of AMRs ANL-XCS-ME-000001, Design Analysis for the Ex-Container Components, and ANL-UDC-MD-000001, Design Analysis for UCF Waste Packages, both to be completed prior to LA.	Not Received
CLST.2.03	ENG2 PRE	Demonstrate how the Tresca failure criterion bounds a fracture mechanics approach to calculating the mechanical failure of the drip shield. DOE stated that it believes its current approach of using ASME Code is appropriate for this application. Additional justification for this conclusion will be included in the next revision of AMR ANL-XCS-ME-000001, Design Analysis for the Ex-Container Components, to be completed prior to LA.	Not Received
CLST.2.04	ENG1 ENG2 PRE	Provide information on the effect of the entire fabrication sequence on phase instability of Alloy 22, including the effect of welding thick sections using multiple weld passes and the proposed induction annealing process. DOE stated that the aging studies will be expanded to include solution annealed and induction annealed Alloy 22 weld and base metal samples from the mock-ups as well as laser peened thick, multi-pass welds. This information will be included in revisions of the AMR "Aging and Phase Stability of the Waste Package Outer Barrier," ANL-EBS-MD-000002, before LA.	Not Received
CLST.2.05	ENG1 ENG2 PRE	Provide the "Aging and Phase Stability of Waste Package Outer Barrier," AMR, including the documentation of the path forward items listed in the "Subissue 2: Effects of Phase Instability of Materials and Initial Defects on the Mechanical Failure and Lifetime of the Containers" presentation, slides 5 & 6. [data input to current models is being further evaluated and quantified to reduce uncertainty; aging of Alloy 22 samples for microstructural characterization, tensile property test, and Charpy impact test is ongoing; theoretical modeling will be employed to enhance confidence in extrapolating aging kinetic data to repository thermal conditions and time scale - modeling will utilize thermodynamic principles of the processes; Alloy 22 samples for SCC compact tension test are being added to aging studies; test program will be expanded to include welded and cold worked materials; effects of stress mitigation techniques such as laser peening and induction annealing on phase instability will be investigated; aging test facility will be expanded to include aging at lower temperatures] DOE stated that the "Aging and Phase Stability of the Waste Package Outer Barrier" AMR, ANL-EBS-MD-000002, Rev. 00 was issued 3/20/00. This AMR will be revised to include the results of the path forward items before LA.	Not Received
CLST.2.06	ENG1 ENG2 PRE	Provide the technical basis for the mechanical integrity of the inner overpack closure weld. DOE will provide the documentation in AMR, ANL-UDC-MD-000001, Rev. 00, Design Analysis for UFC Waste Packages in the next revision, prior to LA.	Not Received
CLST.2.07	ENG1 ENG2 PRE	Provide documentation for the fabrication process, controls, and implementation of the phases which affect the TSPA model assumptions for the waste package (e.g., filler metal, composition range). DOE stated that updates of the documentation on the fabrication processes and controls (TDR-EBS-ND-000003, Waste Package Operations Fabrication Process Report and TDP-EBS-ND-000005, Waste Package Operations FY-00 Closure Weld Technical Guidelines Document) will be available to the NRC in January 2001.	Received

Agreement	Related ISIs or	NRC/DOE Agreement	Status
CLST.2.08	ENG1 ENG2 PRE	Provide documentation of the path forward items in the "Subissue 2: Effects of Phase Instability of Materials and Initial Defects on the Mechanical Failure and Lifetime of the Containers" presentation, slide 16. [future rockfall evaluations will address (1) effects of potential embrittlement of WP closure material after stress annealing due to aging, (2) effects of drip shield wall thinning due to corrosion; (3) effects of hydrogen embrittlement on titanium drip shield; and (4) effects of multiple rock blocks falling on WP and drip shield; future seismic evaluations will address the effects of static loads from fallen rock on drip shield during seismic events] DOE stated that the rockfall calculations addressing potential embrittlement of the waste package closure weld and rock falls of multiple rock blocks will be included in the next revision of the AMR ANL-UDC-MD-000001, Design Analysis for UCF Waste Packages, to be completed prior to LA. Rock fall calculations addressing drip shield wall thinning due to corrosion, hydrogen embrittlement of titanium, and rock falls of multiple rock blocks will be included in the next revision of the AMR ANL-XCS-ME-000001, Design Analysis for the Ex-Container Components, to be completed prior to LA. Seismic calculations addressing the load of fallen rock on the drip shield will be included in the next revision of the AMR ANL-XCS-ME-000001, Design Analysis for the Ex-Container Components, to be completed prior to LA.	Not Received
CLST.2.09	ENG2 PRE	Demonstrate the drip shield and waste package mechanical analysis addressing seismic excitation is consistent with the design basis earthquake covered in the SDS KTI. DOE stated that the same seismic evaluations of waste packages and drip shield (revision of AMRs ANL-UDC-MD-000001 and ANL-XCS-ME-000001) will support both the SDS KTI and the CLST KTI, therefore consistency is ensured. These revisions will be completed prior to LA.	Not Received
CLST.3.01	ENG4 TSPAI	The agreement addresses CLST Subissues 3 & 4. In the revision to the "Summary of In-Package Chemistry for Waste Forms," AMR, the NRC needs to know whether and how initial failures are included in the in-package chemistry modeling, taking into account the multiple barrier analysis. DOE stated that the Summary of In-Package Chemistry for Waste Forms ANL-EBS-MD-000050 deals with time since waste package breach, instead of time of waste package failures. The model is appropriate for the current implementation in the TSPA scenarios because breaches do not occur until after aqueous films may be sustained. Multiple barrier analyses are discussed in the TSPAI IRSR, and therefore will be discussed in the TSPA KTI Technical Exchange.	Received
CLST.3.02	ENG3 ENG4	The agreement addresses CLST Subissues 3 & 4. In the revision to the "Summary of In-Package Chemistry for Waste Forms," AMR, address specific NRC questions regarding radiolysis, incoming water, localized corrosion, corrosion products, transient effects, and a sensitivity study on differing dissolution rates of components. DOE stated that these specific questions are currently being addressed in the revision of the Summary of In-Package Chemistry for Waste Forms AMR, ANL-EBS-MD-000050 and related AMRs and calculations. To be available in January 2001.	Received
CLST.3.03	ENG4	The agreement addresses CLST Subissues 3 & 4. Provide a more detailed calculation on the in-package chemistry effects of radiolysis. DOE stated that the calculations recently performed as discussed at the 9/12/00 Technical Exchange and preceeding teleconferences are being documented. These calculations will be referenced and justified in the revision of the Summary of In-Package Chemistry for Waste Forms AMR, ANL-EBS-MD-000050 and will be available in January 2001.	Received
CLST.3.04	ENG3 ENG4 TSPAI	The agreement addresses CLST Subissues 3 & 4. Need consistency between abstractions for incoming water and sensitivity studies conducted for in-package calculations, in particular, taking into account the interaction of engineered materials on the chemistry of water used for input to in-package abstractions. DOE stated that the revision of the Summary of In-Package Chemistry for Waste Forms AMR, ANL-EBS-MD-000050 will discuss the applicability of abstractions for incoming water, taking into account the revised Environment on the Surfaces of the Drip Shield and Waste Package Outer Barrier AMR. The revision will be available in January 2001.	Received
CLST.3.05	ENG4	The agreement addresses CLST Subissues 3 & 4. Provide the plan for experiments demonstrating in-package chemistry, and take into account subsequent NRC comments, if any. DOE stated that the current planning provides for the analysis of additional in-package chemistry model support. This analysis will determine which parts of the model are amenable to additional support by testing, and which parts are more amenable to sensitivity analysis, or use of analogues. Based on these results, longer range testing will be considered. If testing is determined to be appropriate, test plans will be written in FY01 and made available to the NRC.	Not Received

Agreement	Related ISIs or	NRC/DOE Agreement	Status
CLST.3.06	ENG4	The agreement addresses CLST Subissues 3 & 4. Provide additional technical basis for the failure rate and how the rate is affected by localized corrosion. DOE stated that the technical basis for local corrosion conditions will be added to by additional discussion of local chemistry in the Summary of In-package Chemistry for Waste Forms revision ANL-EBS-MD-000050 which will be available in January 2001. Current Clad Degradation Summary Abstraction AMR Section 6.3, ANL-WIS-MD-000007 and Clad Degradation - Local Corrosion of Zirconium and its Alloys Under Repository Conditions AMR, ANL-EBS-MD-000012 contain the overall technical basis.	Received
CLST.3.07	ENG4	The agreement addresses CLST Subissues 3 & 4. Provide data to address chloride induced localized corrosion and SCC under the environment predicted by in-package chemistry modeling. DOE stated that the technical basis for the models used for localized corrosion and SCC will be expanded in future revisions of the Clad Degradation Summary Abstraction AMR, ANL-WIS-MD-000007, available by LA.	Not Received
CLST.3.08	ENG4	The agreement addresses CLST Subissues 3 & 4. Provide the documentation on the distribution for cladding temperature and stress used for hydride embrittlement. DOE stated that the stresses are documented in the Initial Cladding Conditions AMR, ANL-EBS-MD-000048. CAL-UDC-ME-000001 contains the waste package internal temperatures. Waste package surface temperatures were provided within the TSPA model (ANL-EBS-HS-000003, Rev 00, ICN 01 and ANL-EBS-MD-000049). The updated versions of these documents will be available in January 2001.	Received
CLST.3.09	ENG4	The agreement addresses CLST Subissues 3 & 4. Provide a technical basis for critical stress that is relevant for the environment in which external SCC takes place. DOE stated that critical stress from SCC experiments under more aggressive conditions will be cited in the Revision of the Cladding Degradation Summary Abstraction AMR, ANL-WIS-MD-000007, which will be available in January 2001.	Received
CLST.3.10	ENG4	The agreement addresses CLST Subissues 3 & 4. Provide analysis of the rockfall and vibratory loading effects on the mechanical failure of cladding, as appropriate. DOE stated that the vibratory effects are documented in Sanders et. al. 1992 SAND90-2406, A Method For Determining The Spent-Fuel Contribution To Transport Cask Containment Requirements. This will be discussed in the SDS KTI meeting. The analysis of the rockfall effects on the mechanical failure of cladding will be addressed if the agreed to updated rockfall analysis in Subissue #2, Item 8 and Subissue #1, Item 14 demonstrate that the rock will penetrate the drip shield and damage the waste package.	Partly Received
CLST.4.01	ENG4 TSPAI	The agreement addresses CLST Subissues 3 & 4. In the revision to the "Summary of In-Package Chemistry for Waste Forms," AMR, the NRC needs to know whether and how initial failures are included in the in-package chemistry modeling, taking into account the multiple barrier analysis. DOE stated that the Summary of In-Package Chemistry for Waste Forms ANL-EBS-MD-000050 deals with time since waste package breach, instead of time of waste package failures. The model is appropriate for the current implementation in the TSPA scenarios because breaches do not occur until after aqueous films may be sustained. Multiple barrier analyses are discussed in the TSPAI IRSR, and therefore will be discussed in the TSPA KTI Technical Exchange.	Received
CLST.4.02	ENG3 ENG4	The agreement addresses CLST Subissues 3 & 4. In the revision to the "Summary of In-Package Chemistry for Waste Forms," AMR, address specific NRC questions regarding radiolysis, incoming water, localized corrosion, corrosion products, transient effects, and a sensitivity study on differing dissolution rates of components. DOE stated that these specific questions are currently being addressed in the revision of the Summary of In-Package Chemistry for Waste Forms AMR, ANL-EBS-MD-000050 and related AMRs and calculations. To be available in January 2001.	Received
CLST.4.03	ENG4	The agreement addresses CLST Subissues 3 & 4. Provide a more detailed calculation on the in-package chemistry effects of radiolysis. DOE stated that the calculations recently performed as discussed at the 9/12/00 Technical Exchange and preceeding teleconferences are being documented. These calculations will be referenced and justified in the revision of the Summary of In-Package Chemistry for Waste Forms AMR, ANL-EBS-MD-000050 and will be available in January 2001.	Received
CLST.4.04	ENG3 ENG4 TSPAI	The agreement addresses CLST Subissues 3 & 4. Need consistency between abstractions for incoming water and sensitivity studies conducted for in-package calculations, in particular, taking into account the interaction of engineered materials on the chemistry of water used for input to in-package abstractions. DOE stated that the revision of the Summary of In-Package Chemistry for Waste Forms AMR, ANL-EBS-MD-000050 will discuss the applicability of abstractions for incoming water, taking into account the revised Environment on the Surfaces of the Drip Shield and Waste Package Outer Barrier AMR. The revision will be available in January 2001.	Received

Agreement	Related ISIs or	NRC/DOE Agreement	Status
CLST.4.05	ENG4	The agreement addresses CLST Subissues 3 & 4. Provide the plan for experiments demonstrating in-package chemistry, and take into account subsequent NRC comments, if any. DOE stated that the current planning provides for the analysis of additional in-package chemistry model support. This analysis will determine which parts of the model are amenable to additional support by testing, and which parts are more amenable to sensitivity analysis, or use of analogues. Based on these results, longer range testing will be considered. If testing is determined to be appropriate, test plans will be written in FY01 and made available to the NRC.	Not Received
CLST.4.06	ENG4	The agreement addresses CLST Subissues 3 & 4. Provide additional technical basis for the failure rate and how the rate is affected by localized corrosion. DOE stated that the technical basis for local corrosion conditions will be added to by additional discussion of local chemistry in the Summary of In-package Chemistry for Waste Forms revision ANL-EBS-MD-000050 which will be available in January 2001. Current Clad Degradation Summary Abstraction AMR Section 6.3, ANL-WIS-MD-000007 and Clad Degradation - Local Corrosion of Zirconium and its Alloys Under Repository Conditions AMR, ANL-EBS-MD-000012 contain the overall technical basis.	Received
CLST.4.07	ENG4	The agreement addresses CLST Subissues 3 & 4. Provide data to address chloride induced localized corrosion and SCC under the environment predicted by in-package chemistry modeling. DOE stated that the technical basis for the models used for localized corrosion and SCC will be expanded in future revisions of the Clad Degradation Summary Abstraction AMR, ANL-WIS-MD-000007, available by LA.	Not Received
CLST.4.08	ENG4	The agreement addresses CLST Subissues 3 & 4. Provide the documentation on the distribution for cladding temperature and stress used for hydride embrittlement. DOE stated that the stresses are documented in the Initial Cladding Conditions AMR, ANL-EBS-MD-000048. CAL-UDC-ME-000001 contains the waste package internal temperatures. Waste package surface temperatures were provided within the TSPA model (ANL-EBS-HS-000003, Rev 00, ICN 01 and ANL-EBS-MD-000049). The updated versions of these documents will be available in January 2001.	Received
CLST.4.09	ENG4	The agreement addresses CLST Subissues 3 & 4. Provide a technical basis for critical stress that is relevant for the environment in which external SCC takes place. DOE stated that critical stress from SCC experiments under more aggressive conditions will be cited in the Revision of the Cladding Degradation Summary Abstraction AMR, ANL-WIS-MD-000007, which will be available in January 2001.	Received
CLST.4.10	ENG4	The agreement addresses CLST Subissues 3 & 4. Provide analysis of the rockfall and vibratory loading effects on the mechanical failure of cladding, as appropriate. DOE stated that the vibratory effects are documented in Sanders et. al. 1992 SAND90-2406, A Method For Determining The Spent-Fuel Contribution To Transport Cask Containment Requirements. This will be discussed in the SDS KTI meeting. The analysis of the rockfall effects on the mechanical failure of cladding will be addressed if the agreed to updated rockfall analysis in Subissue #2, Item 8 and Subissue #1, Item 14 demonstrate that the rock will penetrate the drip shield and damage the waste package.	Partly Received
CLST.4.11	ENG4	See also CLST Subissue 3 agreements. In addition, in the revision to the "Defense High Level Waste Glass Degradation," AMR, address specific NRC questions regarding (a) the inconsistency of the rates in acid leg for glasses, (b) the technical basis for use of boron versus silica in the radionuclide release from glass, and (c) clarification of the definition of long term rates of glass dissolution. DOE stated that these questions will be addressed in the Defense High Level Waste AMR revision and will be available in January 2001.	Received
CLST.5.01	ENG1 ENG2 ENG3 ENG4 TSPAI	Provide Revision 1 to the Topical Report. DOE stated that it will provide the Disposal Criticality Analysis Methodology Topical Report, Revision 01, to NRC during January 2001.	Received
CLST.5.02	TSPAI	Provide the Disruptive Events FEPs AMR, the FEPs database, and the Analyses to Support Screening of System-Level Features, Events, and Processes for the Yucca Mountain Total System Performance Assessment-Site Recommendation. DOE stated that it will provide the FEPs AMRs, the Analyses to Support Screening of System-Level Features, Events, and Processes for the Yucca Mountain Total System Performance Assessment-Site Recommendation AMR, and the FEPs database to NRC during January 2001.	Received

Agreement	Related ISIs or	NRC/DOE Agreement	Status
CLST.5.03	ENG1 ENG2 TSPAI	DOE will provide an updated technical basis for screening criticality from the post-closure performance assessment. The technical basis will include (1) a determination of whether the formation of condensed water could allow liquid water to enter the waste package without the failure of the drip shield, and (2) an assessment of improper heat treatment, if it is shown to result in early failure of waste packages, considering potential failure modes. The documentation of the technical basis is comprised of (1) Analysis of Mechanisms for Early Waste Package Failure AMR, (2) Probability of Criticality Before 10,000 years calculation, and (3) Features, Event, and Process System Level and Criticality AMR. The first document will be provided to NRC in FY02, the second and third documents will be provided in FY03.	Not Received
CLST.5.04	ENG1 ENG4 SZ2	Provide the list of validation reports and their schedules. DOE stated that the geochemical model validation reports for "Geochemistry Model Validation Report: Degradation and Release" and "Geochemistry Model Validation Report: Material Accumulation" are expected to be available during 2001. The remainder of the reports are expected to be available during FY2002 subject to the results of detailed planning and scheduling. DOE understands that these reports are required to be provided prior to LA. A list of model validation reports was provided during the technical exchange and is included as an attachment to the meeting summary.	Partly Received
CLST.5.05	ENG1 ENG3 ENG4	Provide information on how the increase in the radiation fields due to the criticality event affects the consequence evaluation because of increased radiolysis inside the waste package and at the surfaces of nearby waste packages or demonstrate that the current corrosion and dissolution models encompass the range of chemical conditions and corrosion potentials that would result from this increase in radiolysis. DOE stated that the preliminary assessment (calculation) of radiolysis effects from a criticality event will be available to NRC during February 2001. The final assessment of these conditions will be available to NRC prior to LA.	Partly Received
CLST.5.06	ENG1 ENG2 TSPAI	Provide a "what-if" analysis to evaluate the impact of an early criticality assuming a waste package failure. DOE stated that it would provide the requested analyses prior to LA. Actual schedule to be provided pending DOE planning process.	Not Received
CLST.5.07	ENG1 ENG2 ENG4 TSPAI	Provide sensitivity analyses that will include the most significant probability/consequence criticality scenarios. DOE stated that it would provide the requested analyses prior to LA. Actual schedule to be provided pending DOE planning process.	Not Received
CLST.6.01	ENG1	Provide documentation for the path forward items in the "Subissue 6: Alternate EBS Design Features - Effect on Container Lifetime" presentation, slides 7 & 8. [perform more sensitivity measurements of general corrosion rates - same approach as taken for Alloy 22; confirm no deleterious effects of fluoride ion and trace heavy metal ions in water on corrosion behavior of titanium - similar approach to that taken in electrochemically based studies on Alloy 22; establish damaging hydrogen levels in titanium alloys - Grade 2 vs Grades 7 and 16 vs Grade 5 and 24 - evaluate hydrogen charged notched tensile speciems and hydrogen pickup of galvanically coupled LTCTF specimens; conduct SCC testing of titanium, similar to approach taken for Alloy 22; confirm intergranular or internal oxidation of titanium is not applicable under YM thermal and environmental conditions] DOE stated that the documentation of the path forward items will be completed and as results become available, they will documented in the revisions of AMRs (ANL-EBS-MD-000005, Stress Corrosion Cracking of the Drip Shield, the Waste Package Outer Barrier and the Stainless Structural Material, and ANL-EBS-MD-000004, General Corrosion and Localized Corrosion of the Drip Shield), to be completed by LA.	Not Received
CLST.6.02	ENG1	Provide additional justification for the use of a 400 ppm hydrogen criterion or perform a sensitivity analysis using a lower value. DOE stated that additional justification will be found in the report "Review of Expected Behaviour of Alpha Titanium Alloys under Yucca Mountain Condition" TDR-EBS-MD-000015, which is in preparation and will be available in January 2001.	Received
CLST.6.03	ENG1	Provide the technical basis for the assumed fraction of hydrogen absorbed into titanium as a result of corrosion. DOE stated that additional justification will be found in the report "Review of Expected Behaviour of Alpha Titanium Alloys under Yucca Mountain Condition" TDR-EBS-MD-000015, which is in preparation and will be available in January 2001.	Received

Agreement	Related ISIs or	NRC/DOE Agreement	Status
CLST.6.04	ENG1 PRE	Provide temperature distribution (CCDF) of the drip shield as a function of time under the current EBS design. DOE stated that the temperature distribution will be provided in the next revision of the AMR, ANL-EBS-MD-000049, Rev 00, ICN 01, which will be available in January 2001.	Received
ENFE.1.01	ENG3 TSPAI	Provide updated FEPs AMRs with additional technical bases for those FEPs previously identified by the NRC in Rev. 03 of the ENFE IRSR as inadequately screened. In Rev 03 of the ENFE IRSR, the NRC identified 17 FEPs associated with Subissue 1 for which no screening arguments were identified in the FEPs data base, screening arguments were inconsistent with other project documents, or inadequate exclusion arguments were provided. The lack of screening arguments has been addressed in Rev 00 of the FEPs data base and Rev 00 of the supporting AMRs. Current revisions (or ICNs) of the FEPs AMRs, scheduled for completion in January 2001, will partially address the remaining NRC comments. Consideration of the remaining NRC comments will be provided in subsequent FEPs AMR revisions, expected to be available as periodic revisions, the entirety of which will be available prior to license application.	Received
ENFE.1.02	TSPAI	Provide the FEPs database. The DOE will provide the FEPs data base to the NRC during March 2001.	Received
ENFE.1.03	ENG3 UZ2	Provide the Drift-Scale Coupled Processes (DST and THC Seepage) Models AMR, Rev. 01 and 02, including (1) information on the quantity of unreacted solute mass that is trapped in dry-out zone in TOUGHREACT simulations, as well as how this would affect precipitation and the resulting change in hydrologic properties and (2) documentation of model validation consistent with the DOE QA requirements. The DOE will provide documentation of model validation, consistent with the DOE QA requirements, in the Drift-Scale Coupled Processes (DST and THC Seepage) Models AMR (MDL-NBS-HS-000001) Rev 01, expected to be available to the NRC in March 2001. The DOE will provide information on the quantity of unreacted solute mass that is trapped in the dryout zone in TOUGHREACT simulations in the Drift-Scale Coupled Processes (DST and THC Seepage) Models AMR Rev 02, expected to be available to the NRC in FY 02.	Partly Received
ENFE.1.04	ENG3 UZ2	Provide additional technical bases for the DOE's treatment of the effects of cementitious materials on hydrologic properties. The DOE will provide additional information on the effects of cementitious materials in an update to the Unsaturated Zone Flow and Transport PMR (TDR-NBS-HS-000002), available in FY 02. Information provided will include results of evaluation of the magnitude of potential effects on hydrologic properties and radionuclide transport characteristics of the unsaturated zone.	Not Received
ENFE.1.05	ENG3 UZ2	Address the various sources of uncertainty (e.g., model implementation, conceptual model, and data uncertainty (hydrologic, thermal, and geochemical)) in the THC model. The DOE will evaluate the various sources of uncertainty in the THC process model, including details as to how the propagation of various sources of uncertainty are calculated in a systematic uncertainty analysis. The DOE will document that uncertainty evaluation in the Drift-Scale Coupled Processes (DST and THC Seepage) Models AMR (MDL-NBS-HS-000001) Rev 02 (or in another future document), expected to be available in FY 02.	Not Received
ENFE.1.06	ENG3 TSPAI	Provide the technical basis for excluding entrained colloids in the analysis of FEP 2.2.10.06.00 (Thermo-Chemical Alteration) or an alternative FEP. The DOE will provide the technical basis for screening entrained colloids in the analysis of FEP 2.2.10.06.00 in a future revision of the Features, Events, and Processes in UZ Flow and Transport AMR (ANL-NBS-MD-000001), expected to be available in FY 02.	Not Received
ENFE.1.07	ENG3	Provide physical evidence that supports the model of matrix fracture interaction precipitation effects (e.g., coring). The DOE will provide the following evidence that supports the model of matrix/fracture interaction precipitation effects: (1) Existing data from the Single Heater Test (SHT) of post-test overcoring Mineralogy-Petrology (Min-Pet) analysis (SHT final report [MOL.20000103.0634] and DTN LASL831151.AQ98.001) is expected to be provided to the NRC in March 2001. (2) Results of ongoing side-wall sampling Min-Pet analyses of DST samples are expected to be provided to the NRC in FY 02. (3) The DOE expects to provide the Drift-Scale Coupled Processes (DST and THC Seepage) Models AMR (MDL-NBS-HS-000001) Rev 01 to the NRC as evidence of matrix-fracture interaction in March 2001.	Partly Received

Agreement	Related ISIs or	NRC/DOE Agreement	Status
ENFE.2.01	ENG3 TSPAI	Provide updated FEPs AMRs with additional technical bases for those FEPs previously identified by the NRC in Rev. 03 of the ENFE IRSR as inadequately screened. In Rev 03 of the ENFE IRSR, the NRC identified 24 FEPs associated with Subissue 2 for which no screening arguments were identified in the FEPs data base, screening arguments were inconsistent with other project documents, or inadequate exclusion arguments were provided. The lack of screening arguments has been addressed in Rev 00 of the FEPs data base and Rev 00 of the supporting AMRs. Current revisions (or ICNs) of the FEPs AMRs, scheduled for completion in January 2001, will partially address the remaining NRC comments. Consideration of the remaining NRC comments will be provided in subsequent FEPs AMR revisions, expected to be available as periodic revisions, the entirety of which will be available prior to license application.	Received
ENFE.2.02	TSPAI	Provide the FEPs database. The DOE will provide the FEPs data base to the NRC during March 2001.	Received
ENFE.2.03	ENG3 TSPAI	Provide the technical basis for FEP 1.2.06.00 (Hydrothermal Activity), addressing points (a) through (e) of NRC Subissue 2 slide handed out at the January 2001 ENFE technical exchange. The DOE will provide additional technical bases for the screening of FEP 1.2.06.00 (Hydrothermal Activity), in a future revision of the Features, Events, and Processes in UZ Flow and Transport AMR (ANL-NBS-MD-000001), expected to be available in FY 02. Within these technical bases, the DOE will address NRC comments [points (a) through (e)] presented on the NRC Subissue 2 slide handed out at the January 2001 ENFE technical exchange or provide justification that it is not needed.	Not Received
ENFE.2.04	ENG1 ENG3	Provide the technical basis for bounding the trace elements and fluoride for the geochemical environment affecting the drip shield and waste package, including the impact of engineered materials. The DOE will document the concentrations of trace elements and fluoride in waters that could contact the drip shield and waste package in a revision to the Environment on the Surfaces of the Drip Shield and Waste Package Outer Barrier AMR (ANL-EBS-MD-000001), which will be available in FY02. In addition, trace elements and fluoride concentrations in introduced materials in the EBS (including cement grout, structural steels, and other materials as appropriate) will be addressed in a revision to the Engineered Barrier System: Physical and Chemical Environment Model AMR (ANL-EBS-MD-000033), expected to be available in FY 02.	Not Received
ENFE.2.05	ENG3	Evaluate data and model uncertainties for specific in-drift geochemical environment submodels used in TSPA calculations and propagate those uncertainties following the approach described in Agreement #5, Subissue 1. The DOE will evaluate data and model uncertainties for specific in-drift geochemical environment submodels used in TSPA calculations and propagate those uncertainties following the approach described in Subissue 1, Agreement #5. The DOE will document the evaluation in an update to the Engineered Barrier System: Physical and Chemical Environment Model AMR (ANL-EBS-MD-000033) (or in another future document), expected to be available in FY 02.	Not Received
ENFE.2.06	ENG3	Evaluate the impact of the range of local chemistry (e.g., dripping of equilibrated evaporated cement leachate and corrosion products) conditions at the drip shield and waste package considering the chemical divide phenomena that may propagate small uncertainties into large effects. The DOE will evaluate the range of local chemical conditions at the drip shield and waste package (e.g. local variations in water composition associated with cement leaching or the presence of corrosion products), considering potential evaporative concentration and the chemical divide effect whereby small differences in initial composition could cause large differences in brine characteristics. This evaluation will be documented in a revision to the Engineered Barrier System: Physical and Chemical Environment Model AMR (ANL-EBS-MD-000033), expected to be available in FY 02.	Not Received
ENFE.2.07	ENG3	Identify specific coupling relationships that are included and excluded from TSPA, including Onsager couples, and give technical bases for their inclusion or exclusion. The DOE will identify specific coupling relationships that are included and excluded from TSPA, including Onsager couples, and give the technical basis for inclusion and exclusion. This information will be documented in a revision to the Engineered Barrier System Degradation, Flow, and Transport PMR (TDR-EBS-MD-000006), expected to be available by September 2001.	Not Received
ENFE.2.08	ENG3	Provide stronger technical basis for the suppression of individual minerals predicted by equilibrium models. The DOE will provide additional technical basis for suppression of individual minerals predicted by equilibrium models, in a revision to the Engineered Barrier System: Physical and Chemical Environment Model AMR (ANL-EBS-MD-000033), expected to be available in FY02.	Not Received

Agreement	Related ISIs or	NRC/DOE Agreement	Status
ENFE.2.09	ENG3	Provide the In-Drift Precipitates/Salts Analysis AMR, Rev. 00, ICN 02, including (1) the major anionic (e.g., fluoride or chloride) and cationic species, and (2) additional technical basis for the low relative humidity model. The DOE will provide the In-Drift Precipitates/Salts Analysis AMR (ANL-EBS-MD-000045), Rev. 00, ICN 02, including the major anionic (e.g., fluoride or chloride) and cationic species, in January 2001. The DOE will provide to the NRC an update to the In-Drift Precipitates/Salts Analysis AMR (ANL-EBS-MD-000045) that will provide additional technical bases for the low relative humidity model, expected to be available in FY 02.	Partly Received
ENFE.2.10	ENG3	Provide additional information about the range of composition of waters that could contact the drip shield or waste package, including whether such waters are of the bicarbonate or chloride-sulfate type. The DOE will describe the range of bulk composition for waters that could affect corrosion of the drip shield or waste package outer barrier, in a revision to the Environment on the Surfaces of the Drip Shield and Waste Package Outer Barrier AMR (ANL-EBS-MD-000001), expected to be available in FY02.	Not Received
ENFE.2.11	ENG3	Provide the technical basis for the current treatment of the kinetics of chemical processes in the in-drift geochemical models. This basis should address data in the figure on page 16 of the G.Gdowski Subissue 2 presentation with appropriate treatment of time as related to abstractions used in TSPA. The DOE will provide additional technical basis for the treatment of precipitation-dissolution kinetics by the in-drift geochemical models, in a revision to the Engineered Barrier System: Physical and Chemical Environment Model AMR (ANL-EBS-MD-000033), expected to be available in FY02. The technical basis will include reaction progress simulation for laboratory evaporative concentration tests, and will include appropriate treatment of time as related to the residence times associated with the abstractions used to represent in-drift processes in TSPA.	Not Received
ENFE.2.12	ENG3	Provide the documentation and analysis of the column crush tuff experiments. The DOE will provide documentation of the results obtained from the crushed tuff hydrothermal column experiment, and of post-test analysis, in new reports specific to the column test, expected to be available by September 2001.	Not Received
ENFE.2.13	ENG3	Provide documentation regarding the deposition of dust and its impact on the salt analysis. The DOE will provide documentation of dust sampling in the Exploratory Studies Facility, and analysis of the dust and evaluation of its impact on the chemical environment on the surface of the drip shield and waste package, in a revision to the Engineered Barrier System: Physical and Chemical Environment Model AMR (ANL-EBS-MD-000033), expected to be available in FY02.	Not Received
ENFE.2.14	ENG1 ENG3	Provide the analysis of laboratory solutions that have interacted with introduced materials. The DOE will provide additional information about laboratory solutions that have interacted with introduced materials, in a revision to the Environment on the Surfaces of the Drip Shield and Waste Package Outer Barrier AMR (ANL-EBS-MD-000001), expected to be available in FY02.	Not Received
ENFE.2.15	ENG3	Provide the additional data to constrain the interpolative low relative humidity salts model. The data should provide the technical basis as to why the assumption of the presence of sodium nitrate is conservative, when modeling and experimental results indicate the presence of other mineral phases for which the deliquesence point is unknown. The DOE will provide additional information to constrain the low-relative humidity salts model. The information will include the deliquescence behavior of mineral assemblages derived from alternative starting water compositions (including bulk water compositions, and local variations associated with cement leaching or the presence of corrosion products) representing the range of potential water compositions in the emplacement drifts. This information will be documented in a revision to the In-Drift Precipitates/Salts Analysis AMR (ANL-EBS-MD-000045), expected to be available in FY02.	Not Received
ENFE.2.16	ENG3	Provide the Drift-Scale Coupled Processes (DST and THC Seepage) Models, Rev. 01, including information supporting both the limited suite mineral model and the more complete extended model. The DOE will provide the Drift-Scale Coupled Processes (DST and THC Seepage) Models AMR (MDL-NBS-HS-000001) Rev 01, including information supporting both the limited suite mineral model and the more complete extended model, in March 2001.	Received

Agreement	Related ISIs or	NRC/DOE Agreement	Status
ENFE.2.17	ENG3	Provide documentation of data used to calibrate models and data to support model predictions, and an assessment of data uncertainty (e.g., sampling and analytical), that includes critical analyses of variables that affect the data measurements and their interpretations (e.g., drift-scale thermal test and evaporation tests). The DOE will provide documentation of data used to calibrate models and data to support model predictions, and an assessment of data uncertainty (e.g., sampling and analytical) in the area of water and gas chemistry from the drift-scale thermal tests and evaporation tests. This documentation will be provided in revisions to the following AMRs: Environment on the Surfaces of the Drip Shield and Waste Package Outer Barrier (ANL-EBS-MD-000001), Engineered Barrier System: Physical and Chemical Environment Model (ANL-EBS-MD-000033), and Drift-Scale Coupled Processes (DST and THC Seepage) Models (MDL-NBS-HS-000001), or other documents as appropriate. All documents or revisions are expected to be available in FY 02.	Not Received
ENFE.2.18	ENG3	The NRC and DOE agreed the following documents would be provided with the schedule indicated: Engineered Barrier System: Physical and Chemical Environment Model (ANL-EBS-MD-000033) Rev. 01: FY 02; Multiscale Thermohydrologic Model (ANL-EBS-MD-000049) Rev. 00, ICN 01: January 2001;Abstraction of Drift-Scale Coupled Processes (ANL-NBS-HS-000029) Rev 01: September 2001; Environment on the Surfaces of the Drip Shield and the Waste Package Outer Barrier (ANL-EBS-MD-000001) Rev. 00, ICN 01: January 2001; Waste Package Degradation PMR (TDR-WIS-MD-000002) Rev. 00, ICN 01: January 2001; Engineered Barrier System Degradation, Flow, and Transport PMR (TDR-EBS-MD-000006) Rev. 01: September 2001; Near Field Environment PMR (TDR-NBS-MD-000001) Rev. 00, ICN 02: January 2001 and Rev. 01: September 2001; Hydrogen Induced Cracking of Drip Shield (ANL-EBS-MD-000006) Rev. 00, ICN 01: January 2001; Drift Degradation Analysis (ANL-EBS-MD-000027) Rev. 01: January 2001; Design Analysis for the Ex-Container Components, ANL-XCS-ME-000001 Rev. 00: January 2001; Longevity of Emplacement Drift Ground Support Materials (ANL-EBS-GE-000003) Rev. 01: January 2001; Stress Corrosion Cracking of the Drip Shield, the Waste Package Outer Barrier, and the Stainless Steel Structural Material AMR (ANL-EBS-MD-000005) Rev. 00, ICN 01: January 2001; In-Drift Microbial Communities (ANL-EBS-MD-000038) Rev. 00, ICN 01: January 2001; Physical and Chemical Environmental Abstraction Model (ANL-EBS-MD-000046) Rev. 00, ICN 01: January 2001; Unsaturated Zone Flow and Transport Model PMR (TDR-NBS-HS-000002) Rev. 01: September 2001; General Corrosion and Localized Corrosion of the Drip Shield (ANL-EBS-MD-000004) Rev. 00: January 2001; Water Distribution and Removal Model (ANL-EBS-MD-000032) Rev. 01: January 2001.	Partly Received
ENFE.3.01	ENG1 ENG3	The NRC and DOE agreed the following documents would be provided in February 2001: WAPDEG Analysis of Waste Package and Drip Shield Degradation AMR (ANL-EBS-PA-000001) Rev 00 ICN 01; Near Field Environment PMR (TDR-NBS-MD-000001) Rev 00 ICN 03; Summary of In-Package Chemistry for Waste Forms AMR (ANL-EBS-MD-000050) Rev 01; Calculation of General Corrosion Rate of Drip Shield and Waste Package Outer Barrier to Support WAPDEG Analysis (CAL-EBS-PA-000002) Rev 01; Abstraction of Models for Stainless Steel Structural Material Degradation (ANL-EBS-PA-000005) Rev 00; In-Package Chemistry Abstraction AMR (ANL-EBS-MD-000037) Rev 01; Total System Performance Assessment for the Site Recommendation (TDR-WIS-PA-000001) Rev 00; Waste Form Colloid-Associated Concentrations Limits: Abstraction and Summary AMR (ANL-WIS-MD-000012) Rev 00 ICN 01	Received
ENFE.3.02	ENG3	Provide the thermodynamic database and the report associated with the database. The DOE will provide the thermodynamic data base [Input Transmittal for Thermodynamic Data Input Files for Geochemical Calculations (MO0009THRMODYN.001)] and Data Qualification Report for the Thermodynamic Data File, DATA0.ympR0 for Geochemical Code EQ 3/6 (TDR-EBS-MD-000012) to the NRC in February 2001.	Received
ENFE.3.03	ENG3 ENG4	Provide analyses to verify that bulk-scale chemical processes dominate the in-package chemical environment. The DOE will provide analyses justifying the use of bulk chemistry as opposed to local chemistry for solubility and waste form degradation models. These analyses will be documented in an update to the Miscellaneous Waste-Form FEPs AMR (ANL-WIS-MD-000009) or in an update to the Summary of In-Package Chemistry for Waste Forms AMR (ANL-EBS-MD-000050), expected to be available in FY 02.	Not Received
ENFE.3.04	ENG4	Complete validation of in-package chemistry models. Agreement #5 for CLST subissue 3 addresses testing plans. Model validation based on this testing and further analysis will be documented in an update to the Summary of In-Package Chemistry for Waste Forms AMR (ANL-EBS-MD-000050), expected to be available in FY 02.	Not Received
ENFE.3.05	ENG3 ENG4 UZ3	Provide the technical basis for selection of radionuclides that are released via reversible and irreversible attachment to colloids for different waste forms in the TSPA. The technical bases for the selection of radionuclides released via reversible and irreversible attachments to colloids for different waste forms is provided in section 3.5.6.1 of the Total System Performance Assessment (TSPA) Model for Site Recommendation (MDL-WIS-PA-000002) Rev 00. This document will be provided to the NRC in January 2001.	Received

Agreement	Related ISIs or	NRC/DOE Agreement	Status
ENFE.4.01	ENG3	Provide the executable version of the most recently qualified version of TOUGHREACT. The DOE will provide the executable TOUGHREACT Rev 2.2 to the NRC by February 2001, subject to the NRC obtaining any applicable agreement for usage of the software.	Received
ENFE.4.02	ENG3	Provide the Drift-Scale Coupled Processes (DST and THC Seepage) Models AMR, Rev. 01 and 02. The DOE will provide the Drift-Scale Coupled Processes (DST and THC Seepage) Models AMR (MDL-NBS-HS-000001) Rev 01 to the NRC in March 2001. The DOE will provide the Drift-Scale Coupled Processes (DST and THC Seepage) Models AMR Rev 02 to the NRC in FY 02.	Partly Received
ENFE.4.03	ENG3 TSPAI	Provide the technical bases for screening out coupled THC effects on radionuclide transport properties and colloids. The DOE will provide the technical bases for screening out coupled THC effects on radionuclide transport properties and colloids in a new AMR or in a revision to an existing AMR, expected to be available in FY 02.	Not Received
ENFE.4.04	ENG3 TSPAI	Provide the technical basis for excluding entrained colloids in the analysis of FEP 2.2.10.06.00 (Thermo-Chemical Alteration) or an alternative FEP. The DOE will provide the technical basis for screening entrained colloids in the analysis of FEP 2.2.10.06.00 in a future revision of the Features, Events, and Processes in UZ Flow and Transport AMR (ANL-NBS-MD-000001), expected to be available in FY 02.	Not Received
ENFE.4.05	TSPAI	Provide the screening criteria for the radionuclides selected for PA. Provide the technical basis for selection of radionuclides that are transported via colloids in the TSPA. The screening criteria for radionuclides selected for TSPA are contained in the AMR Inventory Abstraction (ANL-WIS-MD-000006) Rev 00, ICN 01. The DOE is documenting identification of radionuclides transported via colloids for TSPA in the AMR Colloid-Associated Concentration Limits: Abstraction and Summary (ANL-WIS-MD-000012) Rev 0, in the Total System Performance Assessment for the Site Recommendation (TDR-WIS-PA-000001) Rev 00 ICN 01, and in the Total System Performance Assessment (TSPA) Model for Site Recommendation (MDL-WIS-PA-000002) Rev 00. These documents will be available to the NRC in January 2001.	Received
ENFE.4.06	ENG4 TSPAI	Provide documentation to demonstrate suitability of the bounding values used for colloid transport through the perturbed near-field environment. For example, consider sensitivity analyses to investigate the effects of varying colloid sorption parameters (Kc) on repository performance. The DOE will evaluate the suitability of the colloid transport model under perturbed conditions as discussed in agreement #3 for this subissue. As part of this work, the DOE will consider sensitivity analyses to investigate the effects of varying colloid sorption parameters (Kc) on repository performance. The DOE will also provide the TSPA-SR (TDR-WIS-PA-000001) Rev 00 ICN 01 in January 2001. The TSPA-SR includes sensitivity studies in the form of barrier degradation and parameter sensitivity analyses that investigate the effect of sorption and colloid parameters on repository performance.	Partly Received
ENFE.4.07	TSPAI	Provide updated FEPs AMRs with additional technical bases for those FEPs previously identified by the NRC in Rev. 03 of the ENFE IRSR as inadequately screened. In Rev 03 of the ENFE IRSR, the NRC identified 17 FEPs associated with Subissue 1 for which no screening arguments were identified in the FEPs data base, screening arguments were inconsistent with other project documents, or inadequate exclusion arguments were provided. The lack of screening arguments has been addressed in Rev 00 of the FEPs data base and Rev 00 of the supporting AMRs. Current revisions (or ICNs) of the FEPs AMRs, scheduled for completion in January 2001, will partially address the remaining NRC comments. Consideration of the remaining NRC comments will be provided in subsequent FEPs AMR revisions, expected to be available as periodic revisions, the entirety of which will be available prior to license application.	Received
ENFE.4.08	TSPAI	Provide the FEPs database. The DOE will provide the FEPs data base to the NRC during March 2001.	Received
ENFE.5.01	ENG3 TSPAI	Provide Revision 1 to the Topical Report. DOE will provide the Disposal Criticality Analysis Methodology Topical Report, Revision 01, to NRC during January 2001.	Received
ENFE.5.02	TSPAI	Provide the updated FEPs database. DOE stated that it would provide the FEPs AMRs and the FEPs database to NRC during January 2001.	Received

Agreement	Related ISIs or	NRC/DOE Agreement	Status
ENFE.5.03	ENG1	Provide the applicable list of validation reports and their schedules for external criticality. DOE stated that the geochemical model validation reports for "Geochemistry Model Validation Report: Degradation and Release" and "Geochemistry Model Validation Report: Material Accumulation" are expected to be available during 2001. The remainder of the reports are expected to be available during FY2002 subject to the results of detailed planning and scheduling. DOE understands that these reports are required to be provided prior to LA. A list of model validation reports was provided during the technical exchange and is included as an attachment to the meeting summary.	Partly Received
GEN.1.01	ENG1 ENG2 ENG3 ENG4 SZ1 SZ2 UZ2 UZ3	For NRC comments 3, 5, 8, 9, 10, 12, 13, 15, 16, 18, 21, 24, 27, 36, 37, 41, 42, 45, 46, 50, 56, 64, 69, 75, 78, 81, 82, 83, 93, 95, 96, 97, 98, 102, 103, 104, 106, 109, 110, 111, 113, 116, 118, 119, 120, 122, 123, 124, and 126, DOE will address the concern in the documentation for the specific KTI agreement identified in the DOE response (Attachment 2). The schedule and document source will be the same as the specific KTI agreement.	Not Received
IA.1.01	DIRECT1 TSPAI	In addition to DOE's licensing case, include for Site Recommendation and License Application, for information purposes, the results of a single point sensitivity analysis for extrusive and intrusive igneous processes at 10E-7. DOE agreed that the analysis will be included in TSPA-SR Rev. 0 and will be available to the NRC in November 2000.	Complete
IA.1.02	DIRECT1 TSPAI	Examine new aeromagnetic data for potential buried igneous features (see U.S. Geological Survey, Open-File Report 00-188, Online Version 1.0), and evaluate the effect on the probability estimate. If the data survey specifications are not adequate for this use, this action is not required. DOE agreed and will document the results of the evaluation in an update to the AMR, Characterize Framework for Igneous Activity at Yucca Mountain, Nevada (ANL-MGR-GS-000001), expected to be available in FY 2003.	Not Received
IA.2.01	DIRECT2	Re-examine the ASHPLUME Code to confirm that particle density is appropriately changed when waste particles are incorporated into the ash. (Eruptive AC-4) DOE agreed and will correct the description in the ICN to AMR, Igneous Consequences Modeling for TSPA-SR [ANL-WIS-MD-000017] as needed to address the concern. This will be available to the NRC in January 2001.	Complete
IA.2.02	DIRECT2	Document results of sensitivity studies for particle size, consistent with (1) above. (Eruptive AC-4) DOE agreed and will document the waste particle size sensitivity study in a calculation document. This will be available to the NRC in FY2002.	Not Received
IA.2.03	DIRECT2	Document how the tephra volumes from analog volcanos represent the likely range of tephra volumes from Yucca Mountain Region (YMR) volcanos. (Eruptive AC-1) DOE agreed and will document the basis for determining the range of tephra volumes that is likely from possible future volcanoes in the YMR in the Eruptive Processes AMR (ANL-MGR-GS-000002). This will be available to the NRC in FY2002.	Not Received
IA.2.04	DIRECT2	Document that the ASHPLUME model, as used in the DOE performance assessment, has been compared with an analog igneous system. (Eruptive AC-2) DOE agreed and will complete calculation CAL-WIS-MD-000011 that will document a comparison of the ASHPLUME code results to observed data from the 1995 Cerro Negro eruption. This will be available to the NRC in January 2001. DOE will consider Cerro Negro as an analog and document that in the Eruptive Processes AMR (ANL-MGR-GS-000002). This will be available to the NRC in FY2002.	Complete
IA.2.05	DIRECT1	Document how the current approach to calculating the number of waste packages intersected by conduits addresses potential effects of conduit elongation along a drift. (Eruptive AC-3) DOE agreed and will document the way in which the change in geometry of the repository drifts affects the number of waste packages incorporated into the volcanic conduit. Possible consequences of conduit elongation parallel to drifts will be documented in TSPA-SR Rev. 1, available to the NRC in June 2001.	Complete

Agreement	Related ISIs or	NRC/DOE Agreement	Status
IA.2.06	DOSE2 DOSE3	Develop a linkage between soil removal rate used in TSPA and surface remobilization processes characteristics of the Yucca Mountain region (which includes additions and deletions to the system). (Eruptive AC-5) DOE agreed and will document its approach to include uncertainty related to surface-redistribution processes in TSPA-SR, Rev. 0. DOE will revisit the approach in TSPA-SR, Rev. 1. This documentation will be available to the NRC in June 2001.	Complete
IA.2.07	DOSE2 DOSE3	Document the basis for airborne particle concentrations used in TSPA in Rev. 1 to the Input Values for External and Inhalation Radiation Exposure AMR. (Eruptive AC-5) DOE agreed and will provide documentation for the input values in the Input Parameter Values for External and Inhalation Radiation Exposure Analysis AMR [ANL-MGR-MD-000001] Rev. 1. This will be available to NRC in January 2001.	Complete
IA.2.08	DOSE2 DOSE3	Provide additional justification on the reasonableness of the assumption that the inhalation of particles in the 10-100 micron range is treated as additional soil ingestion, or change the BDCFs to reflect ICRP-30. (Eruptive AC-5) DOE agreed and will review how 10-100 micron particles are considered in the model for the eruptive scenario. The results will be documented in Input Parameter Values for External and Inhalation Radiation Exposure Analysis AMR [ANL-MGR-MD-000001] Rev. 1. This will be available to the NRC in January 2001.	Complete
IA.2.09	DIRECT2	Use the appropriate wind speeds for the various heights of eruption columns being modeled. (Eruptive AC-5) DOE agreed and will evaluate the wind speed data appropriate for the height of the eruptive columns being modeled. This will be documented in a calculation document. This will be available to the NRC in FY2002.	Not Received
IA.2.10	DIRECT1 ENG2	Document the ICNs to the Igneous Consequences AMR and the Dike Propagation AMR regarding the calculation of the number of waste packages hit by the intrusion. Include in these or other documents (1) the intermediate results of the releases from Zone 1 and 2, separately, and (2) the evaluation of thermal and mechanical effects, as well as shock, in assessing the degree of waste package damage in Zone 1 and 2. (Intrusive AC 4) DOE agreed and will provide ICN 1 of the following AMRs: Igneous Consequences Modeling for TSPA-SR AMR [ANL-WIS-MD-000017], the Dike Propagation Near Drifts AMR [ANL-WIS-MD-000015], the Characterize Framework for Igneous Activity at Yucca Mountain, Nevada AMR [ANL-MGR-GS-000001], and the Calculation Number of Waste Packages Hit by Igneous Intrusion [CAL-WIS-PA-000001]. This will be available to the NRC in January 2001. DOE will provide the results showing the relative contributions of releases from Zones 1 and 2 in a calculation document. This will be available to the NRC in FY2002. DOE will provide the evaluation of thermal mechanical effects on waste package damage in Zones 1 and 2 in ICN 1 of the Dike Propagation Near Drifts AMR [ANL-WIS-MD-000015]. This will be available to the NRC in January 2001.	Partly Received
IA.2.11	DOSE2 DOSE3	Provide an analysis that shows the relationship between any static measurements used in the TSPA and expected types and durations of surface disturbing activities associated with the habits and lifestyles of the critical group. DOE will provide an analysis that shows the relationship between any static measurements used in the TSPA and expected types and durations of surface disturbing activities associated with the habits and lifestyles of the critical group in a subsequent revision to the AMR Input Parameter Values for External and Inhalation Radiation Exposure Analysis (ANL-MGR-MD-000001) or equivalent document. This will be available to the NRC in FY02.	Not Received
IA.2.12	DOSE2 DOSE3	Provide clarifying information on how PM10 measurements have been extrapolated to TSP concentrations. This should include consideration of the difference in behavior between PM10 and TSP particulates under both static and disturbed conditions. DOE will provide clarifying information on how PM10 measurements have been extrapolated to TSP concentrations. This will include consideration of the difference in behavior between PM10 and TSP particulates under both static and disturbed conditions in a subsequent revision to the AMR Input Parameter Values for External and Inhalation Radiation Exposure Analysis (ANL-MGR-MD-000001) or equivalent document. This will be available to the NRC in FY02.	Not Received
IA.2.13	DOSE2 DOSE3	Provide the justification that sampling of range of transition period BDCFs is necessarily conservative in evaluating long-term remobilization processes. DOE will provide the justification that sampling of range of transition period BDCFs is necessarily conservative in evaluating long-term remobilization processes in a subsequent revision to the AMR Input Parameter Values for External and Inhalation Radiation Exposure Analysis (ANL-MGR-MD-000001) or equivalent document. This will be available to the NRC in FY02.	Not Received

Agreement	Related ISIs or	NRC/DOE Agreement	Status
IA.2.14	DOSE2 DOSE3	Provide information clarifying the method used in TSPA to calculate how deposit thickness effects the average mass load over the transition period. DOE will provide information clarifying the method used in TSPA to calculate how deposit thickness effects the average mass load over the transition period in a subsequent revision to the AMR Input Parameter Values for External and Inhalation Radiation Exposure Analysis (ANL-MGR-MD-000001) or equivalent document. This will be available to the NRC in FY02.	Not Received
IA.2.15	DOSE2 DOSE3	Clarify that external exposure from HLW-contaminated ash, in addition to inhalation and ingestion, was considered in the TSPA. Include in this clarification the consideration of external exposure during indoor occupancy times, or provide basis for dwelling shielding from outdoor gamma emitters. DOE will clarify that external exposure from HLW-contaminated ash, in addition to inhalation and ingestion, was considered in the TSPA. DOE will include in this clarification the consideration of external exposure during indoor occupancy times, or provide basis for dwelling shielding from outdoor gamma emitters in a subsequent revision to the AMR Input Parameter Values for External and Inhalation Radiation Exposure Analysis (ANL-MGR-MD-000001) or equivalent document. This will be available to the NRC in FY02.	Not Received
IA.2.16	DOSE2 DOSE3	Document that neglecting the effects of climate change on disruptive event BDCFs is conservative. DOE will document that neglecting the effects of climate change on disruptive event BDCFs is conservative in a subsequent revision to the AMRs Input Parameter Values for External and Inhalation Radiation Exposure Analysis (ANL-MGR-MD-000001) and Disruptive Event Biosphere Dose Conversion Factor Analysis (ANL-MGR-MD-000003) or equivalent document. This will be available to the NRC in FY02.	Not Received
IA.2.17	DOSE2 DOSE3	DOE will evaluate conclusions that the risk effects (i.e., effective annual dose) of eolian and fluvial remobilization are bounded by conservative modeling assumptions in the TSPA-SR, Rev 00, ICN1. DOE will examine rates of eolian and fluvial mobilization off slopes, rates of transport in Fortymile Wash, and rates of deposition or removal at proposed critical group location. DOE will evaluate changes in grain size caused by these processes for effects on airborne particle concentrations. DOE will also evaluate the inherent assumption in the mass loading model that the concentration of radionuclides on soil in the air is equivalent to the concentration of radionuclides on soil on the ground does not underestimate dose (i.e., radionuclides important to dose do not preferentially attach to smaller particles). DOE will document the results of investigations in the AMR, Eruptive Processes and Soil Redistribution ANL-MGR-GS-000002, expected to be available in fiscal year 2003 and in the AMR, Input Parameter Values for External and Inhalation Radiation Exposure Analysis, ANL-MGR-MD-000001, available FY 2003, or another appropriate technical document.	Not Received
IA.2.18	DIRECT1 ENG2	DOE will evaluate how the presence of repository structures may affect magma ascent, conduit localization, and evolution of the conduit and flow system. The evaluation will include the potential effects of topography and stress, strain response on existing or new geologic structures resulting from thermal loading of HLW, in addition to a range of physical conditions appropriate for the duration of igneous events. DOE will also evaluate how the presence of engineered repository structures in the LA design (e.g., drifts, waste packages, backfill, etc.) could affect magma flow processes for the duration of an igneous event. The evaluation will include the mechanical strength and durability of natural or engineered barriers that could restrict magma flow within intersected drifts. The results of this investigation will be documented in an update to the AMR, Dike Propagation and Interaction with Drifts, ANL-WIS-MD-000015, expected to be available in FY 2003, or another appropriate technical document.	Not Received
IA.2.19	DIRECT1 ENG2	DOE will evaluate waste package response to stresses from thermal and mechanical effects associated with exposure to basaltic magma, considering the results of evaluations attendant to IA Agreement 2.18. As currently planned, the evaluation, if implemented, would include (1) appropriate at-condition strength properties and magma flow paths, for duration of an igneous event; and (2) aging effects on materials strength properties when exposed to basaltic magmatic conditions for the duration of an igneous event, which will include the potential effects of subsequent seismically induced stresses on substantially intact waste packages. DOE will also evaluate the response of Zone 3 waste packages, or waste packages covered by backfill or rockfall, if exposed to magmatic gases at conditions appropriate for an igneous event, considering the results of evaluations attendant to IA Agreement 2.18. If models take credit for engineered barriers providing delay in radionuclide release, DOE will evaluate barrier performance for the duration of the hypothetical igneous event. The results of this investigation would be documented in an update to the technical product Waste Package Behavior in Magma CAL-EBS-ME-000002, which would be available by the end of FY 2003, or another appropriate technical document.	Not Received

Agreement	Related ISIs or	NRC/DOE Agreement	Status
IA.2.20	DIRECT1 DIRECT2 ENG2	DOE will evaluate how ascent and flow of basaltic magma through repository structures could result in processes that might incorporate HLW, considering the results of evaluations attendant to IA Agreements 2.18 and 2.19. As currently planned, the evaluation, if implemented, would include the potential for HLW incorporation along reasonable potential flow paths that could develop during an igneous event. The evaluation would also include the physical and chemical response of HLW and cladding after heating and potential disruption of waste package and contents, for waste packages remaining in drifts. The evaluation would examine effects that may result in increased solubility potential relative to undisturbed HLW forms. The results of this investigation would be documented in a new AMR to document the waste form response to magmatic conditions, which is expected to be available by the end of FY 2003. DOE will describe the method of HLW incorporation used in DOE models, including consideration of particle aggregation and the effect on waste transport. If models take credit for engineered barriers providing delay in radionuclide release, DOE will evaluate barrier performance for the duration of the hypothetical igneous event. This will be documented in an update to the igneous consequences AMR, ANL-WIS-MD-000017, which is expected to be available in FY 2003, or another appropriate technical document.	Not Received
PRE.03.01	PRE	Provide a plan for identification and estimation of aircraft hazards for the license application. This plan should be consistent with the guidelines in NUREG-0800 and other applicable DOE standards, as appropriate, to a nuclear waste repository. Provide a map delineating the vicinity to be considered in the detailed analysis, taking into consideration available information for civilian and military aircraft, including information from federal and local agencies concerning how such activities may reasonably change. Participate in an Appendix 7 meeting to discuss the aircraft hazards plan, initial data collection and analysis, development of the vicinity map, and the appropriate level of detail for analyses to be presented in the license application assessment. DOE agrees with the request and will provide the plan and map in June 2002. DOE agrees to participate in an Appendix 7 meeting which will be scheduled after the plan and map are provided.	Not Received
PRE.03.02	PRE	Provide an analysis, including (1) selection of the design basis tornado, together with the supporting technical basis; (2) selection of credible tornado missile characteristics for the waste package and other structures, systems, and components, together with the technical bases; and (3) analysis of the effects of impact of the design basis tornado missiles or justification for excluding such tornado missiles as credible hazards. DOE agrees to provide the analysis. The analysis will be available in FY03 and be documented in an update to ANL-MGR-SE-000001 and any other appropriate documents.	Not Received
PRE.06.01	PRE	Provide the update to Quality Assurance Procedure QAP 2-3. DOE agreed to provide the procedure. The procedure will be available in February 2002.	Not Received
PRE.06.02	PRE	Provide the Integrated Safety Analysis Guide. DOE agreed to provide the guide. The guide will be available in February 2002.	Not Received
PRE.07.01	PRE	Provide an update to the Pre-Closure Criticality Analysis Process Report. DOE agreed to provide the report. The report will be available in FY03.	Not Received
PRE.07.02	PRE	Provide the waste package finite element analysis based numerical simulations that represent a significant contribution to DOE's safety case. Provide documentation demonstrating that a sufficient finite element model mesh discretization has been used and the failure criterion adequately bounds the uncertainties associated with effects not explicitly considered in the analysis. These uncertainties include but are not limited to: (1) residual and differential thermal expansion stresses, (2) strain rate effects, (3) dimensional and material variability, (4) seismic effects on ground motion, (5) initial tip-over velocities, and (6) sliding and inertial effects of the waste package contents, etc. In addition, document the loads and boundary conditions used in the models and provide the technical bases and or rationale for them. DOE agreed to provide the information. The information will be available in FY03 and documented in Waste Package Design Methodology Report.	Not Received
PRE.07.03	PRE	Demonstrate that the allowed microstructural and compositional variations of alloy 22 base metal and the allowed compositional variations in the weld filler metals used in the fabrication of the waste packages do not result in unacceptable waste package mechanical properties. DOE will provide justification that the ASME code case for alloy 22 results in acceptable waste package mechanical properties considering allowed microstructural and compositional variations of alloy 22 base metal and the allowed compositional variations in the weld filler metals used in the fabrication of the waste packages. DOE agrees to provide the information in FY03 and document the information in the Waste Package Design Methodology Report.	Not Received

Agreement	Related ISIs or	NRC/DOE Agreement	Status
PRE.07.04	PRE	Demonstrate that the non-destructive evaluation methods used to inspect the alloy 22 and 316 nuclear grade plate material and closure welds are sufficient and are capable of detecting all defects that may alter waste package mechanical properties. DOE will provide justification that the non-destructive evaluation methods used to inspect the alloy 22 and 316 nuclear grade plate material and welds are sufficient and are capable of detecting defects that may adversely affect waste package pre-closure structural performance. DOE agrees to provide the information in FY03 and document the information in the Waste Package Operations Fabrication Process Report.	Not Received
PRE.07.05	PRE	Provide justification that the mechanical properties of the disposal container fabrication and waste package closure welds are adequately represented considering the (1) range of welding methods used to construct the disposal containers, (2) post weld annealing and stress mitigation processes, and (3) post weld repairs. DOE agrees to provide the information in FY03 and document the information in the Waste Package Operations Fabrication Process Report.	Not Received
RDTME.2.01	PRE	Provide Topical Report 3, Preclosure Seismic Design Inputs for a Geologic Repository at Yucca Mountain. Consistent with SDS Subissue 2, Agreement 2, the DOE will provide Seismic Topical Report 3, Preclosure Seismic Design Inputs for a Geologic Repository at Yucca Mountain, expected to be available to the NRC in January 2002.	Not Received
RDTME.2.02	PRE	Provide the substantive technical content of Topical Report 3. The DOE will provide the preliminary seismic design input data sets used in Site Recommendation design analyses to the NRC by April 2001. The DOE will provide the draft final seismic design inputs for license application via an Appendix 7 meeting after calculations are complete prior to delivery of Seismic Topical Report 3.	Partly Received
RDTME.3.01	PRE	Provide the technical basis for the range of relative humidities, as well as the potential occurrence of localized liquid phase water, and resulting affects on ground support systems. The DOE will provide the technical basis for the range of relative humidity and temperature, and the potential effects of localized liquid phase water on ground support systems, during the forced ventilation preclosure period, in the Longevity of Emplacement Drift Ground Support Materials, ANL-EBS-GE-000003 Rev 01, and revision 1 of the Ventilation Model, ANL-EBS-MD-000030, analysis and model reports. These are expected to be available to NRC in September and March 2001, respectively.	Partly Received
RDTME.3.02	PRE	Provide the critical combinations of in-situ, thermal, and seismic stresses, together with their technical bases, and their impacts on ground support performance. The DOE will examine the critical combinations of in-situ, thermal, and seismic stresses, together with their technical bases and their impacts on preclosure ground support performance. These results will be documented in a revision to the Ground Control for Emplacement Drifts for SR, ANL-EBS-GE-000002 (or other document) supporting any potential license application. This is expected to be available to NRC in FY 2003.	Not Received
RDTME.3.03	ENG2 PRE	Provide the Seismic Design Inputs AMR and the Preclosure Seismic Design Inputs for a Geologic Repository at Yucca Mountain, Seismic Topical Report 3. Consistent with SDS Subissue 2, Agreement 2, the DOE will provide the Seismic Design Inputs analysis and model report and Preclosure Seismic Design Inputs for a Geologic Repository at Yucca Mountain, Seismic Topical Report 3. These documents are expected to be available to NRC in January 2002.	Not Received
RDTME.3.04	PRE	Provide in the Design Parameter Analysis Report (or some other document) site-specific properties of the host rock, as a minimum those included in the NRC handout, together with the spatial and temporal variations and uncertainties in such properties, as an update to the information contained in the March 1997 Yucca Mountain Site Geotechnical Report. The DOE will: (1) evaluate the adequacy of the currently available measured and derived data to support the potential repository licensing case and identify areas where available data may warrant additional field measurements or testing to reduce uncertainty. DOE will provide a design parameters analysis report (or other document) that will include the results of these evaluations, expected to be available to NRC in FY 2002; and (2) acquire data and/or perform additional analyses as necessary to respond to the needs identified in 1 above. The DOE will provide these results prior to any potential license application.	Not Received
RDTME.3.05	PRE	Provide the Rock Mass Classification Analysis (or some other document) including the technical basis for accounting for the effects of lithophysae. The DOE will provide a rock mass classification analysis (or other document), including the technical basis for accounting for the effects of lithophysae, expected to be available to NRC in FY 2002.	Not Received

Agreement	Related ISIs or	NRC/DOE Agreement	Status
RDTME.3.06	PRE	Provide the design sensitivity and uncertainty analyses of the rock support system. The DOE will prepare a scoping analysis to determine the significance of the input parameters for review by NRC staff by August 2002. Once an agreed set of significant parameters has been determined by the DOE and the NRC staff, the DOE will prepare an analysis of the sensitivity and uncertainty of the preclosure rock support system to design parameters in a revision to the Ground Control for Emplacement Drifts for SR, ANL-EBS-GE-000002 (or other document) supporting any potential license application. This is expected to be available to NRC in FY 2003.	Not Received
RDTME.3.07	PRE	The DOE should account for the effect of sustained loading on intact rock strength or provide justification for not accounting for it. The DOE will assess the effects of sustained loading on intact rock strength. The DOE will provide the results of this assessment in a design parameters analysis report (or other document), expected to be available to NRC in FY 2002.	Not Received
RDTME.3.08	PRE	Provide the design sensitivity and uncertainty analyses of the fracture pattern (with respect to Subissue 3, Component 1). The DOE will provide sensitivity and uncertainty analysis of fracture patterns (based on observed orientation, spacing, trace length, etc) on the preclosure ground control system design in a revision to the Ground Control for Emplacement Drifts for SR, ANL-EBS-GE-000002 (or other document) supporting any potential license application. This is expected to be available to NRC in FY 2003.	Not Received
RDTME.3.09	PRE	Provide appropriate analysis that shows that rock movements in the invert are either controlled or otherwise remain within the range acceptable to provide for retrieval and other necessary operations within the deposal drifts. DOE will provide appropriate analysis that shows rock movements in the floor of the emplacement drift are within the range acceptable for preclosure operations. The analysis results will be provided in a revision to the Ground Control for Emplacement Drifts for SR, ANL-EBS-GE-000002 (or other document) supporting any potential license application. This is expected to be available to NRC in FY 2003.	Not Received
RDTME.3.10	PRE	Provide technical basis for the assessment that two-dimensional modeling for emplacement drifts is considered to be adequate, considering the fact that neither the in-situ stress field nor the principle fracture orientation are parallel or perpendicular to emplacement drift orientation. The DOE will provide the technical bases for the modeling methods used in ground control analysis in a revision to the Ground Control for Emplacement Drifts for SR, ANL-EBS-GE-000002 (or other document) supporting any potential license application. This is expected to be available to NRC in FY 2003.	Not Received
RDTME.3.11	PRE	Provide continuum and discontinuum analyses of ground support system performance that take into account long-term degradation of rockmass and joint strength properties. The DOE will justify the preclosure ground support system design (including the effects of long term degradation of rock mass and joint strength properties) in a revision to the Ground Control for Emplacement Drifts for SR, ANL-EBS-GE-000002 (or other document) supporting any potential license application. This is expected to be available to NRC in FY 2003.	Not Received
RDTME.3.12	PRE	Provide dynamic analyses (discontinuum approach) of ground support system performance using site specific ground motion time history as input. The DOE will provide appropriate analyses to include dynamic analyses (discontinuum approach) of preclosure ground support systems, using site specific ground motion time histories as input, in a revision to the Ground Control for Emplacement Drifts for SR, ANL-EBS-GE-000002 (or other document) supporting any potential license application. This is expected to be available to NRC in FY 2003.	Not Received
RDTME.3.13	PRE	Provide technical justification for boundary conditions used for continuum and discontinuum modeling used for underground facility design. The DOE will provide the technical justification for boundary conditions used in modeling for preclosure ground control analyses in a revision to the Ground Control for Emplacement Drifts for SR, ANL-EBS-GE-000002 (or other document) supporting any potential license application. This is expected to be available to NRC in FY 2003.	Not Received
RDTME.3.14	PRE UZ2	Provide the results of the ventilation modeling being conducted at the University of Nevada-Reno (Multi-Flux code) and validation testing at the Atlas Facility (validation of the ventilation model based on the ANSYS code), including: 1) the technical bases for the adequacy of discretization used in these models and 2) the technical bases for the applicability of the modeling results to prediction of heat removal from the repository. The DOE will provide the results of the ventilation tests in a update to the Ventilation Model, ANL-EBS-MD-000030, analysis and model report including: 1) the technical bases for the adequacy of discretization used in these models and 2) the technical bases for the applicability of the modeling results to prediction of heat removal from the repository. This is expected to be available to NRC in FY 2002.	Not Received

Agreement	Related ISIs or	NRC/DOE Agreement	Status
RDTME.3.15	ENG2	Provide field data and analysis of rock bridges between rock joints that are treated as cohesion in DRKBA modeling together with a technical basis for how a reduction in cohesion adequately accounts for thermal effects. The DOE will provide clarification of the approach and technical basis for how reduction in cohesion adequately accounts for thermal effects, including any additional applicable supporting data and analyses. Additionally, the adequacy of the cohesion reduction approach will be verified according to the approach described in Subissue 3, Agreement 19, of the Repository Design and Thermal-Mechanical Effects Technical Exchange. This will be documented in a revision to the Drift Degradation Analysis, ANL-EBS-MD-000027, expected to be available to NRC in FY 2003.	Not Received
RDTME.3.16	ENG2	Provide a technical basis for the DOE position that the method used to model joint planes as circular discs does not under-represent the smaller trace-length fractures. The DOE will analyze the available small trace-length fracture data from the Exploratory Studies Facility and Enhanced Characterization of the Repository Block, including their effect on block development. This will be documented in a revision to the Drift Degradation Analysis, ANL-EBS-MD-000027, expected to be available to NRC in FY 2003.	Not Received
RDTME.3.17	ENG2	Provide the technical basis for effective maximum rock size including consideration of the effect of variation of the joint dip angle. The DOE will provide the technical basis for effective maximum rock size including consideration of the effect of variation of the joint dip angle. This will be documented in revisions to the Drift Degradation Analysis, ANL-EBS-MD-000027, and the Rockfall on Drip Shield, CAL-EBS-ME-000001, expected to be available to NRC in FY 2003.	Not Received
RDTME.3.18	ENG1 ENG2	Provide a technical basis for a stress measure that can be used as the equivalent uniaxial stress for assessing the susceptibility of the various engineered barrier system materials to stress corrosion cracking (SCC). The proposed stress measure must be consistent and compatible with the methods proposed by the DOE to assess SCC of the containers in WAPDEG and in accordance with the agreements reached at the CLST Technical Exchange. The DOE will include a detailed discussion of the stress measure used to determine nucleation of stress corrosion cracks in the calculations performed to evaluate waste package barriers and the drip shield against stress corrosion cracking criterion. DOE will include these descriptions in future revisions of the following: Design Analysis for UCF Waste Packages, ANL-UDC-MD-000001, Design Analysis for the Defense High-Level Waste Disposal Container, ANL-DDC-ME-000001, Design Analysis for the Naval SNF Waste Package, ANL-UDC-ME-000001, and Design Analysis for the Ex-Container Components, ANL-XCS-ME-000001. The stresses reported in these documents will be used in WAPDEG and will be consistent with the agreements and associated schedule made at the Container Life and Source Term Technical Exchange (Subissue 1, Agreement 14, Subissue 6, Agreement 1).	Not Received

Agreement	Related ISIs or	NRC/DOE Agreement	Status
RDTME.3.19	ENG2 TSPAI	The acceptability of the process models that determine whether rockfall can be screened out from performance assessment abstractions needs to be substantiated by the DOE by doing the following: (1) provide revised DRKBA analyses using appropriate range of strength properties for rock joints from the Design Analysis Parameters Report, accounting for their long-term degradation; (2) provide an analysis of block sizes based on the full distribution of joint trace length data from the Fracture Geometry Analysis Report for the Stratigraphic Units of the Repository Host Horizon, including small joints trace lengths; (3) verify the results of the revised DRKBA analyses using: (a) appropriate boundary conditions for thermal and seismic loading; (b) critical fracture patterns from the DRKBA Monte Carlo simulations (at least two patterns for each rock unit); (c) thermal and mechanical properties for rock blocks and joints from the Design Analysis Parameters Report; (d) long-term degradation of rock block and joint strength parameters; and (e) site-specific groundmotion time histories appropriate for post-closure period; provide a detailed documentation of the analyses results; and (4) in view of the uncertainties related to the rockfall analyses and the importance of the outcome of the analyses to the performance of the repository, evaluate the impacts of rockfall in performance assessment calculations. DOE believes that the Drift Degradation Analysis is consistent with current understanding of the Yucca Mountain site and the level of detail of the design to date. As understanding of the site and the design evolve, DOE will: (1) provide revised DRKBA analyses using appropriate range of strength properties for rock joints from a design parameters analysis report (or other document), accounting for their long-term degradation; (2) provide an analysis of block sizes based on the full distribution of joint trace length data from the Fracture Geometry Analysis for the Stratigraphic Units of the Repository Host Horizon, ANL-EBS-GE-000006, supplemented by available small joint trace length data; (3) verify the results of the revised DRKBA analyses using: (a) appropriate boundary conditions for thermal and seismic loading; (b) critical fracture patterns from the DRKBA Monte Carlo simulations (at least two patterns for each rock unit); (c) thermal and mechanical properties for rock blocks and joints from a design parameters analysis report (or other document); (d) long-term degradation of joint strength parameters; and (e) site-specific ground motion time histories appropriate for post-closure period. This will be documented in a revision to the Drift Degradation Analysis, ANL-EBS-MD-000027, expected to be available to NRC in FY 2003. Based on the results of the analyses above and subsequent drip shield calculation revisions, DOE will reconsider the screening decision for inclusion or exclusion of rockfall in performance assessment analysis. Any changes to screening decisions will be documented in analyses prior to any potential license application.	Not Received
RDTME.3.20	ENG3 UZ2	Provide the sensitivity analyses including the effects of boundary conditions, coefficient of thermal expansion, fracture distributions, rock mass and fracture properties, and drift degradation (from Subissue 3, Component 3, Slide 39). The DOE will provide sensitivity analyses of thermal-mechanical effects on fracture permeability, including the effects of boundary conditions, coefficient of thermal expansion, fracture distributions, rock mass and fracture properties, and drift degradation. This will be provided consistent with site data and integrated with appropriate models in a future revision to the Coupled Thermal Hydrologic Mechanical Effects on Permeability, ANL-NBS-HS-000037, and is expected to be available to NRC in FY 2003.	Not Received
RDTME.3.21	ENG3 UZ2	Provide the results of additional validation analysis of field tests (from Subissue 3, Component 3, Slide 39). The DOE will provide the results of additional validation analysis of field tests related to the thermal-mechanical effects on fracture permeability in a future revision to the Coupled Thermal Hydrologic Mechanical Effects on Permeability, ANL-NBS-HS-000037, and is expected to be available to NRC in FY 2003.	Not Received
RT.1.01	UZ2 UZ3	Provide the basis for the proportion of fracture flow through the Calico Hills non-welded vitric. DOE will revise the AMR UZ Flow Models and Submodels and the AMR Calibrated Properties Model to provide the technical basis for the proportion of fracture flow through the Calico Hills Nonwelded Vitric. These reports will be available to the NRC in FY 2002. In addition, the field data description will be documented in the AMR In Situ Field Testing of Processes in FY 2002.	Not Received
RT.1.02	SZ2 UZ3	Provide analog radionuclide data from the tracer tests for Calico Hills at Busted Butte and from similar analog and radionuclide data (if available) from test blocks from Busted Butte. DOE will provide data from tracers used at Busted Butte and data from (AECL) test blocks from Busted Butte in an update to the AMR In Situ Field Testing of Processes in FY 2002.	Not Received
RT.1.03	SZ2 TSPAI UZ3	Provide the screening criteria for the radionuclides selected for PA. Provide the technical basis for selection of the radionuclides that are transported via colloids in the TSPA. The screening criteria for radionuclides selected for TSPA are contained in the AMR Inventory Abstraction. DOE is documenting identification of radionuclides transported via colloids for TSPA in the AMR Waste Form Colloid-Associated Concentration Limits: Abstraction and Summary, in the TSPA-SR Technical Report, and in the TSPA-SR Model Document. These documents will be available to the NRC in January 2001.	Received

Agreement	Related ISIs or	NRC/DOE Agreement	Status
RT.1.04	SZ2 UZ3	Provide sensitivity studies on Kd for plutonium, uranium, and protactinium to evaluate the adequacy of the data. DOE will analyze column test data to determine whether, under the flow rates pertinent to the Yucca Mountain flow system, plutonium sorption kinetics are important to performance. If they are found to be important, DOE will also perform sensitivity analyses for uranium, protactinium, and plutonium to evaluate the adequacy of KD data. The results of this work will be documented in an update to the AMR Unsaturated Zone and Saturated Zone Transport Properties available to the NRC in FY 2002.	Not Received
RT.1.05	SZ1 SZ2 UZ3	Provide additional documentation to explain how transport parameters used for performance assessment were derived in a manner consistent with NUREG-1563, as applicable. Consistent with the less structured approach for informal expert judgment acknowledged in NUREG-1563 guidance and consistent with DOE procedure AP-3.10Q, DOE will document how it derived the transport parameter distributions for performance assessment, in a report expected to be available in FY 2002.	Not Received
RT.2.01	SZ1 SZ2	Provide further justification for the range of effective porosity in alluvium, considering possible effects of contrasts in hydrologic properties of layers observed in wells along potential flow paths. DOE will use data obtained from the Nye County Drilling Program, available geophysical data, aeromagnetic data, and results from the Alluvium Testing Complex testing to justify the range of effective porosity in alluvium, considering possible effects of contrasts in hydrologic properties of layers observed in wells along potential flowpaths. The justification will be provided in the Alluvial Testing Complex AMR due in FY 2003.	Not Received
RT.2.02	SZ1 SZ2 TSPAI	The DOE should demonstrate that TSPA captures the spatial variability of parameters affecting radionuclide transport in alluvium. DOE will demonstrate that TSPA captures the variability of parameters affecting radionuclide transport in alluvium. This information will be provided in the TSPA-LA document due in FY 2003.	Not Received
RT.2.03	SZ1 SZ2	Provide a detailed testing plan for alluvial testing (the ATC and Nye County Drilling Program) to reduce uncertainty (for example, the plan should give details about hydraulic and tracer tests at the well 19 complex and it should also identify locations for alluvium complex testing wells and tests and logging to be performed). NRC will review the plan and provide comments, if any, for DOE's consideration. In support and preparation for the October/November 2000 Saturated Zone meeting, DOE provided work plans for the Alluvium Testing Complex and the Nye County Drilling Program (FWP-SBD-99-002, Alluvial Tracer Testing Field Work Package, and FWP-SBD-99-001, Nye County Early Warning Drilling Program, Phase II and Alluvial Testing Complex Drilling). DOE will provide test plans of the style of the Alcove 8 plan as they become available. The plan will be amended to include laboratory testing. In addition, the NRC On Site Representative attends DOE/Nye County planning meetings and is made aware of all plans and updates to plans as they are made.	Not Received
RT.2.04	SZ1 SZ2	The NRC needs DOE to document the pre-test predictions for the ATC. DOE will document pretest predictions for the Alluvial Testing Complex in the SZ In Situ Testing AMR available in October 2001.	Not Received
RT.2.05	SZ2	Provide the laboratory testing plan for laboratory radionuclide transport studies. NRC will review the plan and provide comments, if any, for DOE's consideration. In support and preparation for the October/November 2000 Saturated Zone meeting, DOE provided work plans for the Alluvium Testing Complex and the Nye County Drilling Program (FWP-SBD-99-002, Alluvial Tracer Testing Field Work Package, and FWP-SBD-99-001, Nye County Early Warning Drilling Program, Phase II and Alluvial Testing Complex Drilling). DOE will provide test plans of the style of the Alcove 8 plan as they become available. The plan will be amended to include laboratory testing. In addition, the NRC On Site Representative attends DOE/Nye County planning meetings and is made aware of all plans and updates to plans as they are made.	Not Received

Agreement	Related ISIs or	NRC/DOE Agreement	Status
RT.2.06	SZ2	If credit is taken for retardation in alluvium, the DOE should conduct Kd testing for radionuclides important to performance using alluvium samples and water compositions that are representative of the full range of lithologies and water chemistries present within the expected flow paths (or consider alternatives such as testing with less disturbed samples, use of samples from more accessible analog sites (e.g., 40-mile Wash), detailed process level modeling, or other means). DOE will conduct Kd experiments on alluvium using samples from the suite of samples obtained from the existing drilling program; or, DOE will consider supplementing the samples available for testing from the alternatives presented by the NRC. This information will be documented in an update to the SZ In Situ Testing AMR, available in FY 2003. Kd parameter distributions for TSPA will consider the uncertainties that arise from the experimental methods and measurements.	Not Received
RT.2.07	SZ2	Provide the testing results for the alluvial and laboratory testing. DOE will provide testing results for the alluvial field and laboratory testing in an update to the SZ In Situ Testing AMR available in FY 2003.	Not Received
RT.2.08	SZ1	Provide additional information to further justify the uncertainty distribution of flow path lengths in the alluvium. This information currently resides in the Uncertainty Distribution for Stochastic Parameters AMR. DOE will provide additional information, to include Nye County data as available, to further justify the uncertainty distribution of flowpath lengths in alluvium in updates to the Uncertainty Distribution for Stochastic Parameters AMR and to the Saturated Zone Flow and Transport PMR, both expected to be available in FY 2002.	Not Received
RT.2.09	SZ1	Provide the hydro-stratigraphic cross-sections that include the Nye County data. DOE will provide the hydrostratigraphic cross sections in an update to the Hydrogeologic Framework Model for The Saturated Zone Site-Scale Flow and Transport Model AMR expected to be available during FY 2002, subject to availability of Nye County data.	Not Received
RT.2.10	SZ2 TSPAI UZ3	Provide additional documentation to explain how transport parameters used for PA were derived in a manner consistent with NUREG-1563, as applicable. Consistent with the less structured approach for informal expert judgment acknowledged in NUREG-1563 guidance and consistent with AP-3.10Q, DOE will document how it derived the transport distributions for performance assessment, in a report expected to be available in FY 2002.	Not Received
RT.2.11	SZ1 TSPAI	Provide the updated UZ Flow and Transport and the SZ Flow and Transport FEPs AMRs. DOE will provide updates to the AMRs Features, Events, and Processes in UZ Flow and Transport and Features, Events, and Processes in SZ Flow and Transport, both available in January 2001.	Received
RT.3.01	SZ1 UZ3	For transport through fault zones below the repository, provide the technical basis for parameters/distributions (consider obtaining additional information, for example, the sampling of wells WT-1 and WT-2), or show the parameters are not important to performance. DOE will provide a technical basis for the importance to performance of transport through fault zones below the repository. This information will be provided in an update to the AMR Radionuclide Transport Models Under Ambient Conditions available to the NRC in FY 2002. If such transport is found to be important to performance, DOE will provide the technical basis for the parameters/distributions used in FY 2002. DOE will consider obtaining additional information.	Not Received
RT.3.02	UZ2 UZ3	Provide the analysis of geochemical data used for support of the flow field below the repository. DOE will provide the analysis of geochemical data used for support of the fluid flow patterns in the AMR UZ Flow Models and Submodels, available to the NRC in FY 2002.	Not Received
RT.3.03	SZ1	Provide additional information to further justify the uncertainty distribution of flow path lengths in the tuff. This information currently resides in the Uncertainty Distribution for Stochastic Parameters AMR. DOE will provide additional information, to include Nye County data as available, to further justify the uncertainty distribution of flowpath lengths from the tuff at the water table through the alluvium at the compliance boundary in updates to the Uncertainty Distribution for Stochastic Parameters AMR and to the Saturated Zone Flow and Transport Process Model Report, both expected to be available in FY 2002.	Not Received

Agreement	Related ISIs or	NRC/DOE Agreement	Status
RT.3.04	UZ3	Provide sensitivity studies for the relative importance of the hydrogeological units beneath the repository for transport of radionuclides important to performance. DOE will provide a sensitivity study to fully evaluate the relative importance of the different units below the repository that could be used to prioritize data collection, testing, and analysis. This study will be documented in an update to the AMR Radionuclide Transport Models Under Ambient Conditions available to the NRC in FY 2002.	Not Received
RT.3.05	UZ2 UZ3	Provide the documentation for the Alcove 8/Niche 3 testing and predictive modeling for the unsaturated zone. DOE will provide documentation for the Alcove 8 / Niche 3 testing and predictive modeling for the unsaturated zone in updates to the AMRs In Situ Field Testing of Processes and Radionuclide Transport Models Under Ambient Conditions, both available to the NRC in FY 2002.	Not Received
RT.3.06	UZ2 UZ3	The NRC needs DOE to document the pre-test predictions for the Alcove 8/Niche 3 work. DOE responded that pre-test predictions for Alcove 8 Niche 3 work will be provided to NRC via letter report (Brocoum to Greeves) by mid-January 2001.	Received
RT.3.07	SZ2 UZ3	Provide sensitivity studies to test the importance of colloid transport parameters and models to performance for UZ and SZ. Consider techniques to test colloid transport in the Alcove 8/Niche 3 test (for example, microspheres). DOE will perform sensitivity studies as the basis for consideration of the importance of colloid transport parameters and models to performance for the unsaturated and saturated zones and will document the results in updates to appropriate AMRs, and in the TSPA-LA document, all to be available in FY 2003. DOE will evaluate techniques to test colloidal transport in Alcove 8 / Niche 3 and provide a response to the NRC in February 2001.	Partly Received
RT.3.08	SZ2 UZ3	Provide justification that microspheres can be used as analogs for colloids (for example, equivalent ranges in size, charge, etc.). DOE will provide documentation in the C-Wells AMR to provide additional justification that microspheres can be used as analogs for colloids. The C-Wells AMR will be available to the NRC in October 2001.	Not Received
RT.3.09	SZ2	Provide the documentation for the C-wells testing. Use the field test data or provide justification that the data from the laboratory tests is consistent with the data from the field tests. DOE will provide the C-Wells test documentation and will either use the test data or provide a justified reconciliation of the lab and field test data in the C-Wells AMR available in October 2001.	Not Received
RT.3.10	UZ3	Provide analog radionuclide data from the tracer tests for Calico Hills at Busted Butte and from similar analog and radionuclide data (if available) from test blocks from Busted Butte. DOE will provide data from analog tracers used at Busted Butte and data from (AECL) test blocks from Busted Butte in an update to the AMR In Situ Field Testing of Processes in FY 2002.	Not Received
RT.4.01	SZ2 TSPAI UZ3	Provide Revision 1 to the Topical Report. DOE will provide the Disposal Criticality Analysis Methodology Topical Report, Revision 01, to NRC during January 2001.	Received
RT.4.02	TSPAI	Provide the updated FEPs database. DOE stated that it would provide the FEPs AMRs and the FEPs database to NRC during January 2001.	Received
RT.4.03	ENG3 SZ2 UZ3	Provide the applicable list of validation reports and their schedules for external criticality. DOE stated that the geochemical model validation reports for "Geochemistry Model Validation Report: Degradation and Release" and "Geochemistry Model Validation Report: Material Accumulation" are expected to be available during 2001. The remainder of the reports are expected to be available during FY2002 subject to the results of detailed planning and scheduling. DOE understands that these reports are required to be provided prior to LA. A list of model validation reports was provided during the technical exchange and is included as an attachment to the meeting summary.	Partly Received
SDS.1.01	TSPAI	Provide the updated FEPs: Disruptive Events AMR. DOE will provide the updated FEPs AMR to the NRC. Expected availability is January 2001.	Received

Agreement	Related ISIs or	NRC/DOE Agreement	Status
SDS.1.02	ENG2	Consistent with proposed 10 CFR Part 63, the NRC believes the use of the mean is appropriate, however, DOE may use any statistic as long as it is consistent with site data and technically defensible. DOE will either provide technical justification for use of median values or another statistical measure, such as the mean, or will evaluate and implement an alternative approach. The DOE-proposed approach and its basis will be provided to NRC prior to September 2001. The approach will be implemented prior to any potential LA.	Received
SDS.2.01	ENG2	Regarding ground motion, provide documentation, or point the NRC to the documentation on the expert elicitation process, regarding the feedback to the subject matter experts following the elicitation of their respective judgements. DOE will provide documentation demonstrating the adequacy of the elicitation feedback process by December 2000.	Need Additional Information
SDS.2.02	PRE TSPAI	Provide the updated FEPs: Disruptive Events AMR, the Seismic Design Input Report, and the update to the Seismic Topical Report. DOE will provide the updated FEPs AMR to NRC. Expected availability is January 2001. DOE will provide STR 3 to the NRC for their review. Expected availability is January 2002. The Seismic Design Inputs Report is expected to be available to the NRC by September 2001.	Partly Received
SDS.2.03	ENG2	Consistent with proposed 10 CFR Part 63, the NRC believes the use of the mean is appropriate, however, DOE may use any statistic as long as it is consistent with site data and technically defensible. DOE will either provide technical justification for use of median values or another statistical measure, such as the mean, or will evaluate and implement an alternative approach. The DOE-proposed approach and its basis will be provided to NRC prior to September 2001. The approach will be implemented prior to any potential LA.	Received
SDS.2.04	ENG2	The approach to evaluate seismic risk, including the assessment of seismic fragility and evaluation of event sequences is not clear to the NRC, provide additional information. DOE believes the approach contained in the FEPs AMR will be sufficient to support the Site Recommendation. The updated FEPs AMR is expected to be available in January 2001.	Received
SDS.3.01	UZ2 UZ3	The ECRB long-term test and the Alcove 8 Niche 3 test need to be "fractured-informed" (i.e., observation of seepage needs to be related to observed fracture patterns). Provide documentation which discusses this aspect. DOE responded that for the passive test, any observed seepage will be related to full periphery maps and other fracture data in testing documentation. The documentation will be available by any potential LA. For Niche 3, fracture characterization is complete and a 3-D representation will be included in testing documentation. The documentation will be available August 2001.	Partly Received
SDS.3.02	UZ2 UZ3	The NRC needs DOE to document the pre-test predictions for the Alcove 8 Niche 3 work. DOE responded that pre-test predictions for Alcove 8 Niche 3 work will be provided to NRC via letter report (Brocoum to Greeves) by mid-January 2001.	Received
SDS.3.03	ENG3	The NRC needs to review the Fracture Geometry Analysis for the Stratigraphic Units of the Repository Host Horizon AMR. The NRC will provide feedback and proposed agreements to DOE, if needed, by December 2000.	Need Additional Information
SDS.3.04	ENG2 ENG3 PRE UZ2	The NRC needs DOE to document the discussion of excavation-induced fractures. DOE responded that observations of excavation-induced fractures will be documented in a report or AMR revision by June 2001.	Received
TEF.1.01	ENG3 TSPAI	Provide the FEPs AMRs relating to TEF. The DOE will provide the following updated FEPs AMRs related to thermal effects on flow to the NRC: Disruptive Events FEPs (ANL-NBS-MD-000005) Rev 00 ICN 01; Features, Events, and Processes: System Level (ANL-WIS-MD-000019) Rev 00; Features, Events, and Processes in UZ Flow and Transport (ANL-NBS-MD-000001) Rev 01; Features, Events, and Processes in SZ Flow and Transport (ANL-NBS-MD-000002) Rev 01; Features, Events, and Processes in Thermal Hydrology and Coupled Processes (ANL-NBS-MD-000004) Rev 00 ICN 01; Miscellaneous Waste Form FEPs (ANL-WIS-MD-000009) Rev 00 ICN 01; and Engineered Barrier System Features, Events, and Processes (ANL-WIS-PA-000002) Rev 01. Expected availability: January 2001.	Complete

Agreement	Related ISIs or	NRC/DOE Agreement	Status
TEF.1.02	TSPAI	Provide the FEPs database. The DOE will provide the FEPs data base to the NRC during March 2001.	Complete
TEF.2.01	ENG3 UZ2	Consider measuring losses of mass and energy through the bulkhead of the drift-scale test (DST) and provide the technical basis for any decision or method decided upon (include the intended use of the results of the DST such as verifying assumptions in FEP exclusion arguments or providing support for TSPA models. The DOE should analyze uncertainty in the fate of thermally mobilized water in the DST and evaluate the effect this uncertainty has on conclusions drawn from the DST results. The DOE's position is that measuring mass and energy losses through the bulkhead of the DST is not necessary for the intended use of the DST results. The DST results are intended for validation of models of thermally-driven coupled processes in the rock, and measurements are not directly incorporated into TSPA models. Results of the last two years of data support the validation of DST coupled-process models and the current treatment of mass and energy loss through the bulkhead. The DOE will provide the NRC a white paper on the technical basis for the DOE's understanding of heat and mass losses through the bulkhead and their effects on the results by April 2001. This white paper will include the DOE's technical basis for its decision regarding measurements of heat and mass losses through the DST bulkhead. This white paper will address uncertainty in the fate of thermally mobilized water in the DST and also the effect this uncertainty has on conclusions drawn from the DST results. The NRC will provide comments on this white paper. The DOE will provide analyses of the effects of this uncertainty on the uses of the DST in response to NRC comments.	Partly Received
TEF.2.02	ENG3	Provide the location and access to the Multi-Scale Thermohydrologic Model input and output files. The output files are in the Technical Data Management System. The DTNs are LL000509112312.003, LL000509012312.002, and LL000509212312.004. The input files are located in the Project records system. The document identification number is MOL.20000706.0396. The DOE will provide the requested information to the NRC in January 2001.	Complete
TEF.2.03	ENG1	Provide the following references: Multi-Scale Thermohydrologic Model AMR, ICN 01; Abstraction of Near Field Environment Drift Thermodynamic and Percolation Flux AMR, ICN 01; Engineered Barrier System Degradation Flow and Transport PMR, Rev. 01; and Near Field Environment PMR, ICN 03. DOE will provide to the NRC the following documents: Multi-Scale Thermohydrologic Model AMR (ANL-EBS-MD-00049) Rev 00 ICN 01 (January 2001); Abstraction of Near-Field Environment Drift Thermodynamic and Percolation Flux AMR (ANL-EBS-HS-000003) Rev 00 ICN 01 (January 2001); Engineered Barrier System Degradation, Flow and Transport PMR (TDR-EBS-MD-000006) Rev 01 (September 2001); Near-Field Environment PMR (TDR-NBS-MD-000001) Rev 00 ICN 03 (January 2001)	Partly Received
TEF.2.04	ENG1	Provide the Multi-Scale Thermohydrologic Model AMR, Rev. 01. The DOE will provide the Multi-Scale Thermohydrologic Model AMR (ANL-EBS-MD-00049) Rev 01 to the NRC. Expected availability is FY 02.	Not Received
TEF.2.05	ENG3	Represent the cold-trap effect in the appropriate models or provide the technical basis for exclusion of it in the various scale models (mountain, drift, etc.) considering effects on TEF and other abstraction/models (chemistry). See page 11 of the Open Item (OI) 2 presentation. The DOE will represent the "cold-trap" effect in the Multi-Scale Thermohydrologic Model AMR (ANL-EBS-MD-00049) Rev 01, expected to be available in FY 02. This report will provide technical support for inclusion or exclusion of the cold-trap effect in the various scale models. The analysis will consider thermal effects on flow and the in-drift geochemical environment abstraction.	Not Received
TEF.2.06	ENG3 PRE UZ2	Provide the detailed test plan for Phase III of the ventilation test, and consider NRC comments, if any. The DOE will provide a detailed test plan for the Phase III ventilation test in March 2001. The NRC comments will be provided no later than two weeks after receipt of the test plan, and will be considered by the DOE prior to test initiation.	Complete
TEF.2.07	ENG3 PRE UZ2	Provide the Ventilation Model AMR, Rev. 01 and the Pre-Test Predictions for Ventilation Test Calculation, Rev. 00. The DOE will provide the Ventilation Model AMR (ANL-EBS-MD-000030) Rev 01 to the NRC in March 2001. Note that ventilation test data will not be incorporated in the AMR until FY02. The DOE will provide the Pre-test Predictions for Ventilation Tests (CAL-EBS-MD-000013) Rev 00 to the NRC in February 2001. Test results will be provided in an update to the Ventilation Model AMR (ANL-EBS-MD-000030) in FY 02.	Partly Received

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TEF.2.08	ENG3 UZ2	Provide the Mountain Scale Coupled Processes AMR, or an other appropriate AMR, documenting the results of the outlined items on page 20 of the OI 7 presentation (considering the NRC suggestion to compare model results to the O.M. Phillips analytical solution documented in Water Resources Research, 1996). The DOE will provide the updated Mountain-Scale Coupled Processes Model AMR (MDL-NBS-HS-000007) Rev 01 to the NRC in FY 02, documenting the results of the outlined items on page 20 of DOE's Open Item 7 presentation at this meeting. The DOE will consider the NRC suggestion of comparing the numerical model results to the O.M. Phillips analytical solution documented in WRR (1996).	Not Received
TEF.2.09	ENG1	Provide the Multi-Scale Thermohydrologic Model AMR, ICN 03. The DOE will provide the Multi-Scale Thermohydrologic Model AMR (ANL-EBS-MD-00049) Rev 00 ICN 03 to the NRC. Expected availability July 2001.	Not Received
TEF.2.10	ENG3 UZ2	Represent the full variability/uncertainty in the results of the TEF simulations in the abstraction of thermodynamic variables to other models, or provide technical basis that a reduced representation is appropriate (considering risk significance). The DOE will discuss this issue during the TSPAI technical exchange tentatively scheduled for April 2001.	Not Received
TEF.2.11	ENG3 UZ2	Provide the Calibrated Properties AMR, incorporating uncertainty from all significant sources. The DOE will provide an updated Calibrated Properties Model AMR (MDL-NBS-HS-000003) Rev 01 that incorporates uncertainty from significant sources to the NRC in FY 02.	Not Received
TEF.2.12	UZ2 UZ3	Provide the Unsaturated Zone Flow and Transport PMR, Rev. 00, ICN 02, documenting the resolution of issues on page 5 of the OI 8 presentation. The DOE will provide the Unsaturated Zone Flow and Transport PMR (TDR-NBS-HS-000002) Rev 00 ICN 02 to the NRC in February 2001. It should be noted, however, that not all of the items listed on page 5 of the DOE's Open Item 8 presentation at this meeting are included in that revision. The DOE will include all the items listed on page 5 of the DOE's Open Item 8 presentation in Revision 02 of the Unsaturated Zone Flow and Transport PMR, scheduled to be available in FY 02.	Partly Received
TEF.2.13	UZ2 UZ3	Provide the Conceptual and Numerical Models for Unsaturated Zone Flow and Transport AMR, Rev. 01 and the Analysis of Hydrologic Properties Data AMR, Rev. 01. The DOE will provide updates to the Conceptual and Numerical Models for UZ Flow and Transport (MDL-NBS-HS-000005) Rev 01 and the Analysis of Hydrologic Properties Data (ANL-NBS-HS-000002) Rev 01 AMRs to the NRC. Scheduled availability is FY 02.	Not Received
TSPAI.1.01	TSPAI	Provide enhanced descriptive treatment for presenting barrier capabilities in their final approach for demonstrating multiple barriers. Provide discussion of the capabilities of individual barriers, in light of existing parameter uncertainty (e.g., in barrier and system characteristics) and model uncertainty. DOE will provide enhanced descriptive treatment for presenting barrier capabilities in the final approach for demonstrating multiple barriers. DOE will also provide discussion of the capabilities of individual barriers, in light of existing parameter uncertainty (e.g., in barrier and system characteristics) and model uncertainty. The information will be documented in TSPA Methods and Assumptions document, expected to be available to NRC in FY 2002, for any potential license application.	Not Received
TSPAI.1.02	TSPAI	Provide a discussion of the following in documentation of barrier capabilities and the corresponding technical bases: (1) parameter uncertainty, (2) model uncertainty (i.e., the effect of viable alternative conceptual models), (3) spatial and temporal variability in the performance of the barriers, (4) independent and interdependent capabilities of the barriers (e.g., including a differentiation of the capabilities of barriers performing similar functions), and (5) barrier effectiveness with regard to individual radionuclides. Analyze and document barrier capabilities, in light of existing data and analyses of the performance of the repository system. DOE will provide a discussion of the following in documentation of barrier capabilities and the corresponding technical bases: (1) parameter uncertainty, (2) model uncertainty (i.e., the effect of viable alternative conceptual models), (3) spatial and temporal variability in the performance of the barriers, (4) independent and interdependent capabilities of the barriers (e.g., including a differentiation of the capabilities of barriers performing similar functions), and (5) barrier effectiveness with regard to individual radionuclides. DOE will also analyze and document barrier capabilities, in light of existing data and analyses of the performance of the repository system. The information will be documented in TSPA for any potential license application expected to be available in FY 2003.	Not Received

Agreement	Related ISIs or	NRC/DOE Agreement	Status
TSPAI.2.01	DOSE1 DOSE2 DOSE3 ENG1 ENG3 ENG4 SZ1 SZ2 TSPAI UZ1 UZ2 UZ3	Provide clarification of the screening arguments, as summarized in Attachment 2. See Comment # 5, 7, 8, 9, 10, 13, 18, 19 (Part 5), 21, 32, 41, 47, 50, 53, 58, 67, J-5, J-16, and J-18. DOE will clarify the screening arguments, as summarized in Attachment 2, for the highlighted FEPs. The clarifications will be provided in the referenced FEPs AMR and will be provided to the NRC in FY03.	Not Received
TSPAI.2.02	DIRECT1 DIRECT2 DOSE1 DOSE2 DOSE3 ENG1 ENG2 ENG3 ENG4 SZ1 SZ2 TSPAI UZ1 UZ2 UZ3	Provide the technical basis for the screening argument, as summarized in Attachment 2. See Comment # 3, 4, 11, 12, 19 (Parts 1, 2, and 6), 25, 26, 29, 34, 35, 36, 37, 38, 39, 42, 43, 44, 48, 49, 51, 54, 55, 56, 57, 59, 60, 61, 62, 63, 64, 65, 66, 68, 69, 70, 78, 79, J-1, J-2, J-3, J-4, J-7, J-8, J-9, J-10, J-11, J-12, J-13, J-14, J-15, J-17, J-20, J-21, J-22, J-23, J-24, J-25, J-26, and J-27. DOE will provide the technical basis for the screening argument, as summarized in Attachment 2, for the highlighted FEPs. The technical basis will be provided in the referenced FEPs AMR and will be provided to the NRC in FY03.	Not Received

Agreement	Related ISIs or	NRC/DOE Agreement	Status
TSPAI.2.03	DOSE1 DOSE2 DOSE3 SZ1 SZ2 TSPAI UZ3	Add the FEPs highlighted in Attachment 2 to the appropriate FEPs AMRs. See Comment 19 (Part 7 and 8), 20, and J-6. DOE will add the FEPs highlighted in Attachment 2 to the appropriate FEPs AMRs. The FEPs will be added to the appropriate FEPs AMRs and the AMRs will be provided to the NRC in FY03.	Not Received
TSPAI.2.04	DOSE3 ENG1 ENG2 TSPAI	Provide a clarification of the description of the primary FEP. See Comments 24, 31, and 33. DOE will clarify the description of the primary FEPs, as summarized in Attachment 2, for the highlighted FEPs. The clarifications will be provided in the referenced FEPs AMR and will be provided to the NRC in FY03.	Not Received
TSPAI.2.05	TSPAI	It is not clear to the NRC that the current list of FEPs (i.e., the list of FEPs documented in TDR-WIS-MD-000003, 00/01) is sufficiently comprehensive or exhibits the necessary attribute of being auditable (e.g., transparent and traceable). As discussed in the two TSPAI technical exchanges, there are unclear aspects of the approach that DOE plans to use to develop the necessary documentation of those features, events, and processes that they have considered. Accordingly, to provide additional confidence that the DOE will provide NRC with: (1) auditable documentation of what has been considered by the DOE, (2) the technical basis for excluding FEPs, and (3) an indication of the way in which included FEPs have been incorporated in the performance assessment; DOE will provide NRC with a detailed plan (the Enhanced FEP Plan) for comment. In the Enhanced FEP Plan, DOE will address the following items: (1) the approach used to develop a pre-screening set of FEPs (i.e., the documentation of those things that DOE considered and which the DOE would use to provide support for a potential license application), (2) the guidance on the level-of-detail that DOE will use for redefining FEPs during the enhanced FEP process, (3) the form that the pre-screening list of FEPs will take (e.g., list, database, other descriptions), (4) the approach DOE would use for the ongoing evaluation of FEPs (e.g., how to address potentially new FEPs), (5) the approach that DOE would use to evaluate and update the existing scope and description of FEPs, (6) the approach that DOE would use to improve the consistency in the level of detail among FEPs, (7) how the DOE would evaluate the results of its efforts to update the existing scope and definition of FEPs, (8) how the Enhanced FEP process would support assertions that the resulting set of FEPs will be sufficiently comprehensive (e.g., represents a wide range of both beneficial and potential adverse effects on performance) to reflect clearly what DOE has considered, (9) how DOE would indicate their disposition of included FEPs in the performance assessment, (10) the role and definition of the different hierarchical levels used to document the information (e.g., "components of FEPs" and "modeling issues"), (11) how the hierarchical levels used to document the information would be used within DOE's enhanced FEP process, (12) how the Enhanced FEP Plan would result in documentation that facilitates auditing (i.e., lead to a process that is transparent and traceable), (13) DOE's plans for using configuration management controls to identify FEP dependencies on ongoing work and design changes. DOE will provide the Enhanced Plan to NRC by March 2002.	Not Received
TSPAI.2.06	TSPAI	Provide justification for the approach to: (1) the level of detail used to define FEPs; (2) the degree of consistency among FEPs; and (3) comprehensiveness of the set of FEPs initially considered (i.e., before screening). DOE proposes to meet with NRC periodically to provide assessments of the DOE's progress, once it has initiated the Enhanced FEP process, and on changes to the approach documented in the Enhanced FEP Plan. During these progress meetings DOE agrees to provide a justification for their approach to: (1) the level of detail used to define FEPs; (2) the degree of consistency among FEPs; and (3) comprehensiveness of the pre-screening set of FEPs.	Not Received

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TSPAI.2.07	TSPAI	Provide results of the implementation of the Enhanced FEP Plan (e.g., the revised FEP descriptions, screening arguments, the mapping of FEPs to TSPA keywords, and a searchable index of FEP components), in updates to the FEP AMR documents and the FEP Database. DOE agrees to provide the results of their implementation of the Enhanced FEP Plan (e.g., the revised FEP descriptions, screening arguments, improved database navigation through, for example, the mapping of FEPs to TSPA keywords, a searchable index of FEP components, etc.), information requested in updates to the FEP documents and the FEP Database (or other suitable documents) in FY03.	Not Received
TSPAI.3.01	ENG1 TSPAI	Propagate significant sources of uncertainty into projections of waste package and drip shield performance included in future performance assessments. Specific sources of uncertainty that should be propagated (or strong technical basis provided as to why it is insignificant) include: (1) the uncertainty from measured crevice and weight-loss samples general corrosion rates and the statistical differences between the populations, (2) the uncertainty from alternative explanations for the decrease in corrosion rates with time (such as silica coatings that alter the reactive surface area), (3) the uncertainty from utilizing a limited number of samples to define the correction for silica precipitation, (4) the confidence in the upper limit of corrosion rates resulting from the limited sample size, and (5) the uncertainty from alternative statistical representations of the population of empirical general corrosion rates. The technical basis for sources of uncertainty will be established upon completion of existing agreement items CLST 1.4, 1.5, 1.6, and 1.7. DOE will then propagate significant sources of uncertainty into projections of waste package and drip shield performance included in future performance assessments. This technical basis will be documented in a future revision of the General and Localized Corrosion of Waste Package Outer Barrier AMR (ANL-EBS-MD-000003) expected to be available consistent with the scope and schedules for the specified CLST agreements. The results of the AMR analyses will be propagated into future TSPA analyses for any potential license application.	Not Received
TSPAI.3.02	ENG1 TSPAI	Provide the technical basis for resampling the general corrosion rates and the quantification of the impact of resampling of general corrosion rates in revised documentation (ENG1.1.1). DOE will provide the technical basis for resampling the general corrosion rates and the quantification of the impact of resampling of general corrosion rates in an update to the WAPDEG Analysis of Waste Package and Drip Shield Degradation AMR (ANL-EBS-PA-000001). This AMR is expected to be available to NRC in FY 2003.	Not Received
TSPAI.3.03	ENG1 TSPAI	Provide the technical basis for crack arrest and plugging of crack openings (including the impact of oxide wedging and stress redistribution) in assessing the impact of SCC of the drip shield and waste package in revised documentation (ENG1.1.2 and ENG1.4.1). DOE will provide the technical basis for crack arrest and plugging of crack openings (including the impact of oxide wedging and stress redistribution) in assessing the stress corrosion cracking of the drip shield and waste package in an update to the Stress Corrosion Cracking of the Drip Shield, Waste Package Outer Barrier, and the Stainless Steel Structural Material AMR (ANL-EBS-MD-000005) in accordance with the scope and schedule for existing agreement item CLST 1.12.	Not Received
TSPAI.3.04	ENG1 TSPAI	Provide the technical basis that the representation of the variation of general corrosion rates (if a significant portion is "lack of knowledge" uncertainty) does not result in risk dilution of projected dose responses (ENG1.3.3). DOE will provide the technical basis that the representation of the variation of general corrosion rates results in reasonably conservative projected dose rates. The technical basis will be documented in an update to the WAPDEG Analysis of Waste Package and Drip Shield Degradation AMR (ANL-EBS-PA-000001). This AMR is expected to be available to NRC in FY 2003. These results will be incorporated into future TSPA documentation for any potential license application.	Not Received
TSPAI.3.05	ENG1 TSPAI	Provide the technical basis for the representation of uncertainty/variability in the general corrosion rates in revised documentation. This technical basis should provide a detailed discussion and analyses to allow independent reviewers the ability to interpret the representations of 100% uncertainty, 100% variability, and any intermediate representations in the DOE model (ENG1.3.6). DOE will provide the technical basis for the representation of uncertainty/variability in the general corrosion rates. This technical basis will include the results of 100% uncertainty, 100% variability, and selected intermediate representations used in the DOE model. These results will be documented in an update to the WAPDEG Analysis of Waste Package and Drip Shield Degradation AMR (ANL-EBS-PA-000001) or other document. This AMR is expected to be available to NRC in FY 2003.	Not Received

Agreement	Related ISIs or	NRC/DOE Agreement	Status
TSPAI.3.06	ENG2 TSPAI	Provide the technical basis for the methodology used to implement the effects of seismic effects on cladding in revised documentation. DOE will demonstrate that the methodology used to represent the seismic effects of cladding does not result in an underestimation of risk in the regulatory timeframe (ENG2.1.1). DOE will provide the technical basis for the methodology used to implement the effects of seismic effects on cladding in revised documentation. DOE will demonstrate that the methodology used to represent the seismic effects of cladding does not result in an underestimation of risk in the regulatory timeframe in TSPA-LA. The documentation is expected to be available to NRC in FY 2003.	Not Received
TSPAI.3.07	ENG3 TSPAI UZ2	Provide technical basis for representation of or the neglect of dripping from rockbolts in the ECRB in performance assessment, including the impacts on hydrology, chemistry, and other impacted models. Appropriate consideration will be given to the uncertainties in the source of the moisture, and how those uncertainties impact other models (ENG3.1.1). DOE will provide technical basis for determination of future sources of water in the ECRB, will evaluate the possibility of preferential dripping from engineered materials, and will give appropriate consideration to the uncertainties of the water sources, as well as their potential impact on other models. The work done to date as well as the additional work will be documented in the AMR on In-Situ Field Testing Processes (ANL-NBS-HS-000005) or other documents. This AMR will be available to NRC in FY 2003. DOE will evaluate the role of condensation as a source of water and any impacts of this on hydrologic and chemical conitions in the drift, and DOE will document this work. The effects of condensation will be included in TSPA if found to be potentially important to performance.	Not Received
TSPAI.3.08	ENG3 TSPAI	Provide the technical basis (quantification) for the abstraction of in-package chemistry and it's implementation into the TSPA which will demonstrate that the utilization of the weighted-moving-average methodology will not result in an underestimation of risk (ENG3.1.3). DOE will provide the technical basis (quantification) for the abstraction of in-package chemistry and its implementation into the TSPA, which will demonstrate that the implementation methodology will not result in an underestimation of risk. The technical basis will be documented in TSPA-LA and is expected to be available in FY 2003.	Not Received
TSPAI.3.09	ENG3 TSPAI	Provide the documentation that presents the representation of uncertainty and variability in the near-field environment abstractions in the TSPA (ENG3.1.4). DOE will present the representation of uncertainty and variability in water and gas chemistry entering the drift in the near-field environment abstractions for the TSPA. This will be documented in the Abstraction of Drift-Scale Coupled Processes (ANL-NBS-HS-000029) or other document expected to be available in FY 2003.	Not Received
TSPAI.3.10	ENG3 TSPAI	Provide the documentation of the integrated analyses and comprehensive uncertainty analyses related to the Physical and Chemical Environmental Abstraction Model (ENG3.1.5). DOE will provide the documentation of the integrated analyses and comprehensive uncertainty analyses related to the EBS physical and chemical environment in documentation associated with TSPA for any potential license application. The documentation is expected to be available to NRC in FY 2003.	Not Received
TSPAI.3.11	ENG3 TSPAI UZ2	DOE should account for appropriate integration between the 3D UZ flow model, the MSTH model, and the drift seepage model. In particular, DOE should ensure that relevant spatial distributions are propagated appropriately between the UZ flow model, the thermohydrology model, and the seepage model (ENG3.1.6). DOE will compare the infiltration flux used for the infiltration bins with the 3D Unsaturated Zone flow model and the multi-scale thermohydrologic (MSTH) model results. The technical basis for any approximations in the spatial distribution of flow rates involved in this abstraction will be provided in Abstraction of NFE Drift Thermodynamic Environment and Percolation Flow AMR (ANL-EBS-HS-000003) or other suitable document. In particular, DOE will ensure that the MSTH model output to the seepage abstraction (or any other model that may provide percolation flux to the seepage abstraction) does not lead to underestimation of seepage. This AMR is expected to be available to NRC in FY 2003.	Not Received
TSPAI.3.12	ENG3 TSPAI	DOE should complete testing of corrosion in the chemical environments predicted by the model or provide technical basis why it is not needed (ENG3.1.8). DOE will conduct testing of corrosion in the credible range of chemical environments predicted by the model in accordance with the scope and schedule for existing agreements CLST 1.4 and 1.6 or provide a technical basis why it is not needed.	Not Received
TSPAI.3.13	ENG3 TSPAI	Provide a comparison of the environments for corrosion predicted in the models, to the testing environments used to define empirical corrosion rates in revised documentation (ENG3.2.1). DOE will provide a comparison of the environments for corrosion predicted in the models, to the testing environments utilized to define empirical corrosion rates in revised documentation consistent with the scope and schedule for existing agreement item CLST 1.1.	Not Received

Agreement	Related ISIs or	NRC/DOE Agreement	Status
TSPAI.3.14	ENG4 TSPAI	DOE should account for the full range of environmental conditions for the in-package chemistry model (ENG4.1.1). DOE will update the in-package chemistry model to account for scenarios and their associated uncertainties required by TSPA. This will be documented in the In-Package Chemistry AMR (ANL-EBS-MD-000056) expected to be available to NRC in FY 2003.	Not Received
TSPAI.3.15	ENG4 TSPAI	Define a reference EQ3/6 database for the Yucca Mountain Project. DOE will provide documentation of all deviations from the reference database and justification for those deviations used by different geochemical modeling activities (ENG4.1.2). DOE will define a reference EQ3/6 database for the Yucca Mountain Project. DOE will provide documentation of all the deviations from the reference database and justification for those deviations used by different geochemical modeling activities. The database will be available in FY 2003.	Not Received
TSPAI.3.16	ENG4 TSPAI	DOE should include the possibility of localized flow pathways in the engineered barrier system in TSPA calculations, including the influence of introduced materials on water and gas chemistry on these preferential flow pathways (ENG4.1.6). DOE will evaluate the effect of localized flow pathways on water and gas chemistry in the engineered barrier system as input to TSPA calculations, including the influence of introduced materials on these preferential flow pathways consistent with existing agreements ENFE 2.4, 2.5, and 2.6. This will be documented in an update to the Physical and Chemical Environment Model AMR (ANL-EBS-MD-000033) or other suitable document. This AMR is expected to be available to NRC in FY 2003.	Not Received -
TSPAI.3.17	ENG4 TSPAI	Provide an uncertainty analysis of the diffusion coefficient governing transport of dissolved and colloidal radionuclides through the invert. The analysis should include uncertainty in the modeled invert saturation (ENG4.4.1). DOE will provide an uncertainty analysis of the diffusion coefficient governing transport of dissolved and colloidal radionuclides through the invert. The analysis will include uncertainty in the modeled invert saturation. The uncertainty analysis will be documented in the EBS Radionuclide Transport Abstraction AMR (ANL-WIS-PA-000001) expected to be available to NRC in FY 2003.	Not Received
TSPAI.3.18	TSPAI UZ1	Provide a technical basis that the water-balance plug-flow model adequately represents the non-linear flow processes represented by Richard's equation, particularly over the repository where there is thin soil (UZ1.2.1). DOE will provide a technical basis that the water-balance plug-flow model adequately represents the non-linear flow processes represented by Richard's equation, particularly over the repository where there is thin soil. The technical basis will be documented in an update to the Simulation of Net Infiltration for Modern and Potential Future Climates AMR (ANL-NBS-HS-000032). The AMR is expected to be available to NRC in FY 2003.	Not Received
TSPAI.3.19	TSPAI UZ1	DOE will provide justification for the use of its evapotranspiration model, and defend the use of the analog site temperature data (UZ1.3.1). DOE will provide justification for the use of the evapotranspiration model, and justify the use of the analog site temperature data. The justification will be documented in an update to the Simulation of Net Infiltration for Modern and Potential Future Climates AMR (ANL-NBS-HS-000032) and the Future Climate Analysis AMR (ANL-NBS-GS-000008). The AMRs are expected to be available to NRC in FY 2003.	Not Received
TSPAI.3.20	TSPAI UZ1	Provide access to data supporting the synthetic meteorologic records (4JA.s01 and Area12.s01) (UZ1.3.2). DOE will provide data supporting the synthetic meteorologic records (specifically, data files 4JA.s01 and Area12.s01). These data files will be provided to NRC September 2001.	Received
TSPAI.3.21	TSPAI UZ1	Demonstrate that effects of near surface lateral flow on the spatial variability of net infiltration are appropriately considered (UZ1.5.1). DOE will demonstrate that effects of near surface lateral flow on the spatial variability of net infiltration are appropriately considered in an update to the Simulation of Net Infiltration for Modern and Potential Future Climates AMR (ANL-NBS-HS-000032) and UZ Flow Models and Submodels AMR (MDL-NBS-HS-000006). These AMRs are expected to be available to NRC in FY 2003.	Not Received
TSPAI.3.22	TSPAI UZ2	Provide an assessment or discussion of the uncertainty involved with using a hydrologic property set obtained by calibrating a model on current climate conditions and using that model to forecast flow for future climate conditions (UZ2.3.1). DOE will provide an assessment or discussion of the uncertainty involved with using a hydrologic property set obtained by calibrating a model on current climate conditions and using that model to forecast flow for future climate conditions. This assessment will be documented in the UZ Flow Models and Submodels AMR (MDL-NBS-HS-000006) expected to be available to NRC in FY 2003.	Not Received

Agreement	Related ISIs or	NRC/DOE Agreement	Status
TSPAI.3.23	TSPAI UZ2	DOE should evaluate spatial heterogeneity of hydrologic properties within hydrostratigraphic units and the effect this heterogeneity has on model results of unsaturated flow, seepage into the drifts and transport. DOE should also provide a technical basis for the assessment that bomb-pulse Cl-36 data found below the Paint Brush tuff can be linked to a negligible amount of fast flowing water (UZ2.3.2). DOE will evaluate spatial heterogeneity of hydrologic properties within hydrostratigraphic units and the effect this heterogeneity has on model results of unsaturated flow, seepage into the drifts and transport. This evaluation will be documented in the UZ Flow Models and Submodels AMR (MDL-NBS-HS-000006), Radionuclide Transport Models under Ambient Conditions (MDL-NBS-HS-000008) and Seepage Models for PA Including Drift Collapse AMR (MDL-NBS-HS-000002) expected to be available to NRC in FY 2003. DOE will also provide a technical basis for the assessment that bomb-pulse Cl36 data found below the PTn can be linked to a negligible amount of fast flowing water. The technical basis will be documented in the UZ Flow Models and Submodels AMR (MDL-NBS-HS-000006) expected to be available to NRC in FY 2003.	Not Received
TSPAI.3.24	TSPAI UZ2	Provide the analysis of geochemical and hydrological data (water content, water potential, and temperature) used for support of the flow field below the repository, particularly in the Calico Hills, Prow Pass, and Bullfrog hydrostratigraphic layers. Demonstrate that potential bypassing of matrix flow pathways below the area of the proposed repository, as opposed to the entire site-scale model area, is adequately incorporated for performance assessment, or provide supporting analyses that the uncertainties are adequately included in the TSPA (UZ2.3.3). DOE will provide an analysis of available geochemical and hydrological data (water content, water potential, and temperature) used for support of the flow field below the repository, particularly in the Calico Hills, Prow Pass, and Bullfrog hydrostratigraphic layers. The analyses will demonstrate that potential bypassing of matrix flow pathways below the area of the proposed repository, as opposed to the entire site-scale model area, is adequately incorporated for performance assessment, or provide supporting analyses that the uncertainties are adequately included in the TSPA. These analyses will be documented in the UZ Flow Models and Submodels AMR (MDL-NBS-HS-000006), In-Situ Field Testing of Processes AMR (ANL-NBS-HS-000005), and Calibrated Properties Model AMR (MDL-NBS-HS-000003) expected to be available to NRC in FY 2003.	Not Received
TSPAI.3.25	TSPAI UZ2	DOE should use the Passive Cross Drift Hydrologic test, the Alcove 8 - Niche 3 tests, the Niche 5 test, and other test data to either provide additional confidence in or a basis for revising the TSPA seepage abstraction and associated parameter values (e.g., flow focusing factor, van Genuchten alpha for fracture continuum, etc.), or a provide technical basis for not using it (UZ2.3.4). DOE will utilize field test data (e.g., the Passive Cross Drift Hydrologic test, the Alcove 8 - Niche 3 tests, the Niche 5 test, and other test data) to either provide additional confidence in or a basis for revising the TSPA seepage abstraction and associated parameter values (e.g., flow focusing factor, van Genuchten alpha for fracture continuum, etc.), or provide technical basis for not using it. This will be documented in Seepage Calibration Model and Seepage Testing Data AMR (MDL-NBS-HS-000004) expected to be available to NRC in FY 2003.	Not Received
TSPAI.3.26	TSPAI UZ2	Calibrate the UZ flow model using the most recent data on saturations and water potentials, and clearly document the sources of calibration data and data collection methods (UZ2.3.5). DOE will calibrate the UZ flow model using the most recent data on saturations and water potentials, and document the sources of calibration data and data collection methods. The results will be documented in the Calibrated Properties Model AMR (MDL-NBS-HS-000003) expected to be available to NRC in FY 2003.	Not Received
TSPAI.3.27	TSPAI UZ2	Provide an overview of water flow rates used in the UZ model above and below the repository, in the MSTHM, in the seepage abstraction, and in the in-drift flow path models, to ensure appropriate integration between the various models (UZ2.TT.3). DOE will provide an overview of water flow rates used in the UZ model above and below the repository, in the Multi-Scale Thermohydrologic Model (MSTHM), in the seepage abstraction, and in the in drift flow path models, to ensure appropriate integration between the various models. This will be documented in the TSPA for any potential license application expected to be available to NRC in FY 2003.	Not Received
TSPAI.3.28	TSPAI UZ3	DOE needs to provide independent lines of evidence to provide additional confidence in the use of the active-fracture continuum concept in the transport model (UZ3.5.1). DOE will provide independent lines of evidence to provide additional confidence in the use of the active fracture continuum concept in the transport model. This will be documented in Radionuclide Transport Models under Ambient Conditions AMR (MDL-NBS-HS-000008) and UZ Flow Models and Submodels AMR (MDL-NBS-HS-000006) expected to be available to NRC in FY 2003.	Not Received

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TSPAI.3.29	TSPAI UZ3	Provide verification that the integration of the active fracture model with matrix diffusion in the transport model is properly implemented in the TSPA abstraction (UZ3.TT.3). DOE will provide verification that the integration of the active fracture model with matrix diffusion in the transport model is properly implemented in the TSPA abstraction. This verification will be documented in the Particle Tracking Model and Abstraction of Transport Processes (ANL-NBS-HS-000026) expected to be available to NRC in FY 2003.	Not Received
TSPAI.3.30	SZ2 TSPAI	Provide the technical basis for the contrasting concentrations of colloids available for reversible attachment in the engineered barrier system and the saturated zone. Sensitivity analyses planned in response to RT Agreement 3.07 should address the effect of colloid concentration on Kc. Update, as necessary, the Kc parameter as new data become available from the Yucca Mountain region (SZ2.3.1). DOE will provide the technical basis for the contrasting concentrations of colloids available for reversible attachment in the engineered barrier system and the saturated zone. The sensitivity analyses planned in response to RT Agreement 3.07 will address the effect of colloid concentration on the Kc parameter. The technical basis will be documented in the Waste Form Colloid Associated Concentration Limits: Abstractions and Summary (ANL-WIS-MD-000012) in FY 2003. The Kc parameter will be updated as new data become available from the Yucca Mountain region in the Uncertainty Distribution for Stochastic Parameters AMR (ANL-NBS-MD-000011) in FY2003.	Not Received
TSPAI.3.31	SZ2 TSPAI	Evaluate the effects of temporal changes in saturated zone chemistry on radionuclide concentrations (SZ2.3.2). DOE will reexamine the FEPs, currently included in the performance assessment, that may lead to temporal changes in saturated zone hydrochemistry. If the DOE determines that these FEPs can be excluded, the results will be documented in the FEP Saturated Zone Flow and Transport AMR (ANL-NBS-MD-000002) in FY 2003. If the DOE determines that these FEPs cannot be excluded from the performance assessment, the DOE will evaluate the effects of temporal changes in the saturated zone chemistry on radionuclide concentrations and will document this evaluation in above mentioned AMR.	Not Received
TSPAI.3.32	SZ2 TSPAI	Provide the technical basis that the representation of uncertainty in the saturated zone as essentially all lack-of-knowledge uncertainty (as opposed to real sample variability) does not result in an underestimation of risk when propagated to the performance assessment (SZ2.4.1). DOE will provide the technical basis that the representation of uncertainty (i.e., lack-of-knowledge uncertainty) in the saturated zone does not result in an underestimation of risk when propagated to the performance assessment. A deterministic case from Saturated Zone Flow Patterns and Analyses AMR (ANL-NBS-HS-000038) will be compared to TSPA analyses. The comparison will be documented in the TSPA for any potential license application expected to be available to NRC in FY 2003.	Not Received
TSPAI.3.33	DOSE2 TSPAI	Provide justification that the Kd values used for radionuclides in the soil in Amargosa valley based on the results of a literature review are realistic or conservative for actual conditions at the receptor location (DOSE2.2.1). DOE will provide justification that the Kd values used for radionuclides in the soil in Amargosa Valley are realistic or conservative for actual conditions at the receptor location. The justification will be provided in Evaluate Soil/Radionuclide Removal by Erosion and Leaching AMR (ANL-NBS-MD-000009) or other document expected to be available to NRC in FY 2003.	Not Received
TSPAI.3.34	DOSE3 TSPAI	For the Radionuclides that dominate the TSPA dose, provide the technical basis for selection of Radionuclide or element specific biosphere parameters that are important in the BDCF calculations (e.g. soil to plant transfer factors) (DOSE3.2.1). For the radionuclides that dominate the TSPA dose, DOE will provide the technical basis for selection of radionuclide or element specific biosphere parameters (except for Kds which are addressed in TSPAI 3.33) that are important in the BDCF calculations (e.g. soil to plant transfer factors). The technical basis will be documented in the Transfer Coefficient Analysis AMR (ANL-MGR-MD-000008) or other document and is expected to be available to NRC in FY 2003.	Not Received
TSPAI.3.35	DOSE3 TSPAI	Provide additional justification to support that the assumed crop interception fraction is appropriate for all radionuclides considered and does not result in underestimations of dose. Discussions should address the impacts of electrostatic charge and particle size on the interception fraction for all radionuclides considered in the TSPA (DOSE3.2.5). DOE will provide additional justification to support that the assumed crop interception fraction is appropriate for all radionuclides that dominate the TSPA dose and does not result in underestimations of dose. The justification will include the impacts of electrostatic charge and particle size on the interception fraction. This justification will be documented in Identification of Ingestion Exposure Parameters (ANL-MGR-MD-000006) or other document expected to be available to NRC in FY 2003.	Not Received

Agreement	Related ISIs or	NRC/DOE Agreement	Status
TSPAI.3.36	DOSE3 TSPAI	Document the methodology that will be used to incorporate the uncertainty in soil leaching factors into the TSPA analysis, if that uncertainty is found to be important to the results of the performance assessment (DOSE3.3.1). DOE will document the methodology used to incorporate the uncertainty in soil leaching factors into the TSPA analysis. This will be documented in Nominal Performance Biosphere Dose Conversion Factor Analysis AMR (ANL-MGR-MD-000009), Disruptive Event Biosphere Dose Conversion Factor Analysis (ANL-MGR-MD-000003) or other document expected to be available to NRC in FY 2003.	Not Received
TSPAI.3.37	DOSE3 TSPAI	Provide a quantitative analysis that the sampling method including the correlations to NP used by the TSPA code to abstract the GENII-S process model code adequately represent the uncertainty and variability and correlations for the biosphere process model (DOSE3.4.1). DOE will provide a quantitative analysis that the sampling method including the correlations between BDCFs utilized by the TSPA code to abstract the GENII-S process model data adequately represent the uncertainty and variability and correlations for the biosphere process model. This will be documented in Nominal Performance Biosphere Dose Conversion Factor Analysis AMR (ANL-MGR-MD-000009), Disruptive Event Biosphere Dose Conversion Factor Analysis (ANL-MGR-MD-000003) or other document expected to be available to NRC in FY 2003. Results of these analyses will be documented in the TSPA for any potential license application expected to be available to NRC in FY 2003.	Not Received
TSPAI.3.38	TSPAI	DOE will develop guidance in the model abstraction process that can be adhered to by all model developers so that (1) the abstraction process, (2) the selection of conservatism in components, and (3) representation of uncertainty are systematic across the TSPA model. DOE will evaluate and define approaches to deal with: (1) evaluating non-linear models as to what their most conservative settings may be if conservatism is being used to address uncertainty, and (2) trying to utilize human intuition in a complex system. In addition, DOE will consider adding these items to the internal/external reviewer's checklists to ensure proper implementation of the improved methodology (TSPA0002). DOE will develop written guidance in the model abstraction process for model developers so that (1) the abstraction process, (2) the selection of conservatism in components, and (3) representation of uncertainty, are systematic across the TSPA model. These guidelines will address: (1) evaluation of non-linear models when conservatism is being utilized to address uncertainty, and (2) utilization of decisions based on technical judgement in a complex system. These guidelines will be developed, implemented, and be made available to the NRC in FY 2002.	Not Received
TSPAI.3.39	TSPAI	In future performance assessments, DOE should document the simplifications used for abstractions per TSPAI.3.38 activities. Justification will be provided to show that the simplifications appropriately represent the necessary processes and appropriately propagate process model uncertainties. Comparisons of output from process models to performance assessment abstractions will be provided, with the level of detail in the comparisons commensurate with any reduction in propagated uncertainty and the risk significance of the model (TSPA0003). DOE will document the simplifications utilized for abstractions per TSPAI.3.38 activities for all future performance assessments. Justification will be provided to show that the simplifications appropriately represent the necessary processes and appropriately propagate process model uncertainties. Comparisons of output from process models to performance assessment abstractions will be provided, with the level of detail in the comparisons commensurate with any reduction in propagated uncertainty and the risk significance of the model. The documentation of the information will be provided in abstraction AMRs in FY 2003.	Not Received
TSPAI.3.40	TSPAI	DOE will implement effective controls to ensure that the abstractions defined in the AMR's are consistently propagated into the TSPA, or ensure that the TSPA documentation describes any differences. Specific examples of needed revisions (if still applicable) include: (1) the implementation of flux splitting in the TSPA model, (2) the propagation of thermohydrology uncertainty/variability into the WAPDEG corrosion model calculations, and (3) the implementation of the in-package chemistry abstraction. DOE will implement program improvements to ensure that the abstractions defined in the AMRs are consistently propagated into the TSPA, or ensure that the TSPA documentation describes any differences. Program improvements may include, for example, upgrades to work plans, procedural upgrades, preparation of desktop guides, worker training, increased review and oversight. The program improvements will be implemented and be made available to the NRC during FY 2002.	Not Received
TSPAI.3.41	TSPAI	To provide support for the mathematical representation of data uncertainty in the TSPA, the DOE will provide technical basis for the data distributions used in the TSPA. An example of how this may be accomplished is the representation on a figure or chart of the data plotted as an empirical distribution and the probability distribution assigned to fit these data. DOE will provide the technical basis for the data distributions utilized in the TSPA to provide support for the mathematical representation of data uncertainty in the TSPA. The documentation of the technical basis will be incorporated in documentation associated with TSPA for any potential license application. The documentation is expected to be available to NRC in FY 2003.	Not Received

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TSPAI.3.42	ENG4 TSPAI	DOE should provide a sensitivity analysis on the potentially abrupt changes in colloid concentrations due to shifts in modeled pH and ionic strength across uncertain stability boundaries. This analysis may be combined with plans to address ENFE Agreement 4.06 and RT Agreement 3.07. DOE will complete sensitivity analyses to investigate the effects of varying colloid concentration due to shifts in model predicted pH and ionic strength across uncertain stability boundaries. These analyses will be documented in TSPA for any potential license application expected to be available to NRC in FY 2003.	Not Received
TSPAI.4.01	TSPAI	DOE will document the methodology that will be used to incorporate alternative conceptual models into the performance assessment. The methodology will ensure that the representation of alternative conceptual models in the TSPA does not result in an underestimation of risk. DOE will document the guidance given to process-level experts for the treatment of alternative models. The implementation of the methodology will be sufficient to allow a clear understanding of the potential effect of alternative conceptual models and their associated uncertainties on the performance assessment. The methodology will be documented in the TSPA-LA methods and assumptions document in FY02. The results will be documented in the appropriate AMRs or the TSPA for any potential license application in FY 2003.	Not Received
TSPAI.4.02	TSPAI	DOE will provide the documentation that supports the representation of distribution coefficients (Kd's) in the performance assessment as uncorrelated is consistent with the physical processes and does not result in an underestimation of risk. This will be documented in the TSPA for any potential license application in FY03.	Not Received
TSPAI.4.03	TSPAI	DOE will document the method that will be used to demonstrate that the overall results of the TSPA are stable. DOE will provide documentation that submodels (including submodels used to develop input parameters and transfer functions) are also numerically stable. DOE will address in the method the stability of the results with respect to the number of realizations. DOE will describe in the method the statistical measures that will be used to support the argument of stability. The method will be documented in TSPA LA Methods and Assumptions Document in FY02. The results of the analyses will be provided in the TSPA (or other appropriate documentation) for any potential license application in FY 2003.	Not Received
TSPAI.4.04	TSPAI	DOE will conduct appropriate analyses and provide documentation that demonstrates the results of the performance assessment are stable with respect to discretization (e.g. spatial and temporal) of the TSPA model. This will be documented in the TSPA for any potential license application in FY 2003.	Not Received
TSPAI.4.05	TSPAI	DOE will document the process used to develop confidence in the TSPA models (e.g., steps similar to those described in NUREG-1636). The detailed process is currently documented in the model development procedures that are being evaluated for process improvement in response to the model validation corrective action report CAR-BSC-01-C-001. The upgraded model validation procedures will be available for NRC review in FY 2002.	Not Received
TSPAI.4.06	TSPAI	DOE will document the implementation of the process for model confidence building and demonstrate compliance with model confidence criteria in accordance with the applicable procedures. This will be documented in the respective AMR revisions and made available to NRC in FY 2003.	Not Received
TSPAI.4.07	TSPAI	DOE's software qualification requirements are currently documented in procedure AP SI.1Q which is under review for process improvement as part of software CAR-BSC-01-C-002. During its review of AP SI.1Q, DOE will consider: 1) the procedure it would follow to conduct a systematic and uniform verification — all areas of a code analyzed at a consistent level, 2) the process it would follow to ensure correct implementation of algorithms, and 3) the process it would follow for the full disclosure of calculations and results. DOE will document compliance with the improved process in the verification documentation required by AP SI.1Q. Software qualification record packages for the affected programs will be available for NRC review in FY 2003.	Not Received
USFIC.3.01	UZ1	Provide the documentation sources and schedule for the Monte Carlo method for analyzing infiltration. DOE will provide the schedule and identify documents expected to contain the results of the Monte Carlo analyses in February 2002.	Not Received
USFIC.3.02	UZ1	Provide justification for the parameters in Table 4-1 of the Analysis of Infiltration Uncertainty AMR (for example, bedrock permeability in the infiltration model needs to be reconciled with the Alcove 1 results/observations. Also, provide documentation (source, locations, tests, test results) for the Alcove 1 and Pagany Wash tests. DOE will provide justification and documentation in a Monte Carlo analyses document. The information will be available in February 2002.	Not Received

Agreement	Related ISIs or	NRC/DOE Agreement	Status
USFIC.4.01	UZ2 UZ3	The ongoing and planned testing are a reasonable approach for a licensing application with the following comments: (i) consider a mass balance of water for alcove 8/Niche 3 cross over test; (ii) monitor evaporation during all testing; (iii) provide the documentation of the test plan for the Passive Cross Drift Hydrologic test; (iv) provide the NRC with any Cross Drift seepage predictions that may have been made for the Passive Cross Drift Hydrologic test; (v) provide documentation of the results obtained and the analysis for the Passive Cross Drift Hydrologic test. This documentation should include the analysis of water samples collected during entries into the Cross Drift (determination whether the water comes from seepage or condensation); (vi) provide documentation of the results obtained and the analysis for the Alcove 7 test. This documentation should include the analysis of water samples collected during entries into Alcove 7 (determination whether the water comes from seepage or condensation); (vii) provide the documentation of the test plan for the Niche 5 test; (viii) provide documentation of the results obtained and the analysis for the Niche 5 test; (ix) provide documentation of the results obtained and the analysis for the Systematic Hydrologic Characterization test; (x) provide documentation of the results obtained and the analysis for the Niche 4 test; and (xi) provide documentation of the results obtained from the calcite filling test. Include interpretation of the observed calcite deposits found mostly at the bottom of the lithophysal cavities. DOE stated that: (1) a mass balance of water for the Alcove 8/Niche 3 test has been considered, but is not feasible due to the size of the collection system that would be required. A collection system to obtain a mass balance is being developed for the Niche 5 test (i); (2) evaporation will be monitored for all tests where evaporation is a relevant process (ii); (3) test plans for Niche 5 and the Cross Drift Hydrologic tests are expected to be available to NRC FY 2002 (iii, vii); (4) the Cross Drift seepage predictions will be documented in the Seepage Calibration Model and Seepage Testing Data AMR (MDL-NBS-HS-000004) expected to be available to NRC by FY 2003 (iv); (5) DOE will document the results for the tests identified above (except calcite filling observations) in the In-Situ Field Testing of Processes AMR (ANL-NBS-HS-000005) expected to be available to NRC in FY 2003 (v), (vi), (viii),(ix),(x); (6) results of the calcite filling observations will be documented in Analysis of Geochemical Data for the Unsaturated Zone (ANL-NBS-HS-000017) and the UZ Flow Models and Submodels (MDL-NBS-HS-000006) expected to be available to NRC FY 2003 (xi).	Not Received
USFIC.4.02	UZ2	Include the effect of the low-flow regime processes (e.g., film flow) in DOE's seepage fraction and seepage flow, or justify that it is not needed. DOE will include the effect of the low-flow regime processes (e.g., film flow) in the seepage fraction and seepage flow, or justify that it is not needed. These studies will be documented in Seepage Models for PA Including Drift Collapse AMR (MDL-NBS-HS-000002) expected to be available to NRC in FY 2003.	Not Received
USFIC.4.03	UZ2	When conducting seepage studies, consider smaller scale tunnel irregularities in drift collapse or justify that it is not needed. When conducting seepage studies, DOE will consider smaller scale tunnel irregularities in drift collapse or justify that it is not needed. These studies will be documented in Seepage Models for PA Including Drift Collapse AMR (MDL-NBS-HS-000002) expected to be available to NRC in FY 2003.	Not Received
USFIC.4.04	UZ2	Provide final documentation for the effectiveness of the PTn to dampen episodic flow, including reconciling the differences in chloride-36 studies. DOE will provide final documentation for the effectiveness of the PTn to dampen episodic flow, including reconciling the differences in chlorine-36 studies These studies will be documented in UZ Flow Models and Submodels AMR (MDL-NBS-HS-000006) expected to be available to NRC in FY 2003.	Not Received
USFIC.4.05	UZ2	Provide the analysis of geochemical data used for support of the flow field below the repository.	Complete
USFIC.4.06	UZ2	Provide documentation of the results obtained from the Comparison of Continuum and Discrete Fracture Network Models modeling study. Alternatively, provide justification of the continuum approach at the scale of the seepage model grid (formerly June 20 letter, item xiii). DOE will provide documentation of the results obtained from the Comparison of Continuum and Discrete Fracture Network Models modeling study or provide justification of the continuum approach at the scale of the seepage model grid. This will be documented in Seepage Calibration Model and Seepage Testing Data AMR (MDL-NBS-HS-000004) or other suitable document expected to be available to NRC in FY 2003.	Not Received

Agreement	Related ISIs or	NRC/DOE Agreement	Status
USFIC.4.07	UZ2	Provide documentation of the results obtained from the Natural Analogs modeling study. The study was to apply conceptual models and numerical approaches developed from Yucca Mountain to natural analog sites with observations of seepage into drifts, drift stability, radionuclide transport, geothermal effects, and preservation of artifacts. DOE will provide documentation of the results obtained from the Natural Analogs modeling study. The study was to apply conceptual models and numerical approaches developed from Yucca Mountain to natural analog sites with observations of seepage into drifts, drift stability, radionuclide transport, geothermal effects, and preservation of artifacts. This will be documented in the Natural Analogs for the Unsaturated Zone AMR (ANL-NBS-HS-000007) expected to be available to NRC FY 2002.	Not Received
USFIC.5.01	SZ1	The NRC believes that the incorporation of horizontal anisotropy in the site scale model should be reevaluated to ensure that a reasonable range for uncertainty is captured. The data from the C-wells testing should provide a technical basis for an improved range. As part of the C-wells report, DOE should include an analysis of horizontal anisotropy for wells that responded to the long-term tests. Results should be included for the tuffs in the calibrated site scale model. DOE will provide the results of the requested analyses in C-wells report(s) in October 2001, and will carry the results forward to the site-scale model, as appropriate.	Not Received
USFIC.5.02	SZ1	Provide the update to the SZ PMR, considering the updated regional flow model. A revision to the Saturated Zone Flow and Transport PMR is expected to be available and will reflect the updated United States Geological Survey (USGS) Regional Groundwater Flow Model in FY 2002, subject to receipt of the model report from the USGS (reference item 9).	Not Received
USFIC.5.03	SZ1 SZ2	DOE's outline for collecting data in the alluvium appears reasonable but lacks detail. Provide a detailed testing plan for alluvial testing to reduce uncertainty (for example, the plan should give details about hydraulic and tracer tests at the well 19 complex and it should also identify locations for alluvium complex testing wells and tests and logging to be performed). NRC will review the plan and provide comments, if any, for DOE's consideration. In support and preparation for this meeting, DOE provided work plans for the Alluvium Testing Complex and the Nye County Drilling Program (FWP-SBD-99-002, Alluvial Tracer Testing Field Work Package, and FWP-SBD-99-001, Nye County Early Warning Drilling Program, Phase II and Alluvial Testing Complex Drilling). DOE will provide test plans of the style of the Alcove 8 plan as they become available. In addition, the NRC On Site Representative attends DOE/Nye County planning meetings and is made aware of all plans and updates to plans as they are made.	Not Received
USFIC.5.04	SZ1	Provide additional information to further justify the uncertainty distribution of flow path lengths in the alluvium. This information currently resides in the Uncertainty Distribution for Stochastic Parameters AMR. DOE will provide additional information, to include Nye County data as available, to further justify the uncertainty distribution of flowpath lengths in alluvium in updates to the Uncertainty Distribution for Stochastic Parameters AMR and to the Saturated Zone Flow and Transport PMR, both expected to be available in FY 2002.	Not Received
USFIC.5.05	SZ1	Provide the hydro-stratigraphic cross-sections that include the Nye County data. DOE will provide the hydrostratigraphic cross sections in an update to the Hydrogeologic Framework Model for the Saturated Zone Site-Scale Flow and Transport Model AMR expected to be available during FY 2002, subject to availability of the Nye County data.	Not Received
USFIC.5.06	SZ1	Provide a technical basis for residence time (for example, using C-14 dating on organic carbon in groundwater from both the tuffs and alluvium). DOE will provide technical basis for residence time in an update to the Geochemical and Isotopic Constraints on Groundwater Flow Directions, Mixing, and Recharge at Yucca Mountain, Nevada AMR during FY 2002.	Not Received
USFIC.5.07	SZ1	Provide all the data from SD-6 and WT-24. Some of this data currently resides in the Technical Data Management System, which is available to the NRC and CNWRA staff. DOE will include any additional data from SD-6 and WT-24 in the Technical Data Management System in February 2001.	Complete
USFIC.5.08	SZ1	Taking into account the Nye County information, provide the updated potentiometric data and map for the regional aquifer, and an analysis of vertical hydraulic gradients within the site scale model. DOE will provide an updated potentiometric map and supporting data for the uppermost aquifer in an update to the Water-Level Data Analysis for the Saturated Zone Site-Scale Flow and Transport Model AMR expected to be available in October 2001, subject to receipt of data from the Nye County program. Analysis of vertical hydraulic gradients will be addressed in the site-scale model and will be provided in the Calibration of the Site-Scale Saturated Zone Flow Model AMR expected to be available during FY 2002.	Not Received

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USFIC.5.09	SZ1	Provide additional information in an updated AMR or other document for both the regional and site scale model (for example, grid construction, horizontal and vertical view of the model grid, boundary conditions, input data sets, model output, and the process of model calibration). The updated USGS Regional Groundwater Flow Model is a USGS Product, not a Yucca Mountain Site Characterization Project product. It is anticipated that this document will be available in September 2001. DOE believes that the requested information is now available in the current version of the Calibration of the Site-Scale Saturated Zone Flow Model AMR and will be carried forward in future AMR revisions.	Not Received
USFIC.5.10	SZ1	Provide in updated documentation of the HFM that the noted discontinuity at the interface between the GFM and the HFM does not impact the evaluation of repository performance. DOE will evaluate the impact of the discontinuity between the Geologic Framework Model and the Hydrogeologic Framework Model on the assessment of repository performance and will provide the results in an update to the Hydrogeologic Framework Model for the Saturated-Zone Site-Scale Flow and Transport Model AMR during FY 2002.	Not Received
USFIC.5.11	SZ1	In order to test an alternative conceptual flow model for Yucca Mountain, run the SZ flow and transport code assuming a north-south barrier along the Solitario Canyon fault whose effect diminishes with depth or provide justification not to. DOE will run the saturated zone flow and transport model assuming the specified barrier and will provide the results in an update to the Calibration of the Site-Scale Saturated Zone Flow Model AMR expected to be available during FY 2002.	Not Received
USFIC.5.12	SZ1	Provide additional supporting arguments for the Site-Scale Saturated Zone Flow model validation or use a calibrated model that has gone through confidence building measures. The model has been calibrated and partially validated in accordance with AP 3.10Q, which is consistent with NUREG-1636. Additional confidence-building activities will be reported in a subsequent update to the Calibration of the Site-Scale Saturated Zone Flow Model AMR, expected to be available during FY 2002.	Not Received
USFIC.5.13	SZ1	Provide the evaluation of the ongoing fluid inclusion studies (for example, UNLV, State of Nevada, and USGS). DOE's consideration of the fluid inclusion studies will be documented in an update to the Saturated Zone Flow and Transport PMR expected to be available in FY 2002, subject to availability of the studies.	Not Received
USFIC.5.14	SZ1 TSPAI	Provide the updated SZ FEPs AMR. DOE will provide the updated Features, Events, and Processes in Saturated Zone Flow and Transport AMR in February 2001.	Complete
USFIC.6.01	UZ3	The DOE will provide the final sensitivity analysis on matrix diffusion (for UZ) in the TSPA-SR, Rev. 0. Due date: December 2000. The saturated zone information will be available in TSPA-SR, Rev.1, expected to be available in June 2001.	Partly Received
USFIC.6.02	UZ3	The DOE will provide the final detailed testing plan for Alcove 8. The testing plan will be provided by August 28, 2000. The NRC staff will provide comments, if any, no later than two weeks after receiving the testing plan.	Complete
USFIC.6.03	UZ3	The DOE will complete the Alcove 8 testing, taking into consideration the NRC staff comments, if any, and document the results in a DOE-approved AMR, due date: May 2001.	Not Received
USFIC.6.04	SZ1 SZ2	Provide the documentation for the C-wells testing. Use the field test data or provide justification that the data from the laboratory tests is consistent with the data from the field tests. DOE will provide the C-wells test documentation and will either use the test data or provide a justified reconciliation of the lab and field test data in C-wells document(s) in October 2001.	Not Received

NRC COMMENTS ON FEATURES, EVENTS, AND PROCESSES AND PATH FORWARD FOR RESOLUTION, INCLUDING DOE AND NRC AGREEMENTS

This appendix summarizes the NRC comments on the DOE consideration of features, events, and processes and the paths forward for their resolutions. The evaluation is presented in the form of a table (Table B–1) with the following fields:

Comment A detailed explanation of the concern staff identified.

Path forward Description of the agreed on path forward reached with DOE. Comments were discussed with DOE at the DOE and NRC Technical Exchanges on May 15–17 and August 6–10, 2001. Agreements on items related to Igneous Activity were reached at the September 5, 2001, DOE and NRC Technical Exchange.

Table B–1. NRC Comments on Features, Events, and Processes and Path Forward for Resolution Including, DOE and NRC Agreements

Integrated Subissue	Technical Exchange	Comment	Path Forward
Direct1	75	Various features, events, and processes that could potentially influence the evolution of an igneous event intersecting the repository have not been identified as being relevant for disruptive events. These include 1.1.02.00.00 (Excavation/Construction) changes to the rock around the repository from excavation and construction could affect dike/repository interactions and influence how a dike behaves near the surface. Additionally, repository features such as ventilation shafts could provide a path to the surface that would bypass the repository. 1.1.04.01.00 (Incomplete Closure) if the design of the repository includes a seal at the end of the drifts strong enough to contain magma that is relied on for performance calculations, failure to complete these seals could significantly affect repository performance. 2.1.03.12.00 [Canister Failure (Long-Term)] for intrusive volcanism, credit is taken for the waste packages remaining mostly intact other than an end cap breach following magma interactions. The only waste package failure mechanism investigated to take this credit is internal gas pressure buildup. Other waste package failure mechanisms such as differential expansion of the inner and outer waste packages and phase changes in Alloy 22 from the long-term exposure to elevated temperatures are not considered. 2.1.07.02.00 (Mechanical Degradation or Collapse of Drift) could affect magma-repository interactions and affect the dose as a result of an igneous event. 2.3.01.00.00 (Topography and Morphology) the topography may affect dike propagation near the surface; dike propagation probably should be discussed as part of this feature, event, and process.	The following agreements reached at the September 5, 2001, DOE and NRC Technical Exchange, address the NRC comments: 1.1.02.00.00 (Excavation/Construction)—Igneous Activity Subissue 2, Agreement 18 1.1.04.01.00 (Incomplete Closure)—Igneous Activity Subissue 2, Agreement 18 2.1.03.12.00 [Canister Failure (Long-Term)]—Igneous Activity Subissue 2, Agreement 19 2.1.07.02.00 (Mechanical Degradation or Collapse of Drift)—Igneous Activity Subissue 2, Agreement 18 2.3.01.00.00 (Topography and Morphology)—Igneous Activity Subissue 2, Agreement 18 Igneous Activity Subissue 2, Agreement 18: DOE will evaluate how the presence of repository structures may affect magma ascent, conduit localization, and evolution of the conduit and flow system. The evaluation will include the potential effects of topography and stress, strain response on existing or new geologic structures resulting from thermal loading of high-level waste, and a range of physical conditions appropriate for the duration of igneous events. DOE will also evaluate how the presence of engineered repository structures in the License Application design (e.g., drifts, waste packages, and backfill) could affect magma flow processes for the duration of an igneous event. The evaluation will include the mechanical strength and durability of natural or engineered barriers that could restrict magma flow within intersected drifts. The results of this investigation will be documented in an update to the Analysis Model Report titled Dike Propagation and Interaction with Drifts, ANL-WIS-MD-000015, expected to be available in fiscal year 2003, or another appropriate technical document. Igneous Activity Subissue 2, Agreement 19: DOE will evaluate waste package response to stresses from thermal and mechanical effects associated with exposure to basaltic magma, considering the results of evaluations attendant to Igneous Activity Subissue 2, Agreement 18. As currently planned, the evaluation, if implemented, would include (i) appropriate at-condition strength properties and magma flow paths, for duration of an igneous event; and (ii) aging effects on materials strength properties when exposed to basaltic magmatic conditions for the duration of an igneous event, which will include the potential effects of subsequent seismically induced stresses on substantially intact waste packages. DOE will also evaluate the response of Zone 3 waste packages, or waste packages covered by backfill or rockfall, if exposed to magmatic gases at conditions appropriate for an igneous event, considering the results of evaluations attendant to Igneous Activity Subissue 2, Agreement 18. If models take credit for engineered barriers providing delay in radionuclide release, DOE will evaluate barrier performance for the duration of the hypothetical igneous event. The results

Table B–1. NRC Comments on Features, Events, and Processes and Path Forward for Resolution Including, DOE and NRC Agreements (continued)			
Integrated Subissue	**Technical Exchange**	**Comment**	**Path Forward**
			of this investigation would be documented in an update to the technical product Waste Package Behavior in Magma, CA–EBS–ME–000002, which would be available by the end of fiscal year 2003, or another appropriate technical document.
Direct1 Dose2	IA-1	2.3.02.02.00 (Radionuclide Accumulation in Soil) is included for irrigation deposition only; however, this screening argument is too limited because it excludes transport of volcanic ash from other areas to the critical group location (CRWMS M&O, 2001a). DOE indicated that redistribution will be accounted for by conservatively assuming that the wind is blowing toward the critical group and maintaining a high mass load in years after the event. DOE has not provided a demonstration that these conservatisms actually bound the effects of redistribution. Similar comment applies to the following items: 2.3.02.03.00 (Soil and Sediment Transport). In the screening argument, it is claimed that 100-percent south-blowing wind direction assumption accounts for aeolian and fluvial transport processes. Additional technical basis for this statement is needed. 2.3.13.02.00 (Biosphere Transport) excludes transport in surface water. 2.3.11.02.00 (Surface Runoff and Flooding) 2.3.01.00.00 (Topography and Morphology). It is necessary to consider the effect of this item on redistribution of radionuclides after an igneous event.	Igneous Activity Subissue 2, Agreement 17 addresses the NRC comments. DOE will evaluate conclusions that the risk effects (i.e., effective annual dose) of eolian and fluvial remobilization are bounded by conservative modeling assumptions in the document Total System Performance Assessment for Site Recommendation, Revison 00, ICN1. DOE will examine rates of eolian and fluvial mobilization off slopes, rates of transport in Fortymile Wash, and rates of deposition or removal at the proposed critical group location. DOE will evaluate changes in grain size caused by these processes for effects on airborne particle concentrations. DOE will also evaluate the inherent assumption in the mass loading model that the concentration of radionuclides on soil in the air is equivalent to the concentration of radionuclides on soil on the ground does not underestimate dose (i.e., radionuclides important to dose do not preferentially attach to smaller particles). DOE will document the results of investigations in the Analysis Model Report titled Eruptive Processes and Soil Redistribution, ANL–MGR–GS–000002, expected to be available in fiscal year 2003 and in the Analysis Model Report titled Input Parameter Values for External and Inhalation Radiation Exposure Analysis, ANL–MGR–MD–000001, to be available in fiscal year 2003, or another appropriate technical document.
Dose1 Dose2 Dose3	17	DOE selected a subset of the full list of features, events, and processes as applicable for biosphere screening in CRWMS M&O (2001a). Some entries potentially applicable to biosphere dose conversion factor calculations (that should at least be considered for screening) have not been included in the scope of the document (CRWMS M&O, 2001a). These include 2.3.11.04.00 (Groundwater Discharge to Surface) 1.3.07.02.00 (Water Table Rise) 3.2.10.00.00 (Atmospheric Transport of Contaminants) 1.2.04.01.00 (Igneous Activity) 2.2.08.01.00 (Groundwater Chemistry/Composition in Unsaturated Zone and Saturated Zone) (i.e., chemical species can impact dose coefficient selection) 2.2.08.11.00 (Distribution and Release of Nuclides from the Geosphere) 3.1.01.01.00 (Radioactive Decay and Ingrowth) 1.2.04.07.00 (Ash Fall).	DOE will provide a technical basis in the Evaluation of the Applicability of Biosphere-Related Features, Events, and Processes, ANL–MGR–MD–000011, to address the NRC comments for 2.3.11.04.00 (Groundwater Discharge to Surface), 1.3.07.02.00 (Water Table Rise), and 2.2.08.11.00 (Distribution and Release of Nuclides from the Geosphere). No further action is required for 3.2.10.00.00 (Atmospheric Transport of Contaminants) and 1.2.04.01.00 (Igneous Activity). DOE agreed to provide clarification of the screening argument in the Evaluation of the Applicability of Biosphere-Related Features, Events, and Processes, ANL–MGR–MD–000011, for 2.2.08.01.00 (Groundwater Chemistry/Composition in Unsaturated Zone and Saturated Zone), to address the NRC comment. DOE will add links to the Evaluation of the Applicability of Biosphere-Related Features, Events, and Processes, ANL–MGR–MD–000011, for 3.1.01.01.00 (Radioactive Decay and Ingrowth) and 1.2.04.07.00 (Ashfall), to address the NRC comment.
ENG1 ENG4 UZ3	57	1.1.02.03.00 (Undesirable Materials Left) is screened out on the basis of low consequences (CRWMS M&O, 2001f). Although a report cited by the DOE (CRWMS M&O, 1995) provides an analysis of acceptable upper bounds on materials introduced into the repository, no analysis has been conducted to determine if the current design will meet these limits. An assumption	DOE agreed to provide the technical basis for the screening argument in the Engineered Barrier System Features, Events, and Processes, ANL–WIS–PA–000002, to address the NRC comment. The technical basis involves use of the Waste Isolation Evaluation: Tracers, Fluids, and Materials, and Excavation Methods for Use in the Package 2C

Table B–1. NRC Comments on Features, Events, and Processes and Path Forward for Resolution Including, DOE and NRC Agreements (continued)			
Integrated Subissue	**Technical Exchange**	**Comment**	**Path Forward**
		that the limits will be adhered to during the preclosure period is considered inadequate to exclude 1.1.02.03.00 (Undesirable Materials Left). DOE should provide adequate technical basis for the effect of introduced materials on water chemistry.	Exploratory Studies Facility Construction, BABE00000–01717–2200–00007 Revision 04. As part of Container Life and Source Term Subissue 1, Agreement 1, DOE also agreed to provide additional justification on the effect of introduced materials on water chemistry in a revision to the analysis and model report, Environment on the Surfaces of the Drip Shield and Waste Package Outer Barrier AMR, ANL–EBS–MD–000001, before license application.
UZ2	68	1.2.02.01.00 (Fractures) is screened as included for seepage and is screened as excluded on the basis of low consequence for permanent effects (CRWMS M&O, 2001b). Generation of new fractures and reactivation of preexisting fractures may significantly change the flow and transport paths. Newly formed and reactivated fractures typically result from thermal, seismic, or tectonic events. Thermally induced changes in stress may result in permeability changes between drifts that could act to divert flow toward drifts. See also comment on 2.2.06.01.00 [Changes in Stress (Due to Thermal, Seismic, or Tectonic Effects) Change Porosity and Permeability of Rock].	The thermal-mechanical effects on rock properties are addressed by an existing DOE and NRC agreement (Repository Design and Thermal-Mechanical Effects Subissue 3, Agreements 20 and 21). The FEPs in Thermal Hydrology and Coupled Processes, ANL–NBS–MD–000004, will be revised on completion to meet this agreement.
ENG2 UZ2 SZ1	J-25	1.2.02.02.00 (Faulting). Changes of fault characteristics have been screened as excluded on the basis of low consequence (CRWMS M&O, 2000b); formation of new faults has been excluded on the basis of low probability. 1.2.02.03.00 (Fault Movement Shears Waste Container) has been excluded on the basis of low probability. 1.2.03.02.00 (Seismic Vibration Causes Container Failure) has been excluded on the basis of low consequence (CRWMS M&O, 2000a). In these items, the DOE screening argument relies, in large part, on the median values of fault displacements and ground motions for postclosure (less than 10^{-6}/year), rather than the mean values. The screening arguments do not provide sufficient technical justification for staff review. The staff consider that the mean more reliably incorporates uncertainty and is a more reasonable and prudent statistical measure than the median. DOE agreed to address this concern in a forthcoming Request for Additional Information.	This issue is addressed by existing agreements between DOE and NRC (Structural Deformation and Seismicity Subissue 1 Agreement 2) and an NRC letter dated August 3, 2001. Features, Events, and Processes: Screening for Disruptive Events, ANL–WIS–MD–000005, will be revised on completion of this work.
ENG2	J-26	The screening argument for 1.2.02.03.00 (Fault Movement Shears Waste Container) is based, in part, on specific setback distances that will be used by DOE in the repository design (CRWMS M&O, 2000a). The setback distances are a function of fault displacement magnitudes. Thus, the setback values used in the design may need to be reassessed after the displacement issue is resolved.	This issue is addressed by existing agreements between DOE and NRC (Structural Deformation and Seismicity Subissue 1 Agreement 2) and an NRC letter dated August 3, 2001. Features, Events, and Processes: Screening for Disruptive Events, ANL–WIS–MD–000005, will be revised on completion of this work.
ENG2 UZ2 SZ1	J-27	1.2.03.01.00 (Seismic Activity) has been screened as excluded on the basis of low consequence of effects on such components as the drip shield and waste package and included with regard to effects on cladding (CRWMS M&O, 2000a). The distributions for	This issue is addressed by existing agreements between DOE and NRC (Structural Deformation and Seismicity Subissue 2 Agreement 1) and an NRC letter dated August 3, 2001. Features, Events, and

Table B–1. NRC Comments on Features, Events, and Processes and Path Forward for Resolution Including, DOE and NRC Agreements (continued)			
Integrated Subissue	**Technical Exchange**	**Comment**	**Path Forward**
		ground-motion parameters were developed using the Probabilistic Seismic Hazard Assessment Expert Elicitation. There are apparent discrepancies among these input parameters from several experts. DOE agreed to address this concern in a forthcoming Request for Additional Information.	Processes: Screening for Disruptive Events, ANL–WIS–MD–000005, will be revised on completion of this work.
ENG2	78	1.2.03.02.00 (Seismic Vibration Causes Container Failure) features, events, and processes have been excluded from consideration in the total system performance assessment code (CRWMS M&O, 2000a, 2001c). The screening argument cites preliminary seismic analyses of the drip shield and waste package as the basis for this screening decision (CRWMS M&O, 2000b). Because these analyses were not available at the time of this review, it is not clear whether the appropriate combinations of dead loads (caused by drift collapse, fallen rock blocks, or both), rock block impacts, and seismic excitation were considered. Moreover, the ability of these loads to initiate cracks, propagate preexisting cracks, or both may not have been adequately addressed. In addition, DOE has not demonstrated that the drip shield, pallet, and waste package will respond in a purely elastic manner when subjected to the aforementioned loading conditions. The screening argument for 1.2.03.02.00 (Seismic Vibration Causes Container Failure) also states "... it does not appear credible that the drip shield would be breached, because the drip shield has been designed to withstand up to a 6-MT rockfall" based on the rockfall on drip shield analyses performed by DOE (CRWMS M&O, 2000c). DOE, however, has not adequately demonstrated that the drip shield has, in fact, been designed to withstand 6-MT rock blocks {see the comments on 2.1.07.01.00 [Rockfall (Large Block)], 2.1.07.02.00 (Mechanical Degradation or Collapse of Drift), and 2.1.07.05.00 (Creeping of Metallic Materials in the Engineered Barrier Subsystem) for additional discussion relevant to rockfall and seismic analyses}. See also comment on 1.2.02.02.00 (Faulting).	Existing agreements from the Container Life and Source Term Subissue 2, Agreements 2 and 8; Repository Design and Thermal-Mechanical Effects Subissue 3, Agreements 17 and 19; and Structural Deformation and Seismicity Subissue 1, Agreement 2, and Subissue 2, Agreement 3, address related work. DOE agreed to provide clarification of the screening argument in FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation, ANL–EBS–PA–000002, and Features, Events, and Processes: Screening for Disruptive Events, ANL–WIS–MD–000005, to address the NRC comment.
UZ3 Direct1	J-22	1.2.04.02.00 (Igneous Activity Causes Changes to Rock Properties) is screened as excluded from the radionuclide transport in the unsaturated zone abstraction, on the basis of low consequence (CRWMS M&O, 2000d, 2001d). Although various of the arguments presented (scale and duration) may be reasonable, natural analogs (CRWMS M&O, 2000e) suggest time scales of thousands of years (Ratcliff, et al., 1994) and alteration scales of tens of meters. Furthermore, modeling studies of the effects of silica redistribution on fracture porosity and permeability (CRWMS M&O, 2000e) have yielded conflicting results (Matyskiela, 1997), suggesting additional clarification is needed. Probability may also be an aspect to use in developing screening arguments for 1.2.04.02.00 (Igneous Activity Causes Changes to Rock Properties) provided probability is consistent with the probabilities used for the igneous disruptive scenario.	This issue is addressed by existing agreements between DOE and NRC (Evolution of the Near-Field Environment Subissue 1 Agreement 4, Subissue 4 Agreements 3 and 4, and Radionuclide Transport Subissue 1 Agreement 5). Features, Events, and Processes in Unsaturated Zone Flow and Transport, ANL–NBS–MD–000001, will be revised on completion of this work.

Table B–1. NRC Comments on Features, Events, and Processes and Path Forward for Resolution Including, DOE and NRC Agreements (continued)

Integrated Subissue	Technical Exchange	Comment	Path Forward
SZ1 Dose1 Dose2	8	1.2.04.07.00 (Ash Fall). DOE assumes that ash fall blankets the region between the repository and the compliance boundary (CRWMS M&O, 2000f). Radionuclides associated with ash fall are then assumed to be transported instantaneously into the saturated zone. DOE presented only the case for uniform distribution. Moreover, parameter values and models used in the ash fall analysis are not clear. Some parameters used in the model are not well documented and other parameters, such as the number of waste packages that fail, are not viewed as conservative. DOE should provide additional bases for the choice of models and parameters used to screen this item.	DOE agreed to provide clarification of the screening argument in the Features, Events, and Processes in SZ Flow and Transport, ANL–NBS–MD–000002, to address the NRC comment.
Dose1 Dose2	J-24	1.2.04.07.00 (Ash Fall). The screening argument in CRWMS M&O (2000f) for ash fall impacting the saturated zone [i.e., secondary 1.2.04.07.01 (Soil Leaching Following Ash Fall)] includes a three order-of-magnitude error in calculation of the concentration of radionuclides in the well water. Although conservative assumptions are used in the analysis, the error found in Table 6-1 would cause the calculated dose to be 0.161Sv[16.1 rem], instead of 1.61×10^{-2} [1.61×10^{-4}], and would not support a low-consequence screening argument.	DOE agreed to provide the technical basis for the screening argument in Features, Events, and Processes in SZ Flow and Transport, ANL–NBS–MD–000002, screening argument, to address the NRC comment.
SZ2 ENG3	4	1.2.06.00.00 (Hydrothermal Activity). [Saturated Zone]: In CRWMS M&O (2001e), this item is excluded on the basis of low consequence. For saturated zone transport, the argument is that the adopted K_d distributions account for possible lithologic changes and thermal effects, with reference to CRWMS M&O (2000g). However, the latter document does not provide a clear technical basis that the K_ds were derived in such a fashion. In addition, though the screening argument is based on low consequence, there is a reference at the conclusion of the supplemental discussion to the low probability of hydrothermal activity (CRWMS M&O, 2001e). Resolution of this issue is necessary to address the issue of changes in the geothermal gradient in 2.2.10.13.00 [Density-Driven Groundwater Flow (Thermal)]. DOE should provide a stronger technical basis for the assertion that possible hydrothermal effects on K_d values are accounted for in the total system performance assessment. [Unsaturated Zone]: This item is excluded in the unsaturated zone on the basis of low consequence and low probability (CRWMS M&O, 2000h). DOE has not yet provided sufficient technical bases for models explaining elevated temperatures in the unsaturated zone from approximately 122 million years ago or adequately addressed the timing and mode of formation of Type B faults, which record elevated temperatures.	[Saturated Zone]: This issue is addressed by existing DOE and NRC agreements (Radionuclide Transport Subissue 1, Agreement 5, and Subissue 2, Agreement 10). Features, Events, and Processes in SZ Flow and Transport, ANL–NBS–MD–000002, will be updated as necessary to reflect the results of these existing agreements. [Unsaturated Zone]: As part of the Evolution of the Near-Field Environment Subissue 2, Agreement 3, DOE agreed to provide additional technical bases for the screening of 1.2.06.00 (Hydrothermal Activity), addressing points discussed at the January 2001 Evolution of the Near-Field Environment Technical Exchange. DOE agreed to revise the screening argument in a future revision of Features, Events, and Processes in UZ Flow and Transport AMR, (ANL–NBS–MD–000001), expected to be available in fiscal year 2002.
UZ2	J-23	1.2.06.00.00 (Hydrothermal Activity). Excluded on the basis of low consequence for basaltic magmatism and low probability for silicic magmatism (CRWMS M&O, 2001d). A consistent approach for the screening arguments is needed. The screening argument is considered incomplete because (i) past hydrothermal activity in the Yucca Mountain region is not clearly	This issue is addressed by existing DOE/NRC agreements (Radionuclide Transport Subissue 1 Agreement 5 and Subissue 2 Agreement 10). Features, Events, and Processes in SZ Flow and Transport, ANL-NBS-MD-000002, will be updated as necessary to reflect the results of these existing agreements.

Table B–1. NRC Comments on Features, Events, and Processes and Path Forward for Resolution Including, DOE and NRC Agreements (continued)			
Integrated Subissue	**Technical Exchange**	**Comment**	**Path Forward**
		related to basaltic igneous activity and (ii) probability screening arguments in CRWMS M&O (2001d) are incomplete with respect to silicic magmatism. In addition, DOE cites unpublished studies by the U.S. Geological Survey and the University of Nevada, Las Vegas that reportedly demonstrates hydrothermal activity was a site characteristic until about 2 million years ago. Additional unpublished work by Dublyanski and others, however, does not support this conclusion. None of the unpublished work, however, has supported the conclusion that the likelihood of hydrothermal activity at Yucca Mountain during the next 10,000 years is clearly <1:10,000. Absent a clear linkage to the consequences of basaltic igneous activity, or a demonstrated technical basis for probability values below 1 in 10,000 in 10,000 years, DOE has an incomplete technical basis to screen 1.2.06.00.00 (Hydrothermal Activity) from further consideration.	
UZ1 Dose2 Dose3	J-16	1.2.07.01.00 (Erosion/Denudation) is screened as excluded on the basis of low consequence (CRWMS M&O, 2001d). The rationale for exclusion from the unsaturated zone on the basis of low consequence is incomplete. It is necessary to consider onset and extent of erosion caused by construction and characterization activities at the ground surface and the long-term effects on shallow infiltration.	DOE agreed to provide clarification of the screening argument in Features, Events, and Processes in UZ Flow and Transport, ANL–NBS–MD–000001, to address the NRC comment.
UZ1	J-17	1.2.10.02.00 (Hydrologic Response to Igneous Activity). Excluded based on low consequence (CRWMS M&O, 2001d). Argument to exclude focuses on intrusive events. It should be noted that extrusive events could increase shallow infiltration for the repository in two ways: (i) lava flow would modify or dam a wash overlying the repository and (ii) volcanic fragment and ash layer, which would be highly permeable, may act to trap infiltrating water, shield it from evaporation, and reduce transpiration—all leading to increased shallow infiltration across the repository. There are no data to support or exclude the temporal extent of increased shallow infiltration, though this could be bounded from decades to thousands of years.	DOE agreed to provide the technical basis for the screening argument in Features, Events, and Processes in UZ Flow and Transport, ANL–NBS–MD–000001, screening argument, to address the NRC comment.
UZ1	J-18	1.3.04.00.00 (Periglacial Effects). Excluded by low probability (CRWMS M&O, 2001d). Although other periglacial processes will not likely occur at Yucca Mountain, the freeze/thaw process is currently active. Freeze/thaw mechanical erosion will likely increase as the climate cools, however. The magnitude of erosion will not likely be significant even during the cooler climate condition. The screening argument should be clarified to acknowledge the current freeze/thaw process.	DOE agreed to provide clarification of the screening argument in Features, Events, and Processes in UZ Flow and Transport, ANL–NBS–MD–000001, to address the NRC comment.
SZ1 SZ2 Dose1 Dose3	11	1.3.07.01.00 (Drought/Water Table Decline). According to information in CRWMS M&O (2001e), this item is excluded because of low consequence. DOE states "... a lower water table could result in less travel through the alluvial aquifer and as a result, less sorption and retardation of the contaminant plume." However, no evidence is presented that precludes a water table decline. Current flow models assume that groundwater flow through the saturated alluvium is	This issue is addressed by existing DOE and NRC agreements (Radionuclide Transport Subissue 2, Agreement 8, and Unsaturated and Saturated Flow Under Isothermal Conditions Subissue 5, Agreement 4). Features, Events, and Processes in SZ Flow and Transport, ANL–NBS–MD–000002, will be updated as necessary to reflect the results of these existing agreements and to clarify the screening argument.

Table B–1. NRC Comments on Features, Events, and Processes and Path Forward for Resolution Including, DOE and NRC Agreements (continued)			
Integrated Subissue	**Technical Exchange**	**Comment**	**Path Forward**
		relatively shallow. As water tables decline, how will flow through the alluvium be affected? Is it possible that a larger component of flow will be through the deep carbonate system? Will the upward gradient observed at some locations be affected? Are there distinct pathways that are dependent on elevation of the water table? It is likely that the transport times will stay the same or increase from water table decline, however, the exclusion argument provided seems insufficient. Additional technical justification is required to fully exclude 1.3.07.01.00 (Drought/Water Table Decline).	
SZ2	7	1.4.06.01.00 (Altered Soil or Surface Water Chemistry). This item is excluded on the basis of low probability (CRWMS M&O, 2001d), but it is not addressed as part of the scope of document ANL–NBS–MD–000002 (CRWMS M&O, 2000f). The probability argument is not supported by a calculation or estimate. This item is possibly relevant for the Integrated Subissue Radionuclide Transport in the Saturated Zone because of possible changes in groundwater chemistry.	DOE agreed to provide clarification of the screening argument in Features, Events, and Processes in SZ Flow and Transport, ANL–NBS–MD–000002, to address the NRC comments. The analysis and model report will also address the aggregate effects of 1.4.06.01.00 (Altered Soil or Surface Water Chemistry) on the unsaturated and saturated zones.
Dose3 Dose1	18	The biosphere analysis and model report on features, events, and processes (CRWMS M&O, 2001a) indicates that any future changes in 1.4.07.01.00 (Water Management Activities) can be excluded based on 10 CFR Part 63. This item includes well pumping from an aquifer as a water management activity. The conclusion that changes to water management activities may be excluded is not supported by the regulation. The draft regulation indicates the behaviors and characteristics of the farming community shall be consistent with current conditions of the region surrounding the Yucca Mountain site and that climate evolution shall be consistent with the geologic record. As the climate becomes wetter and cooler, the farming community is likely to pump less water out of the aquifer, consistent with sites analogous to the predicted future climate of Yucca Mountain. This reduction in pumping would not be considered a change in the behavior or characteristics of the critical group because the community would still be raising similar crops using similar farming methods.	DOE agreed to provide clarification of the screening argument in Features, Events, and Processes in SZ Flow and Transport, ANL–NBS–MD–000002, to address the NRC comment.
ENG1	48	2.1.01.04.00 (Spatial Heterogeneity of Emplaced Waste) is screened as excluded on the basis of low consequence (CRWMS M&O, 2000i). Waste placed in Yucca Mountain will have physical, chemical, and radiological properties that will vary. The effect of spatial heterogeneity of the waste on repository-scale response is excluded based on low consequence, however, the heterogeneity within a waste package is implicitly included in the evaluation of in-package temperature used to determine perforation of the commercial spent nuclear fuel cladding. Spatial variability that may affect degradation of engineering barriers, such as conditions leading to crevice corrosion versus passive corrosion of an outer container, is not considered in this feature-event-process.	Spatial variability that may affect degradation of the waste package will be addressed as part of the resolution of an existing agreement (Container Life and Source Term Subissue 1, Agreement 1). The scope of the agreement includes evaluation of the range of chemical environments on the waste package.
ENG 4	50	2.1.02.13.00 (General Corrosion of Cladding). Excluded based on low probability of occurrence (CRWMS M&O, 2000j). Although general corrosion of	DOE agreed to provide clarification of the screening argument in Clad Degradation Features, Events, and

Table B–1. NRC Comments on Features, Events, and Processes and Path Forward for Resolution Including, DOE and NRC Agreements (continued)			
Integrated Subissue	**Technical Exchange**	**Comment**	**Path Forward**
		cladding could expose large areas of irradiated fuel matrix and produce hydrides, it is argued that this corrosion is a slow process. The arguments are based on extrapolation to low temperatures at test data obtained at temperatures above 250 °C [482 °F] and in measurements of oxide thickness from specific fuel rods after reactor operation and exposure to water in reactor pool storage.	Processes Analysis and Model Report, ANL–WIS–MD–000008, to address the NRC comment.
ENG4	51	2.1.02.14.00 (Microbially Induced Corrosion of Cladding). Included as part of localized corrosion model on the basis that microbial activity may induce local pH decreases and the local acidic environment may produce multiple penetrations of the cladding (CRWMS M&O, 2000j). It is stated, however, that microbially induced corrosion resulting from sulfide produced by sulfate-reducing bacteria and organic acid-producing bacteria is not expected to occur, because of resistance of zirconium to these species. The arguments are poorly worded stating that microbially induced corrosion is not expected to occur (not probable or credible) because microbial activity is screened out at the scale of the repository model as a significant bulk process. The argument of local acidic pH causing localized corrosion of cladding contradicts experimental evidence showing that zirconium alloys are resistant to corrosion in reducing and oxidizing acids. In addition, the argument contradicts other DOE arguments to screen out pitting corrosion by chloride anions {see 2.1.02.16.00 [Localized Corrosion (Pitting) of Cladding]}. Screening arguments for inclusion or exclusion should be consistent with screening decisions for related entries [see 2.1.02.15.00 (Acid Corrosion of Cladding from Radiolysis)]. A third group of bacteria iron oxidizers should also be considered in the analysis (NRC, 2001).	This issue is addressed by an existing DOE and NRC agreement (Container Life and Source Term Subissue 3, Agreement 7). DOE agreed to provide clarification of the screening argument in Clad Degradation—FEPs Screening Arguments, ANL–WIS–MD–000008, Analysis and Model Report to address the NRC comment. The new cladding local corrosion model will reference In-Drift Microbial Communities Analysis and Model Report, ANL–EBS–MD–000038, which includes discussion of iron oxidizing bacteria. Clad Degradation—FEPs Screening Arguments, ANL–WIS–MD–000008, Analysis and Model Report will be revised to be consistent with the updated Summary–Abstraction Analysis and Model Report.
ENG4	49	2.1.02.15.00 (Acid Corrosion of Cladding from Radiolysis). Included as part of the localized corrosion model on the basis that formation of HNO_3 and H_2O_2 ions [sic] by radiolysis can enhance corrosion of cladding (CRWMS M&O, 2000j). It is stated, however, that zirconium has excellent corrosion resistance to HNO_3 and concentrated H_2O_2. The arguments are poorly worded, stating that radiolysis is not expected to occur until waste package failure; then, the gamma dose will be too low to produce sufficient HNO_3 and H_2O_2 to promote general corrosion, however, localized corrosion could be possible. The argument of local acidic pH causing localized corrosion of cladding contradicts experimental evidence showing that zirconium alloys are resistant to corrosion in reducing and oxidizing acids. In addition, the argument contradicts other DOE arguments to screen out pitting corrosion by chloride anions {see 2.1.02.16.00 [Localized Corrosion (Pitting) of Cladding]}. In the Basis for Screening, undue consideration is given to alkaline conditions arising from the concrete liner, whereas the possibility of acidic conditions (pH< 2) is not discussed.	Radiolysis is addressed by an existing DOE and NRC agreement (Container Life and Source Term Subissue 3, Agreement 7). DOE agreed to provide clarification of the screening argument in Clad Degradation—FEPs Screening Arguments, ANL–WIS–MD–000008, to address the NRC comment.
ENG4	47	2.1.02.17.00 [Localized Corrosion (Crevice Corrosion) of Cladding]. Excluded based on low probability of occurrence (CRWMS M&O, 2000j). Experimental	DOE agreed to provide clarification of the screening argument in Clad Degradation—FEPs Screening Arguments, ANL–WIS–MD–000008, to address the

Table B–1. NRC Comments on Features, Events, and Processes and Path Forward for Resolution Including, DOE and NRC Agreements (continued)			
Integrated Subissue	**Technical Exchange**	**Comment**	**Path Forward**
		evidence is cited to indicate that crevice corrosion has not been observed in zirconium alloys exposed to chloride solutions, including NRC and CNWRA results. There is a need to develop a better understanding of localized corrosion of zirconium alloys before confirming this conclusion because the data are limited. In the report, Clad Degradation—Local Corrosion of Zirconium and Its Alloys Under Repository Conditions (CRWMS M&O, 2000k). It is noted that crevice corrosion may occur in the presence of fluoride ions.	NRC comment using data relevant to the proposed repository. In addition, Container Life and Source Term Subissue 3, Agreement 7, also addresses part of the concern.
ENG4	41	2.1.02.20.00 (Pressurization from Helium Production Causes Cladding Failure). Included as a process of internal gas pressure buildup that increases the cladding stress contributing to delayed hydride cracking and strain (creep?) failures (CRWMS M&O, 2000j). The wording could be more precise in the text where it is stated that helium production from alpha decay is the main source of pressure buildup.	DOE agreed to provide clarification of the screening argument in Clad Degradation—FEPs Screening Arguments, ANL–WIS–MD–000008, to address the NRC comment.
ENG4	53	2.1.02.22.00 (Hydride Embrittlement of Cladding). Excluded based on low probability of occurrence (CRWMS M&O, 2000j). The DOE screening argument states that the in-package environment and cladding stresses are not conducive to hydride cracking. The NRC staff believe that reorientation of preexisting hydride and embrittlement depends on temperature in addition to the required stresses. Clarification is needed on the cladding temperature and stress distributions used in the analysis. Several of the secondary features, events, and processes related to various processes leading to hydrogen entry into the cladding are listed next. 2.1.02.22.01 [Hydride Embrittlement from Zirconium Corrosion (of Cladding)]. Excluded because of low probability of occurrence because the hydrogen pickup as a result of cladding corrosion is low, because of the low corrosion rate, and because of the relatively small pickup fraction. The experimental hydrogen pickup fraction is provided, and it is argued the corrosion rate is low. The conclusion DOE reached regarding failure of cladding as a result of hydrogen pickup from general corrosion is acceptable. The screening arguments, however, can be justified better using quantitative arguments for the corrosion rate during disposal conditions. 2.1.02.22.02 [Hydride Embrittlement from Waste Package Corrosion and Hydrogen Absorption (of Cladding)]. Excluded because of the low probability of occurrence because the hydrogen generated by corrosion of waste packages and waste package internals and present as a molecule in gas or dissolved in water is not directly absorbed by the cladding. It is argued, on the basis of experimental data, that hydrogen absorption occurred through the reaction with water and not from the dissolved molecular hydrogen. The conclusion DOE reached regarding failure of cladding as a result of absorption of hydrogen gas generated by corrosion of waste package materials is acceptable. The screening arguments, however, can be better organized.	DOE agreed to provide clarification of the screening argument in Clad Degradation—FEPs Screening Arguments, ANL–WIS–MD–000008, to address the NRC comment.

Table B–1. NRC Comments on Features, Events, and Processes and Path Forward for Resolution Including, DOE and NRC Agreements (continued)			
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		2.1.02.22.03 (Hydride Embrittlement from Galvanic Corrosion of Waste Package Contacting Cladding). Excluded because of the low probability of occurrence because corrosion of waste package internals will not result in hydriding of cladding. It is argued, using some experimental data as bases, that galvanic coupling to carbon steel will not be conducive to hydrogen charging because corrosion products will interrupt the electrical contact. It is claimed also that the nickel content both in Zircaloy-2 and -4 is not sufficient to induce the necessary hydrogen charging. The conclusion DOE reached regarding failure of cladding as a result of hydrogen entry from galvanic coupling with internal components of the waste packages is, in general, acceptable. The screening arguments, however, could be better supported by more relevant experimental data. 2.1.02.22.04 [Delayed Hydride Cracking (of Cladding)]. Excluded because of the low probability of occurrence. The analysis is based on the use of calculated values for the distribution of the stress intensity factor, which is compared with the threshold stress intensity for irradiated Zircaloy-2. The conclusion DOE reached regarding failure of cladding as a result of delayed hydride cracking is acceptable. The DOE analysis of delayed hydride cracking is based on material properties of cladding containing mostly circumferential hydrides. DOE needs to provide cladding temperatures and stress distributions and demonstrate these are insufficient to cause hydride reorientation. 2.1.02.22.05 [Hydride Reorientation (of Cladding)]. Excluded because of the low probability of occurrence, since tested fuel rods did not exhibit hydride reorientation at stresses higher than those expected at the repository temperatures. It is argued, in addition, that with hydride reorientation, stresses will be insufficient for hydride embrittlement and clad failure. Therefore, hydride reorientation has not been included in the model abstraction for cladding degradation. DOE agreed to provide updated documentation on the distribution of cladding temperatures and hoop stresses, which are critical parameters needed to evaluate the propensity to hydride reorientation and embrittlement [see 2.1.02.22.00 (Hydride Embrittlement of Cladding)]. 2.1.02.22.06 [Hydride Axial Migration (of Cladding)]. Excluded based on low probability because it is unlikely that sufficient hydrogen can be moved to the cooler ends of the fuel rods because of a lack of large temperature gradients in the waste packages. Based on studies for storage up to 90 years, it is concluded that the temperature gradients are not sufficient to induce redistribution of hydrides. The conclusion DOE reached regarding redistribution of hydrides caused by temperature gradients is acceptable. The screening arguments, however, should include the combined effects of stress and temperature. 2.1.02.22.07 [Hydride Embrittlement from Fuel Reaction (Causes Failure of Cladding)]. Excluded based on low probability of occurrence because hydride embrittlement from fuel reaction is only observed in boiling water reactors and a high-	

Table B–1. NRC Comments on Features, Events, and Processes and Path Forward for Resolution Including, DOE and NRC Agreements (continued)			
Integrated Subissue	**Technical Exchange**	**Comment**	**Path Forward**
		temperature steam environment is required for failure propagation, conditions that are unlikely even after waste package failure. The conclusion is acceptable because it is not a credible failure mechanism. However, the screening arguments are, to say the least, confusing.	
ENG1 ENG2 ENG3	34	2.1.03.02.00 (Stress Corrosion Cracking of Waste Containers). Screened as included for waste package and as excluded for drip shield on the basis of low consequence (CRWMS M&O, 2001c). The screening argument states ... Source of stress for cracks is due to cold work stress and cracks caused by rockfall. However, these cracks tend to be tight (i.e., small crack opening displacement) and fill with corrosion products and carbonate minerals. These corrosion products will limit water transport through the drip shield and, thus, not contribute significantly to the overall radionuclide release rate from the underlying failed waste packages ... . The screening argument for the drip shield is weak. Simplified DOE calculations indicate cracks will take considerable time to fill with corrosion products (Stress Corrosion Cracking of the Drip Shield, the Waste Package Outer Barrier, and the Stainless Steel Structural Material, ANL–EBS–MD–000005). Cracks that develop in the drip shield may propagate, open up, or both when subjected to subsequent loads caused by rockfall/drift collapse, seismic excitation, or both allowing significant groundwater infiltration through the drip shield.	This issue is contained in existing DOE and NRC agreement (Container Life and Source Term Subissue 2, Agreement 8). DOE will update FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation, ANL–EBS–PA–000002, screening argument on completion of the agreement.
ENG1 ENG2 ENG3	30	2.1.03.05.00 (Microbially Mediated Corrosion of Waste Container). Screened as included for waste package and as excluded for drip shield on the basis of low consequence (CRWMS M&O, 2001c). Quantitative data on microbially influenced corrosion of drip shield materials such as Titanium Grades 7 and 16 are not available from the literature. If microbially influenced corrosion of the drip shield occurs, it would not have an effect on dose. Accelerated corrosion rates of the drip shield have been evaluated and do not affect dose (CRWMS M&O, 2000l).	This issue is addressed by an existing agreement (Container Life and Source Term Subissue 2, Agreement 8). No additional DOE action is required.
ENG1 ENG2 ENG3	35	2.1.03.08.00 (Juvenile and Early Failure of Waste Containers). Screened as included for manufacturing and welding defects in waste container degradation analysis and as excluded for manufacturing defects in drip shield degradation analysis and early failure of the waste package and drip shield from improper quality control during emplacement (CRWMS M&O, 2001c). The screening argument states The major effect of pre-existing manufacturing defects is to provide sites for crack growth by stress corrosion cracking, potentially leading to an early failure. Among other exposure condition parameters, tensile stress is required to initiated stress corrosion cracking. Because during fabrication the welds of drip shields will be annealed before placement in the emplacement drift, drip shields are not subject to stress corrosion cracking. Also, other sources of stresses in the drip shield induced by backfill and earthquakes are insignificant to cause stress corrosion cracking.	Manufacturing defects associated with the drip shield will be addressed during the resolution of an existing agreement item for the waste package (Container Life and Source Term Subissue 2, Agreement 7). FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation, ANL–EBS–PA–000002, will be updated to reflect the results of this agreement. Mechanical integrity of the drip shield will be addressed during resolution of an existing agreement item for the waste package (Container Life and Source Term Subissue 2, Agreement 6). FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation, ANL–EBS–PA–000002, will be updated to reflect the results of this agreement. Rockfall effects on the drip shield will be addressed during the resolution of an existing agreement item for the waste package (Container Life and Source Term Subissue 2, Agreement 8). FEPs Screening of

Table B–1. NRC Comments on Features, Events, and Processes and Path Forward for Resolution Including, DOE and NRC Agreements (continued)			
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		The manufacturing defects in the drip shield are excluded from TSPA analysis based on low consequence to the expected annual dose rate. The basis for this assessment is that slap-down analysis of a 21-pressurized water reactor waste packages resulted in stresses in the waste package material of less than 90 percent of the ultimate tensile strength. The impact energy associated with the emplacement error is substantially less than that expected in a vertical tip-over. Emplacement errors are not expected to result in any damage. The results of the slap-down analysis are cited as the screening analyses of several features, events, and processes. The damage reported in the slap-down analyses is concerning. Although the impact energy of emplacement errors may be substantially less than that experienced in the slap-down analyses, a proper assessment of the extent of waste package damage as a result of emplacement errors should be performed.	Processes and Issues in Drip Shield and Waste Package Degradation, ANL–EBS–PA–000002, will be updated to reflect the results of this agreement. FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation, ANL–EBS–PA–000002, will be revised to address damage from improper quality control and emplacement of the drip shield. The criteria for damage to the waste package during emplacement will be addressed by administrative procedures for emplacement operations to be developed before operation of the facility.
ENG2	J-1	2.1.03.11.00 (Container Form) has been excluded from consideration in the total system performance assessment code (CRWMS M&O, 2001c). DOE has not addressed the varying clearance between the drip shield and different waste package designs and the concomitant effects this clearance may have on the consequences of rock block impacts, seismic excitation, or both.	This issue is addressed by existing agreements between DOE and NRC (Container Life and Source Term Subissue 2 Agreement 8). FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation, ANL–EBS–PA–000002, will be revised on completion of this work.
UZ1 UZ2	J-19	2.1.05.01.00 (Seal Physical Properties). Excluded based on low consequence (CRWMS M&O, 2001d). It is difficult to assess this item solely based on the screening argument provided. The assessment can be performed once the actual design (ventilation tunnel locations) is released, backfill is described, and the analysis of runoff and flooding is incorporated into the screening argument. 2.1.05.02.00 (Groundwater Flow and Radionuclide Transport in Seals) and 2.1.05.03.00 (Seal Degradation). Excluded based on low consequence, using screening argument for 2.1.05.01.00 (Seal Physical Properties). The adequacy of the screening argument cannot be assessed until the actual design (ventilation tunnel locations) is released, backfill is described, and the analysis of runoff and flooding is incorporated into the screening arguments.	DOE stated it would adopt more rigorous configuration controls as the design advances. These controls will identify features, events, and processes screening arguments that could potentially change when design changes occur.
ENG3 ENG4 UZ3	J-3	2.1.06.01.00 (Degradation of Cementitious Materials in Drift). The effects of degradation of cementitious materials on seepage chemistry are excluded on the basis of low consequence (CRWMS M&O, 2001f). Exclusion is based on arguments in 2.1.09.01.00 (Properties of the Potential Carrier Plume in the Waste and Engineered Barrier Subsystem) (CRWMS M&O 2001f) that chemical models show a negligible effect of grout associated with rock bolts. NRC raised questions about these models pertaining to the treatment of evaporation and the chemical divide phenomenon (Evolution of the Near-Field Environment Technical Exchange). Concerns about grout chemical effects are related to recent observations of dripping	This issue is addressed by existing agreements between DOE and NRC (Evolution of the Near-Field Environment Subissue 2 Agreements 6, 10, and 14, and Radionuclide Transport Subissue 1 Agreement 5). Engineered Barrier System Features, Events, and Processes, ANL–WIS–PA–000002, will be revised on completion of this work.

Table B–1. NRC Comments on Features, Events, and Processes and Path Forward for Resolution Including, DOE and NRC Agreements (continued)			
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		from rock bolt holes in the sealed cross drift test. The argument for screening chemical effects of cementitious materials in the drift is considered inadequate. Because degradation products may affect water chemistry, and, therefore, radionuclide sorption behavior, the effect of this database entry on radionuclide transport in the unsaturated zone should e evaluated also. Currently, this entry is not addressed for the unsaturated zone (CRWMS M&O, 2001d). It is necessary to the development of technical bases that degradation of cementitious materials has a negligible effect on water chemistry within and below the drift. Screening would be supported by addressing the following technical exchange agreements: Evolution of the Near-Field Environment Subissue 2, Agreements 6 and 14, deal with model and laboratory results pertinent to the effects of engineered barrier subsystem materials, including cementitious on water chemistry. Radionuclide Transport Subissue 1, Agreement 5, and Subissue 2, Agreement 10, concern the technical bases for transport parameter uncertainty distributions.	
ENG2 UZ3	J-2 J-4	2.1.06.05.00 (Degradation of Invert and Pedestal) has been screened as excluded on the basis of low consequence (CRWMS M&O, 2001f). [Comment 1]: Rock block impact orientations with the waste package will be affected by degradation of the invert. Comment 2.1.07.01.00 [Rockfall (large block)] stated angled rock block impacts near the closure lid weld may have undesirable consequences. Furthermore, stability of the waste package during seismic excitation will be affected by a degraded invert foundation. Corrosion of the steel pallet components should be considered when evaluating stability of the waste package on its supporting pallet on a degraded invert foundation. [Comment 2]: Invert degradation is excluded on the basis of low consequence (CRWMS M&O, 2001f). The argument that changes to diffusive properties of the invert will be negligible to dose is not supported by demonstration (by sensitivity analyses) of the significant effect of diffusive release through the invert during the first 20,000 years (CRWMS M&O, 2000m, Volume II, Section 3.3). The sensitivity shown in the Repository Safety Strategy also applies to the first 10,000 years. The screening argument contradicts this information. The screening argument should directly address possible effects of degradation on invert diffusive properties.	[Comment 1]: This issue is addressed by existing agreements between DOE and NRC (Container Life and Source Term Subissue 2 Agreement 8). Engineered Barrier System Features, Events, and Processes, ANL–WIS–PA–000002, will be revised on completion of this work. [Comment 2]: DOE agreed to provide the technical basis for the screening argument in Engineered Barrier System Features, Events, and Processes, ANL–WIS–PA–000002, to address the NRC comment.
ENG1	39	2.1.06.06.00 (Effects and Degradation of Drip Shield). Excluded based on low consequence (CRWMS M&O, 2001c). The drip shield is an important component of the engineered barrier subsystem, and its function and degradation are explicitly considered in the total	The ability of the additional loading combinations to initiate, propagate, or both preexisting cracks is being addressed in existing agreements (Container Life and Source Term Subissue 2, Agreements 8 and 9). DOE agreed to provide the technical basis for the screening

Table B–1. NRC Comments on Features, Events, and Processes and Path Forward for Resolution Including, DOE and NRC Agreements (continued)			
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		system performance assessment. The degradation of the drip shield from corrosion processes is considered directly in the model abstraction for waste package degradation, whereas remaining aspects of drip shield behavior are considered as part of the engineered barrier subsystem analysis. For the secondary feature-event-process 2.1.06.06.01 (Oxygen Embrittlement of Ti Drip Shield), DOE argues that oxygen embrittlement is explicitly considered in the screening argument, but no discussion is provided. It is noted that this issue is most relevant to mechanical failure of the drip shield, which is discussed in 2.1.07.01.00 (Rockfall) and 2.1.07.02.00 (Mechanical Degradation or Drift Collapse). Although physical and chemical degradation processes have been included in the total system performance assessment, their effects on the ability of the drip shield to withstand dead loads (caused by drift collapse, fallen rock blocks, or both), rock block impacts, and seismic excitation are not accounted for in the screening arguments (CRWMS M&O, 2001c,f). CRWMS M&O (2000o) states the impact of rockfall on the degraded drip shield has been screened as excluded until more detailed structural response calculations for the drip shield under various rock loads are available. No references are provided in this document when and where these analyses will be available.	argument in FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation, ANL–EBS–PA–000002, to address the NRC comment.
ENG1	29	2.1.06.07.00 (Effects at Material Interfaces) is screened as excluded on the basis of low consequence (CRWMS M&O, 2001c). The basic chemical processes that occur at phase boundaries (principally liquid/solid) are included in other features, events, and processes. Solid/solid contact occurs or could occur between the drip shield and the invert, backfill, or both, (if included in the Yucca Mountain project design) between the waste package and the invert, backfill, or both, (if included in the Yucca Mountain project design) between the pedestal and the waste package, drip shield, or both, and between the waste form and any other engineered barrier subsystem component materials. Because these materials are all relatively inert, no significant solid/solid interaction mechanisms have been identified relative to the basic seepage water-induced corrosion of the engineered barrier subsystem components and, hence, this feature-event-process is excluded on the basis of low consequence. However, interfaces between solid phases in contact with an aqueous phase can accelerate degradation processes such as crevice corrosion of the waste package or galvanic coupling of the drip shield to steel components [see screening arguments 2.1.03.01.00 (Corrosion of Waste Containers) and 2.1.03.04.00 (Hydride Cracking of Waste Containers and Drip Shields)].	This issue is addressed by an existing agreement (Container Life and Source Term Subissue 6, Agreement 1). DOE agreed to provide clarification of the screening argument in FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation, ANL–EBS–PA–000002, as necessary, on completion of the agreement item.
ENG2 ENG4	79	2.1.07.01.00 [Rockfall (Large Block)]. [Disruptive Event & Waste Package]: The effects of 2.1.07.01.00 [Rockfall (Large Block)] on the drip shield and waste package have been screened as excluded (CRWMS M&O, 2000a, 2001c,f). The Drift Degradation Analysis Analysis and	Existing agreements from Repository Design and Thermal Mechanical Effects agreements (Subissue 3, Agreements 17 and 19) and Container Life and Source Term (Subissue 2, Agreements 2, 3, and 8) address related work. DOE agreed to provide clarification of the screening argument in FEPs Screening of Processes and Issues in Drip Shield and Waste Package

Table B–1. NRC Comments on Features, Events, and Processes and Path Forward for Resolution Including, DOE and NRC Agreements (continued)			
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		Model Report (CRWMS M&O, 2000n) indicates that thermal loading, seismicity, and time-dependent mechanical degradation of the host rock would have minor effects on the integrity of the drifts through the entire period of regulatory concern. The NRC staff at the DOE and NRC Repository Design and Thermal-Mechanical Effects Technical Exchange identified several deficiencies [see the comments on 2.1.07.02.00 (Mechanical Degradation or Collapse of Drift) for additional discussion pertaining to the DOE rockfall analyses]. As noted at the Container Life and Source Term and Repository Design and Thermal-Mechanical Effects Technical Exchanges, the rockfall on drip shield analyses (CRWMS M&O, 2000c) did not consider (i) temperature effects on mechanical material behavior, (ii) seismic motion of the supporting invert, (iii) point load impacts, (iv) appropriate material failure criteria, (v) material degradation processes, (vi) multiple rock block impacts, or (vii) boundary conditions that account for the potential interactions between the drip shield and gantry rails. Consequently, DOE has not adequately demonstrated that the drip shield has been designed to withstand 6-, 10-, or 13-MT rock-block impacts. Because the framework for the invert is constructed from carbon steel, the potential degradation may affect orientation of the waste packages during time. In other words, the invert floor cannot be expected to keep the waste packages in a horizontal position for the entire regulatory period. As a result, rock-block impacts on the waste package may occur at angles not perpendicular to the waste package longitudinal axis. Angled rock-block impacts near the closure lid welds may have significantly different results than nonangled impacts. This scenario is new and was not presented to DOE. [Cladding]: Mechanical failure of cladding from rockfall is excluded based on low probability because rockfall on an intact waste package will not cause rod failure (CRWMS M&O, 2000j). The main screening argument is based on an intact waste package. The discussion is confusing because arguments based on the presence of backfill are also used in quantitative estimates. Although the conclusion can be acceptable, because of the presence of an intact waste package, the screening arguments should be improved on the basis of appropriate calculations.	Degradation, ANL–EBS–PA–000002, and Features, Events, and Processes: Screening for Disruptive Events, ANL–WIS–MD–000005, to address the NRC comment.
ENG1 ENG2 ENG3	77	2.1.07.02.00 (Mechanical Degradation or Collapse of Drift) has been screened as excluded (CRWMS M&O, 2000a 2001f) based on CRWMS M&O (2000n), which indicates that the emplacement drifts would essentially maintain their integrity through the period of regulatory concern. DOE is expected to revise the Drift Degradation Analysis to satisfy Repository Design and Thermal-Mechanical Effects Agreements 3.17 and 3.19 (DOE and NRC Technical Exchange on Repository Design and Thermal-Mechanical Effects, February 6–8, 2001, Las Vegas, Nevada). At this stage, the screening argument is considered closed-pending given the existence of the Repository	No additional DOE action is required. Repository Design and Thermal-Mechanical Effects Subissue 3, Agreements 17 and 19, address concern on drift collapse.

Table B–1. NRC Comments on Features, Events, and Processes and Path Forward for Resolution Including, DOE and NRC Agreements (continued)			
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		Design and Thermal-Mechanical Effects Agreements 3.17 and 3.19. It should be noted, however, that the current state of knowledge on unsupported openings in fractured rock indicates most drifts are likely to collapse soon after cessation of maintenance. This opinion is consistent with the conclusion of the DOE expert panel on drift stability* and recent analyses of the behavior of unsupported drifts in fractured rock during seismic loading from an earthquake (Hsiung, et al., 2001). Drift collapse could have implications on temperature, chemistry, seepage into drifts, and drip shield performance.	
ENG1 ENG2 ENG3	37	2.1.07.05.00 (Creeping of Metallic Materials in the Engineered Barrier Subsystem) has been excluded from consideration in the total-system performance assessment code (CRWMS M&O, 2001c,f). Although DOE correctly points out in the screening argument (CRWMS M&O, 2001c) " ... the deformation of many titanium alloys loaded to yield point does not increase with time" (American Society for Metals International, 1990), it still does not specifically address the potential for creeping of titanium Grades 7 and 24. For example, some titanium alloys have been shown to creep at room temperatures (Ankem, et al., 1994). Creeping of the titanium drip shield subjected to dead loads caused by fallen rock blocks, drift collapse, or both could significantly reduce the clearance between the drip shield and waste package during time. As a result, the drip shield may cause substantial damage to the waste package during its dynamic response to subsequent seismic loads. In addition, creeping could potentially cause separation of the individual drip shield units.	Treatment of creep of the drip shield will be addressed as part of an existing agreement related to drip shield rockfall analyses (Container Life and Source Term Subissue 2, Agreement 8). DOE agreed to provide the technical basis for the screening argument in FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation, ANL–EBS–PA–000002, to address the NRC comment.
ENG1 ENG2 ENG4	56	2.1.07.06.00 (Floor Buckling) has been screened as excluded in (CRWMS M&O, 2001f) and EBS Radionuclide Transport Abstraction Analyses and Model Report (CRWMS M&O, 2000o) based on analyses documented in Repository Ground Support Analysis for Viability Assessment (CRWMS M&O, 1998a), which indicate that floor heave from thermal-mechanical effects would not exceed approximately 10 mm [0.391 in]. However, to address concerns raised by the NRC staff about appropriateness of the thermal-mechanical properties used in DOE calculations (such as the analyses cited previously), DOE agreed to revise its assessment of floor buckling [Repository Design and Thermal-Mechanical Effects Agreement 3.9 (DOE and NRC Technical Exchange on Repository Design and Thermal-Mechanical Effects, February 6–8, 2001, Las Vegas, Nevada)]. Note the screening argument relies on analyses that DOE agreed to address outstanding NRC concerns in Repository Design and Thermal-Mechanical Effects Agreements 3.2–3.13 (Repository Design and Thermal-Mechanical Effects Technical Exchange, February 6–8, 2001, Las Vegas, Nevada).	This issue is addressed by existing DOE and NRC agreements (Repository Design and Thermal-Mechanical Effects Subissue 3, Agreements 2–13). DOE agreed to include the analysis of floor buckling for postclosure conditions, consistent with the site-specific parameters and loading conditions used to satisfy Repository Design and Thermal-Mechanical Effects Subissue 3, Agreements 2–13. Engineered Barrier Subsystem Features, Events, and Processes, ANL–WIS–PA–000002, will be revised to include this information.
UZ2	59	2.1.08.04.00 (Cold Traps) is screened as excluded on the basis of low consequence (CRWMS M&O, 2001f). Emplacement of waste in the drifts creates thermal gradients within the repository that may result in condensation forming on the roof of the drifts or	This issue is addressed by an existing DOE and NRC agreement (Thermal Effects on Flow Subissue 2, Agreement 5). Engineered Barrier System Features, Events, and Processes, ANL–WIS–PA–000002, will be revised on completion of this agreement.

Table B–1. NRC Comments on Features, Events, and Processes and Path Forward for Resolution Including, DOE and NRC Agreements (continued)			
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		elsewhere in the engineered barrier subsystem, leading to enhanced dripping on the drip shields, waste packages, or exposed waste material. The DOE Multiscale Thermohydrologic Model does not account for mass transport along the length of drifts. The only Multiscale Thermohydrologic Model submodel that includes thermal hydrology (i.e., mass transport) is a cross section of a drift, so it accounts for potential condensation only along the radial axis.	
ENG1 ENG3	42	2.1.08.07.00 (Pathways for Unsaturated Flow and Transport in the Waste and Engineered Barrier System) evaluates unsaturated flow and radionuclide transport that may occur along preferential pathways in the waste and engineered barrier subsystem (CRWMS M&O, 2000i). DOE indicates that preferential pathways are already included via "... a series of linked one-dimensional flowpaths and mixing cells through the engineered barrier subsystem, drip shield, waste package, and into the invert" (CRWMS M&O, 2000i). Staff are concerned that preferred pathways in the engineered barrier subsystem are not being evaluated at the appropriate scale. Water has been observed to drip preferentially along grouted rock bolts in the enhanced characterization of the repository block, (e.g., demonstrating that introduced materials can influence the location of preferred flow pathways). Interactions with engineered materials, such as cementitious and metallic components, can have a significant effect on evolved water and gas compositions. Because the description of 2.1.08.07.00 (Pathways for Unsaturated Flow and Transport in the Waste and Engineered Barrier System) states "Physical and chemical properties of the engineered barrier subsystem and waste form, in both intact and degraded states, should be considered in evaluating [preferential] pathways ... ", staff expect the screening arguments to be based on an evaluation of these topics (NRC, 2000).	This issue is addressed by an existing DOE and NRC agreement (Evolution of the Near-Field Environment Subissue 2, Agreements 6, 10, and 14). Engineered Barrier System Features, Events, and Processes, ANL–WIS–PA–000002, will be updated on completion of these agreement items.
ENG3	54	2.1.09.02.00 (Interaction with Corrosion Products) is excluded in the engineered barrier subsystem (except for colloid-related effects) on the basis of low consequence (CRWMS M&O, 2001f). As noted in the DOE and NRC Technical Exchange on Evolution of the Near-Field Environment, changes in seepage water chemistry resulting from interactions with engineered materials and their corrosion products were not adequately addressed in CRWMS M&O (2000p). Water has been observed to drip preferentially along grouted rock bolts in the enhanced characterization of the repository block, (e.g., demonstrating that introduced materials can influence the location of preferred flow pathways). Seepage waters that have interacted with engineered materials and their corrosion products can have a significant effect on evolved water and gas compositions.	This issue is addressed by an existing DOE and NRC agreement (Evolution of the Near-Field Environment Subissue 2, Agreements 6, 10, and 14). Engineered Barrier System Features, Events, and Processes, ANL–WIS–PA–000002, will be updated on completion of these agreement items.
ENG1	36	2.1.09.03.00 (Volume Increase of Corrosion Products) is screened as excluded on the basis of low consequence (CRWMS M&O, 2001c). The presence of waste package corrosion products with higher molar volume than the uncorroded material that may change the stress state in the material being corroded is excluded in the case of the waste package based on	DOE agreed to provide the technical basis for the screening argument in FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation, ANL–EBS–PA–000002, to address the NRC comment.

Table B–1. NRC Comments on Features, Events, and Processes and Path Forward for Resolution Including, DOE and NRC Agreements (continued)			
Integrated Subissue	**Technical Exchange**	**Comment**	**Path Forward**
		low consequence. These products, however, may have an effect on corrosion processes such as stress corrosion cracking of the outer container, after its initial breaching, that may affect radionuclide release [see 2.1.03.07.00 (Mechanical Impact on the Waste Container and Drip Shield)]. The possibility of additional sources of stress arising from the formation of corrosion products should be evaluated in regard to stress corrosion cracking. See comment for 2.1.11.05.00 (Differing Thermal Expansion of Repository Components).	
ENG1	55	2.1.09.07.00 (Reaction Kinetics in Waste and Engineered Barrier Subsystem). [Engineered Barrier Subsystem]: Item is screened as excluded on the basis of low consequence (CRWMS M&O, 2001f). Consideration of chemical reactions, such as radionuclide dissolution/precipitation reactions and reactions controlling the reduction-oxidation state is included by considering reaction kinetics in the in-package equilibrium model, however, reaction kinetics are excluded based on low consequence for the engineered barrier subsystem. But these processes may affect composition of the near-field environment, particularly trace elements. The effect on corrosion of container materials could be indirect and should be considered. [Waste Form Miscellaneous]: Item is screened as excluded on the basis of low consequence (CRWMS M&O, 2000i). Adequate technical bases have not been provided to demonstrate that the combination of transport processes and reaction kinetics in the engineered barrier subsystem will not adversely impact performance by altering the composition of water contacting the drip shield and waste package.	This issue is addressed by an existing DOE and NRC agreement (Evolution of the Near-Field Environment Subissue 2, Agreements 5, 8, 11, and 12). Engineered Barrier System Features, Events, and Processes, ANL–WIS–PA–000002, will be updated on completion of these agreement items.
UZ2	63	2.1.09.12.00 [Rind (Altered Zone) Formation in Waste, Engineered Barrier Subsystem, and Adjacent Rock]. The thermal-hydrological-chemical model is screened as included, and the thermal-hydrological model, effects on transport is screened as excluded on the basis of low consequence (CRWMS M&O, 2001b). Thermal-chemical processes alter the rock forming the drift walls mineralogically. These alterations have hydrological, thermal, and mineralogical properties different from the current country rock.	This issue is addressed by existing agreements between DOE and NRC (Evolution of the Near-Field Environment Subissue 1, Agreement 3). FEPs in Thermal Hydrology and Coupled Processes, ANL–NBS–MD–000004, will be revised on completion, to meet this agreement.
ENG4 UZ3 SZ2	5	2.1.09.21.00 (Suspension of Particles Larger Than Colloids). CRWMS M&O (2001e) states these particles will be included and treated as colloids. 2.1.09.21.00 (Suspension of Particles Larger Than Colloids) is not addressed in CRWMS M&O (2001d), however, and is noted as excluded in two other model components in the Yucca Mountain FEP Database (CRWMS M&O, 2001g). Furthermore, it is not clear how the effects of particles are included with colloids. 2.1.09.21.00 (Suspension of Particles Larger Than Colloids) should be addressed as part of the scope of CRWMS M&O (2001d). In addition, the integration of 2.1.09.21.00 (Suspension of Particles Larger Than Colloids) across the engineered barrier subsystem, unsaturated zone, and saturated zone should be clarified.	DOE agreed to provide clarification for the screening argument in Features, Events, and Processes in SZ Flow and Transport, ANL–NBS–MD–000002, to address the NRC comment.

Table B–1. NRC Comments on Features, Events, and Processes and Path Forward for Resolution Including, DOE and NRC Agreements (continued)			
Integrated Subissue	**Technical Exchange**	**Comment**	**Path Forward**
ENG4 UZ3	J-5	2.1.09.21.00 (Suspensions of Particles Larger than Colloids) is screened excluded from the engineered barrier subsystem transport and waste form release abstractions (CRWMS M&O, 2000q, 2001d). Exclusion is based on the assumption that although particles may be transported through fractures in the unsaturated zone, low groundwater velocities through the saturated zone would lead to particle settling (CRWMS M&O, 2000q), suggesting inconsistency in the screening analysis. Without quantitative measures of particle size, pore size, groundwater velocity, and chemical variability, however, these qualitative assertions are difficult to evaluate. Because DOE includes colloid formation features, events, and processes in its screening analysis, and because of the large amounts of iron particles that may be introduced in the engineered barrier subsystem, particle transport through the engineered barrier subsystem into the unsaturated zone is plausible. Exclusion of 2.1.09.21.00 (Suspensions of Particles Larger Than Colloids) may be acceptable, but it is necessary to have a more complete technical basis and calculations to support exclusion of this item on the basis of low consequence.	DOE agreed to provide clarification of the screening argument in Waste Form Colloid-Associated Concentration Limits: Abstraction and Summary ANL–WIS–MD–000012, to address the NRC comment.
UZ2	65	2.1.11.02.00 (Nonuniform Heat Distribution/Edge Effects in Repository). The thermal-hydrological and thermal-hydrological-chemical aspects are screened as included and the (thermal-mechanical effects) are screened as excluded on the basis of low consequence (CRWMS M&O, 2001b). Temperature inhomogeneities in the repository lead to localized accumulation of moisture. Uneven heating and cooling at repository edges lead to nonuniform thermal effects during both the thermal peak and the cool-down periods.	Repository-wide, nonuniform heating effects are the subject of existing DOE and NRC agreements (Thermal Effects on Flow Subissue 2, Agreement 5, and Repository Design and Thermal-Mechanical Effects Subissue 3, Agreements 20 and 21). FEPs in Thermal Hydrology and Coupled Processes, ANL–NBS–MD–000004, will be revised on completion of this agreement. Thermal-Hydrological-Mechanical continuum modeling will address nonuniform effects at a mountain scale. This information will be provided in Coupled Thermal-Hydrological-Mechanical Effects on Permeability Analysis and Model Report, ANL–NBS–HS–000037.
ENG1 ENG2	38	2.1.11.05.00 (Differing Thermal Expansion of Repository Components) has been excluded from consideration in the total-system performance assessment code (CRWMS M&O, 2001c,f). The technical basis for excluding differing thermal expansion effects on repository performance is not comprehensive nor adequate. For example, according to the screening arguments (CRWMS M&O, 2001c), ... the difference in temperature between the inside of the waste package inner barrier (316NG) and the outside of the waste package outer barrier (Alloy 22) never exceeds 2 °C [35.6 °F]. As an illustrative example, using the coefficients of thermal expansion for the two materials discussed above (i.e., Alloy 22 and 316NG) and a bounding 5 °C [41 °F] (or 5 K) temperature difference between them, the calculated strain is $2.15 \cdot 10^{5}$. This strain is so small that thermal expansion of waste package barriers will result in a negligible effect on expected mean dose rate. A ~1 mm [0.0394 in] gap will prevent the resultant stress due to the differing thermal expansion coefficients of the waste package materials from reaching a critical level that could lead to stresses in	DOE agreed to provide the technical basis for the screening argument in FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation, ANL–EBS–PA–000002, to address the NRC comment.

Table B–1. NRC Comments on Features, Events, and Processes and Path Forward for Resolution Including, DOE and NRC Agreements (continued)			
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		the waste package barriers. The Waste Package Operation Fabrication Process Report (CRWMS M&O, 2000r, Section 8.1.8) requires a loose fit between the outer barrier (Alloy 22) and the inner shell (316NG stainless steel) to accommodate the differing thermal expansion coefficients, and so 2.1.11.05.00 (Differing thermal expansion of repository components) can be excluded for the waste packages based on low consequence to the expected annual dose. The quoted rationale is not technically correct and does not address the limited clearance between the inner and outer barriers of the waste package in the axial direction, which may be as small as 2 mm [0.0787 in] according to design drawings (CRWMS M&O, 2000s). In addition, the differential thermal expansion between various invert components and the drift wall (to which they are attached) has not been addressed. 2.1.11.05.00 (Differing Thermal Expansion of Repository Components) is excluded on the basis of low consequence (CRWMS M&O, 2001c,f). Peak temperature of waste packages with 0.5-m [19.68-in] spacing and 50-year ventilation is 278 °C [532.4 °F] with backfill and 176 °C [348.8 °F] without backfill. The screening argument is that the temperature differential between the inner type 316NG barrier and the outer Alloy 22 barrier is 5C° [41 °F] with a corresponding strain of 2.15×10^{5}. This calculation is performed using the difference between the thermal expansion coefficients for Type 316NG stainless steel and Alloy 22 using the maximum expected temperature difference between the waste package barriers. There will be at least a 1-mm [0.0394-in]gap between the barriers, and no thermal stresses are predicted. Calculations should use a temperature of the waste package rather than the difference between waste package barriers. The clearance between the inner type 316NG barrier and the outer Alloy 22 barrier is 0 to 4 mm [0.1575 in] as specified in the waste package design and fabrication process report (CRWMS M&O, 2000r). It is implicit that this clearance is specified at ambient temperature [i.e., 25 °C (77 °F)] because (i) no temperature is specified and (ii) the Alloy 22 waste package outer barrier will be heated to 371 °C [700 °F] for inner 316NG barrier cylinder installation. Using a temperature of 186 °C [366.8 °F], the calculated strain is 7.99×10^{4}. For a waste package with clearance gaps of 1 mm [0.0394 in] or less at 25 °C [77 °F], thermal stresses will occur as a result of the differences in thermal expansion.	
ENG3	60	The exclusion of 2.1.12.01.00 (Gas Generation) and 2.1.12.05.00 (Gas Generation from Concrete) in CRWMS M&O (2000i, 2001f) is unacceptable, because adequate technical bases have not been provided to justify the characterization of chemical environments in the engineered barrier subsystem in terms of bulk water and gas compositions. The possibility of local heterogeneity in gas composition in the drift, altering the chemistry of the drip shield/waste package environment and adversely	This issue is partially addressed by an existing DOE and NRC agreement (Evolution of the Near-Field Environment Subissue 2, Agreement 6). DOE agreed to provide the technical basis for the screening argument in Engineered Barrier System Features, Events, and Processes, ANL–WIS–PA–000002, to address the NRC comment.

Table B–1. NRC Comments on Features, Events, and Processes and Path Forward for Resolution Including, DOE and NRC Agreements (continued)

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		impacting repository performance, should be explored. Local variations in the efficiency of advection/diffusion processes, relative to reaction rates, should be evaluated.	
ENG1 ENG3 ENG4	32	2.1.13.01.00 (Radiolysis) is excluded based on low consequence (CRWMS M&O, 2000i, 2001c). [Waste Package]: Alpha, beta, gamma, and neutron irradiations of air saturated water can cause changes in chemical conditions (Eh, pH, and concentration of reactive radicals) and positive shifts in corrosion potential from the formation of hydrogen peroxide. DOE, on the bases of experimental work, concluded that radiolysis will not lead to localized corrosion of Alloy 22. Additional work, however, is necessary to complete the evaluation of the critical potentials related to localized corrosion of Alloy 22. [Waste Form Miscellaneous]: Screening argument considers only radiolysis of water to produce hydrogen and oxidants. No consideration of the formation of nitric acid resulting from radiolysis in presence of air. Spent nuclear fuel is expected to have higher dissolution rates at lower pH, thus, ignoring nitric acid may underestimate radionuclide release. Potential production of nitric acid from radiolysis of N_2 in air should be considered. It is necessary to consider potential effect of acid environments on the corrosion of Alloy 22 and titanium.	DOE agreed to provide additional information on critical potentials for localized corrosion at the DOE and NRC Container Life and Source Term Technical Exchange (September 12–13, 2000). DOE agreed to provide clarification of the screening argument in FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation, ANL–EBS–PA–000002, to address the NRC comment.
ENG4 UZ3 SZ2	74	2.1.14.01.00 (Criticality in Waste and Engineered Barrier Subsystem) was preliminarily excluded in the document (CRWMS M&O, 2000t) based on low probability. A preliminary screening status was assigned because the criticality calculations were not complete for DOE spent nuclear fuel after igneous intrusion and near-field and far-field criticality of all waste types following igneous disruption. The excluded screening status will be regarded unacceptable until concerns on the calculation of the probability for criticality are addressed. Because the probability of criticality depends on the presence of a breach of the waste package barriers, most of the discussion of criticality probability is focused on the probability of waste package failure. DOE referenced the document, Probability of Criticality in 10,000 Years (CRWMS M&O, 2000u), for addressing the criticality probability from early failure by stress corrosion cracking, waste package damage after igneous intrusion, and seismic events. DOE referenced the screening argument for rockfall [2.1.07.01 (Rockfall)] for screening damage to the waste package and drip shield from seismically induced rockfall. In general, DOE needs to address the concerns raised on the waste package and mechanical disruption related features, events, and processes, and the issues raised at the Container Life and Source Term Technical Exchange before it can conclude there is no waste package breach before 10,000 years. The concerns on the probability calculation in the document, Probability of Criticality in 10,000 Years (CRWMS M&O, 2000u) are	The current criticality agreements include concerns and DOE does not need to take any additional action. The following entries are also considered closed-pending in light of existing criticality agreements: 2.1.14.02.00 (Criticality *In Situ*, Nominal Configuration, Top Breach) 2.1.14.03.00 (Criticality *In Situ*, Waste Package Internal Structures Degrade Faster Than Waste Form, Top Breach) 2.1.14.04.00 (Criticality *In Situ*, Waste Package Internal Structures Degrade at Same Rate as Waste Form, Top Breach) 2.1.14.05.00 (Criticality *In Situ*, Waste Package Internal Structures Degrade Slower Than Waste Form, Top Breach) 2.1.14.06.00 (Criticality *In Situ*, Waste Form Degrades in Place and Swells, Top Breach) 2.1.14.07.00 (Criticality *In Situ*, Bottom Breach Allows Flow Through Waste Package, Fissile Material Collects at Bottom of Waste Package) 2.1.14.08.00 (Criticality *In Situ*, Bottom Breach Allows Flow Through Waste Package, Waste Form Degrades in Place) 2.1.14.09.00 (Near-Field Criticality, Fissile Material Deposited in Near-Field Pond) 2.1.14.10.00 (Near-Field Criticality, Fissile Solution Flows into Drift Lowpoint) 2.1.14.11.00 (Near-Field Criticality, Fissile Solution Is Adsorbed or Reduced in Invert) 2.1.14.12.00 (Near-Field Criticality, Filtered Slurry, or Colloidal Stream Collects on Invert Surface)

Table B–1. NRC Comments on Features, Events, and Processes and Path Forward for Resolution Including, DOE and NRC Agreements (continued)			
Integrated Subissue	**Technical Exchange**	**Comment**	**Path Forward**
		• The conclusion of waste package failure probability of 2.7 x 10 ^{11} from stress corrosion cracking, based on the equation in Section 6.1.1, is contrary to the total system performance assessment results that indicate the first waste package failure, using the upper-bound curve, from stress corrosion cracking at approximately 10,000 years. • The screening argument for 1.2.03.02.00 (Seismic Vibration Causes Container Failure) fails to consider the appropriate combinations of dead loads (caused by drift collapse, fallen rock blocks, or both), rock block impact, and seismic excitation or the ability of these loads to initiate cracks, propagate preexisting cracks, or both. • The screening argument for seismic events does not consider the indirect effects, such as causing dents, which could aid in the collection and channeling of water, or tilting the waste packages, which would result in greater height of the water within the waste package. Seismic shaking, combined with a sloped waste package, may also allow materials to accumulate at one end of a waste package to form a more reactive geometry. • The screening argument for seismically induced rockfall damaging the drip shield and waste package includes several deficiencies as documented in the staff review of the Drift Degradation Analysis Analysis and Model Report (CRWMS M&O 2000n) and 2.1.07.01.00 [Rockfall (Large Block)]. Other concerns related to the impact of rockfall on the waste package are reflected in the comments on the related features, events, and processes. • The calculation of the criticality probability does not fully consider mechanisms that could result in accelerated degradation of the fuel during an igneous event, such as burning Zircaloy or creep of the fuel at high temperatures. • The analysis of damage to DOE Zone 2 waste packages (CRWMS M&O, 2000u) fails to consider long-term exposure to high temperatures changing the microstructure of Alloy 22 and reducing the mechanical strength of the material (e.g., Rebak, et al., 1999) or the differences in thermal expansion between the inner barrier type 316NG stainless steel and the outer barrier Alloy 22 causing significant hoop-stress on waste package walls, in addition to the internal pressurization effects analyzed in CRWMS M&O (2000u). Analyses in CRWMS M&O (2000u) also do not consider potentially adverse chemical reactions, such as sulfidation reactions, in response to magmatic degassing or contact with basaltic magma. These processes could cause a more significant breach than the 10-cm^2 [1.55-in^2] hole currently assumed for waste packages located in DOE Zone 2 during basaltic igneous events. • The calculation does not consider any changes to drift by the magma, such as magma solidifying in the lower part of the drift, causing ponding above	2.1.14.13.00 (Near-Field Criticality Associated with Colloidal Deposits) 2.2.14.01.00 (Critical Assembly Forms Away from Repository) 2.2.14.02.00 (Far-Field Criticality, Precipitation in Organic Reducing Zone in or Near Water Table) 2.2.14.03.00 (Far-Field Criticality, Sorption on Clay/Zeolite in Topopah Springs Basal Vitrophyre) 2.2.14.04.00 (Far-Field Criticality, Precipitation Caused by Hydrothermal Upwell or Redox Front in the Saturated Zone) 2.2.14.05.00 (Far-Field Criticality, Precipitation in Perched Water Above Topopah Springs Basal Vitrophyre) 2.2.14.06.00 (Far-Field Criticality, Precipitation in Fractures of Topopah Springs Welded Rock) 2.2.14.07.00 (Far-Field Criticality, Dryout Produces Fissile Salt in a Perched Water Basin) 2.2.14.08.00 (Far-Field Criticality Associated with Colloidal Deposits)

Table B–1. NRC Comments on Features, Events, and Processes and Path Forward for Resolution Including, DOE and NRC Agreements (continued)			
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		and around the waste package, or fractures forming in the cooled magma, that may provide preferential pathways to the waste package. Finally, the unsaturated flow may be modified by the presence of 1,170 °C [2,138 °F] magma so current parameters may no longer be valid. • The criticality probability document is inconsistent when discussing the water content of the magma in Section 5.3.2. The text indicates the magma would consist of a conservative 5-wt% water content, but Table 5-1 lists the water content as only 0.05 wt%. The computer files provided with the document that contained the actual calculations used a more realistic water content of 1.6 percent. A water content of 5 wt% would clearly be conservative, but justification needs to be provided if a lower water content is used in the calculations.	
UZ2	69	2.2.01.01.00 (Excavation and Construction-Related Changes in the Adjacent Host Rock). Initial effects on seepage are screened as included, and permanent thermal-hydrological-chemical and thermal-mechanical effects are screened as excluded on the basis of low consequence (CRWMS M&O, 2001b). Stress relief leading to dilation of joints and fractures is expected in an axial zone of up to one diameter-width surrounding the tunnels.	Thermal-mechanical effects on rock properties are addressed by an existing DOE and NRC agreement (Repository Design and Thermal-Mechanical Effects Subissue 3, Agreements 20 and 21). FEPs in Thermal Hydrology and Coupled Processes, ANL–NBS–MD–000004, will be revised on completion of this agreement.
ENG2 UZ2	62	2.2.01.02.00 (Thermal and Other Waste and Engineered Barrier Subsystem-Related Changes in the Adjacent Host Rock) is screened as excluded on the basis of low consequence (thermal-mechanical effects) and low probability (thermal-hydrological-chemical and backfill effects) (CRWMS M&O, 2001b). Changes in host rock properties result from thermal effects or other factors related to emplacement of the waste and engineered barrier subsystem, such as mechanical or chemical effects of backfill. Properties that may be affected include rock strength, fracture spacing and block size, and hydrologic properties such as permeability. The screening argument did not consider mechanical degradation of the rock mass, such as fracture-wall rock alteration owing to long-term exposure to heat, moisture, and atmospheric conditions. Such degradation would increase the severity of mechanical failure (Ofoegbu, 2000). DOE, however, is expected to reevaluate its assessment of long-term mechanical degradation to satisfy outstanding DOE and NRC agreements (Repository Design and Thermal-Mechanical Effects Subissue 3, Agreements 11 and 19). In the analyses, it is necessary to account for long-term mechanical degradation of the host rock mass in the assessment of drift degradation, rockfall, and changes in hydrological properties and their effects on repository performance.	Thermal-mechanical effects on fractures will be addressed by existing agreements between DOE and NRC (Repository Design and Thermal-Mechanical Effects Subissue 3, Agreements 20 and 21). FEPs in Thermal Hydrology and Coupled Processes, ANL–NBS–MD–000004, will be revised on completion of this agreement. Long-term degradation of the host rock is addressed by existing agreements between DOE and NRC (Repository Design and Thermal-Mechanical Effects Subissue 3, Agreements 11 and 19). DOE will provide an improved technical basis for 2.2.01.02.00 (Thermal and Other Waste and Engineered Barrier Subsystem-Related Changes in the Adjacent Host Rock) by performing a postclosure drift deformation analysis that incorporates postclosure loads and rock properties using relevant information from existing agreements (Repository Design and Thermal-Mechanical Effects Subissue 3, Agreements 2–13). Engineered Barrier System Features, Events, and Processes, ANL–WIS–PA–000002, will be revised to include this information.
UZ2 ENG3	66	2.2.06.01.00 [Changes in Stress (Due to Thermal, Seismic, or Tectonic Effects), Change Porosity, and Permeability of Rock] is screened as excluded on the basis of low consequence and low probability (for one secondary entry) (CRWMS M&O, 2001b). Even small changes in the fracture openings cause large changes in permeability. The rock deforms according to the	Thermal-mechanical effects on rock properties are addressed by an existing DOE and NRC agreement (Repository Design and Thermal-Mechanical Effects Subissue 3, Agreements 20 and 21). FEPs in Thermal Hydrology and Coupled Processes, ANL–NBS–MD–000004, and the Features, Events, and Processes: Screening for Disruptive Events,

Table B–1. NRC Comments on Features, Events, and Processes and Path Forward for Resolution Including, DOE and NRC Agreements (continued)			
Integrated Subissue	**Technical Exchange**	**Comment**	**Path Forward**
		rock stress field. Changes in the groundwater flow and in the temperature field will change the stress acting on the rock, which will, in turn, change the groundwater flow. 2.2.06.01.00 [Change in Stress (Due to Thermal, Seismic, or Tectonic Effects), Change Porosity, and Permeability of Rock] is excluded as having low consequence to dose (CRWMS M&O, 2000a). However, the DOE analyses used to support the screening argument (CRWMS M&O, 2000v) did not consider water-flux diversion toward a drift from the adjacent pillar caused by increased aperture of subhorizontal fractures in the pillar from thermal-mechanical response. Such flux diversion would cause increased water flow to the drifts.	ANL–WIS–MD–000005, will be revised on completion of this agreement.
UZ2	J-20	2.2.07.05.00 (Flow and Transport in the Unsaturated Zone from Episodic Infiltration). Excluded based on low consequence (CRWMS M&O, 2001d). Screening argument asserts that episodic infiltration is expected to be attenuated by flow in the paintbrush nonwelded tuff layer such that unsaturated zone flow beneath this layer is effectively steady-state. Analyses to support this assertion, however, have only considered episodic infiltration with an average of 5 mm/yr [0.197 in/yr] infiltration flux. Area-average infiltration flux over the proposed repository horizon at Yucca Mountain is expected to exceed 20 mm/yr [0.787 in/yr] during future wetter climate conditions.	This issue is addressed by existing agreements between DOE and NRC (Unsaturated and Saturated Flow Under Isothermal Conditions Subissue 4 Agreement 4). Features, Events, and Processes in UZ Flow and Transport, ANL–NBS–MD–000001, will be revised on completion of this work.
UZ3 SZ1 SZ2	J-6	2.2.07.15.00 (Advection and Dispersion). As defined, this item does not apply to the unsaturated zone and is not discussed in CRWMS M&O (2001d). Given that advection and dispersion are key components of the DOE radionuclide transport in the unsaturated zone model abstraction, the definition of 2.2.07.15.00 (Advection and Dispersion) should be extended to include these aspects (advection and dispersion) in the unsaturated zone.	DOE will add this features, events, processes to Features, Events, and Processes in UZ Flow and Transport, ANL–NBS–MD–000001, and present the DOE discussion in the screening argument.
UZ2	USFIC-1	2.2.07.18.00 (Film Flow into Drifts) is screened as included on the basis of low consequence (low film flow rates). Higher film flow rates into drifts are considered included (CRWMS M&O, 2001d). Technical bases for the screening argument for 2.2.07.18.00 (Film Flow into Drifts) will derive from work needed to satisfy the Unsaturated and Saturated Flow Under Isothermal Conditions Subissue 4, Agreement 2.	At the Unsaturated and Saturated Flow Under Isothermal Conditions DOE and NRC Technical Exchange, DOE agreed to include the effect of the low-flow regime processes (e.g., film flow) in the DOE seepage fraction and seepage flow, or justify that it is not needed (Subissue 4, Agreement 2). No additional work is required to derive the technical basis for the screening argument for 2.2.07.18.00 (Film Flow into Drifts).
UZ3	J-7	2.2.08.01.00 (Groundwater Chemistry/Composition in Unsaturated Zone and Saturated Zone) is excluded. DOE included the current ambient groundwater conditions in the Total System Performance Assessment–Site Recommendation abstraction of radionuclide transport in the unsaturated zone, but has excluded future changes (CRWMS M&O, 2000w, 2001d). DOE asserts that thermal effects on chemistry are minimal, but assertion focuses mainly on the effects of dissolution and precipitation on hydrologic properties. The screening argument refers to a model of thermal-chemical effects on seepage water chemistry at the drift wall (CRWMS M&O,	This issue is addressed by existing agreements between DOE and NRC (Evolution of the Near-Field Environment Subissue 1 Agreement 4, and Subissue 4 Agreements 3 and 4, Radionuclide Transport Subissue 1 Agreement 5, and Subissue 2 Agreement 10). Features, Events, and Processes in UZ Flow and Transport, ANL–NBS–MD–000001, will be revised on completion of this work.

Table B–1. NRC Comments on Features, Events, and Processes and Path Forward for Resolution Including, DOE and NRC Agreements (continued)			
Integrated Subissue	**Technical Exchange**	**Comment**	**Path Forward**
		2000x). Because modeled effects fell within the range of variation included in total system performance assessment, it is asserted that effects farther from the drift would be smaller, based on an unverified assumption (CRWMS M&O, 2001d). This argument does not address chemical changes below the repository, which are likely to be more significant than changes above, because of interactions with the engineered barrier subsystem and waste materials. Even so, predicted changes in key geochemical parameters (pH and total carbon) in seepage water are large enough to have an effect on sorption coefficients. Without the details on how expert judgment was used to derive the Total System Performance Assessment–Site Recommendation sorption parameters, it is not clear how the effects of changes in the ambient chemistry system are incorporated into the transport calculations. The technical basis for this exclusion is not satisfactory.	
UZ3 SZ2	J-8	2.2.08.02.00 (Radionuclide Transport Occurs in a Carrier Plume in Geosphere) is excluded from the Total System Performance Assessment–Site Recommendation abstraction of radionuclide transport in the unsaturated zone on the basis of low consequence (CRWMS M&O, 2000d, 2001d). The key assumption (CRWMS M&O, 2001d; Assumption 11) is that results from the near-field thermal-hydrological-chemical coupled processes model (CRWMS M&O, 2000x) can be used to bound the effects of similar coupled processes on far-field flow and transport. This assumption has not yet been verified. Because the screening argument for this item is focused primarily on thermal effects on the chemistry of seepage water entering the emplacement drifts, it does not appear to include other potential effects (colloids, interactions with waste forms, and engineered barrier subsystem materials). Also, 2.1.09.01.00 (Properties of a Carrier Plume in the Engineered Barrier Subsystem) is included in the process model report (CRWMS M&O, 2001f, y), suggesting that radionuclide transport in a carrier plume should be included in transport beyond the engineered barrier subsystem. The arguments presented for exclusion of 2.2.08.02.00 (Radionuclide Transport Occurs in a Carrier Plume in Geosphere) (CRWMS M&O, 2001d) do not appear sufficient at this time.	This issue is addressed by existing agreements between DOE and NRC (Evolution of the Near-Field Environment Subissue 1 Agreement 4, and Subissue 4 Agreements 3 and 4, and Radionuclide Transport Subissue 1 Agreement 5). Features, Events, and Processes in UZ Flow and Transport, ANL–NBS–MD–000001, will be revised on completion of this work.
UZ2 UZ3	J-9	2.2.08.03.00 [Geochemical Interactions in Geosphere (Dissolution, Precipitation, Weathering) and Effects on Radionuclide Transport] is excluded (CRWMS M&O, 2000d, 2001d) from the Total System Performance Assessment–Site Recommendation abstraction of radionuclide transport in the unsaturated zone on the basis of low consequence. The key assumption (CRWMS M&O, 2001d; Assumption 11) is that results from the near-field thermal-hydrological-chemical coupled processes model (CRWMS M&O, 2000x) can be used to bound the effects of similar coupled processes on far-field flow and transport. This assumption has not yet been verified. Predicted mineralogical changes (CRWMS M&O, 2000x) in response to the thermal effects of the repository are small (calcite only). Predicted changes in porosity and	This issue is addressed by existing agreements between DOE and NRC (Evolution of the Near-Field Environment Subissue 1 Agreements 4 and 7, and Subissue 2 Agreement 6). Features, Events, and Processes in UZ Flow and Transport, ANL–NBS–MD–000001, will be revised on completion of this work.

Table B–1. NRC Comments on Features, Events, and Processes and Path Forward for Resolution Including, DOE and NRC Agreements (continued)			
Integrated Subissue	**Technical Exchange**	**Comment**	**Path Forward**
		permeability are also small. Transport through fractures is conservatively modeled in the Total System Performance Assessment–Site Recommendation, assuming no retardation. The screening argument, however, only addresses changes in seepage water chemistry. It does not address the possibility of reduced (or enhanced) matrix diffusion through precipitation and dissolution. Diffusion into the matrix and sorption on matrix minerals can be an important retardation mechanism. The effect of small-volume changes on fracture armoring and diffusion into the matrix may be important. The current screening arguments are not sufficient and will depend, in part, on the verification of Assumption 11 that far-field changes to radionuclide transport in the unsaturated zone will be less than the calculated near-field changes (CRWMS M&O, 2001d). Effects on flow are excluded based on low consequence. Problems with modeling of drift-scale coupled processes (CRWMS M&O, 2000x) used to support this screening argument have been raised by NRC. Current agreements from the Evolution of the Near-Field Environment Technical Exchange may provide additional technical basis for the screening argument.	
UZ3	J-10	2.2.08.06.00 (Complexation in Geosphere) is excluded. DOE included the effects of ambient condition complexation in the Total System Performance Assessment–Site Recommendation abstraction of radionuclide transport in the unsaturated zone, but has excluded future changes (CRWMS M&O, 2000d, 2001d). The effects of complexation are "implicitly included in the radionuclide sorption coefficients," but there is no clear technical basis regarding the effects of organics or other ligands provided in establishing the K_d distributions (CRWMS M&O 2001d). Experimental results reported in Triay, et al. (1997) that form much of the basis for the sorption coefficient distributions only address the effects of organics on neptunium and plutonium sorption. The analysis and model report (CRWMS M&O, 2000w) does not provide additional information on the effect of organics on other radionuclides. The current process models do not address the effects of complexation on transport parameters, and the exclusion of changes to complex formation does not have sufficient support. In addition, the screening argument refers to modeling results on repository effects on seepage chemistry, which may not be relevant to transport conditions below the repository (CRWMS M&O, 2001d).	This issue is addressed by existing agreements between DOE and NRC (Evolution of the Near-Field Environment Subissue 1 Agreement 4, and Subissue 4 Agreements 3 and 4, and Radionuclide Transport Subissue 1 Agreement 5). Features, Events, and Processes in UZ Flow and Transport, ANL–NBS–MD–000001, will be revised on completion of this work.
Dose2 Dose3	20	The Yucca Mountain Project Database (CRWMS, 2001g) (Revision 00 ICN 01) does not indicate that 2.2.08.07.00 (Radionuclide Solubility Limits in the Geosphere) is relevant to the biosphere. This item is relevant for limiting the quantity of radioactive material that can leach radionuclides out of the soil or tephra deposit in the biosphere compared with the quantity of radionuclides that would be predicted to leach out of the deposit using only leach rate limits.	DOE will add this item to Evaluation of the Applicability of Biosphere-Related Features, Events, and Processes, ANL–MGR–MD–000011, and present the DOE discussion in the screening argument.

Table B–1. NRC Comments on Features, Events, and Processes and Path Forward for Resolution Including, DOE and NRC Agreements (continued)			
Integrated Subissue	**Technical Exchange**	**Comment**	**Path Forward**
UZ3	J-11	2.2.08.07.00 (Radionuclide Solubility Limits in the Geosphere) is excluded from the Total System Performance Assessment–Site Recommendation abstraction of radionuclide transport in the unsaturated zone on the basis of low consequence (CRWMS M&O, 2000d, 2001d). The DOE screening argument assumes that radionuclide solubility limits in the geosphere may be different and indicates that radionuclide solubility limits in the geosphere are conservatively ignored with respect to solubility reduction in the far field (CRWMS M&O, 2000d). This argument makes valid points, but the possibility of increasing solubility limits should also be considered. Solubility limits in the geosphere will be determined by interaction between the contaminant plume and the host rock.	This issue is addressed by existing agreements between DOE and NRC (Evolution of the Near-Field Environment Subissue 4 Agreement 3). Features, Events, and Processes in UZ Flow and Transport, ANL–NBS–MD–000001, will be revised on completion of this work.
UZ3 SZ2	J-12	2.2.10.01.00 (Repository-Induced Thermal Effects in Geosphere) is excluded from the Total System Performance Assessment–Site Recommendation abstraction of radionuclide transport in the unsaturated zone on the basis of low consequence (CRWMS M&O, 2000d, 2001d). The screening argument is only partially supported by near-field thermal-chemical modeling for a limited number of hydrochemical constituents and minerals (CRWMS M&O, 2000x) and is not directly related to the effects on radionuclide transport. The technical basis for the screening is not sufficient at this time and future evaluation of the exclusion of 2.2.10.01.00 (Repository-Induced Thermal Effects in Geosphere) will depend, in part, on the verification of Assumption 11 that far-field changes to radionuclide transport in the unsaturated zone will be less than the calculated near-field changes (CRWMS M&O, 2001d).	This issue is addressed by existing agreements between DOE and NRC (Evolution of the Near-Field Environment Subissue 1 Agreement 4, and Subissue 4 Agreements 3 and 4, and Radionuclide Transport Subissue 1 Agreement 5). Features, Events, and Processes in UZ Flow and Transport, ANL–NBS–MD–000001, will be revised on completion of this work.
SZ1	13	2.2.10.02.00 (Thermal Convection Cell Develops in Saturated Zone) is screened as excluded on the basis of low consequence (CRWMS M&O, 2000f). DOE indicates that temperatures at the water table are expected to approach 80 °C [176 °F]. DOE further points out the resulting concern is that thermally driven water flow in the upper tuff aquifer could increase groundwater velocities relative to the system without heat sources. Additional justification for exclusion is necessary.	DOE agreed to provide clarification of the screening argument in Features, Events, and Processes in Saturated Zone Flow and Transport, ANL–NBS–MD–000002, to address the NRC comment.
UZ2 SZ1 SZ2	3	2.2.10.03.00 (Natural Geothermal Effects). It is stated that natural geothermal effects are included because the current geothermal gradient is addressed in the saturated zone flow and transport model (CRWMS M&O, 2001e). This discussion, however, does not address the potential for spatial and temporal variations in that gradient, which is part of the description of 2.2.10.03.00 (Natural Geothermal Effects). Resolution of this issue is necessary to address changes in the geothermal gradient in 2.2.10.13.00 [Density-Driven Groundwater Flow (Thermal)].	This issue is addressed by an existing DOE and NRC agreement (Unsaturated and Saturated Flow Under Isothermal Conditions Subissue 5, Agreement 13). Features, Events, and Processes in Saturated Zone Flow and Transport, ANL–NBS–MD–000002, will be updated, as necessary, to reflect the results of this existing agreement.
ENG2 ENG3 UZ2	70	2.2.10.04.00 (Thermal-Mechanical Alteration of Fractures Near Repository) is screened excluded on the basis of low consequence (CRWMS M&O, 2000h, 2001b). See discussion in 2.2.06.01.00 [Changes in Stress (Due to Thermal, Seismic, or Tectonic Effects), Change Porosity, and Permeability of Rock]. Heat	The thermal-mechanical effects on rock properties are addressed by an existing DOE and NRC agreement (Repository Design and Thermal-Mechanical Effects Subissue 3, Agreements 20 and 21). FEPs in Thermal Hydrology and Coupled Processes, ANL–NBS–MD–000004, will be revised on completion

Table B–1. NRC Comments on Features, Events, and Processes and Path Forward for Resolution Including, DOE and NRC Agreements (continued)			
Integrated Subissue	**Technical Exchange**	**Comment**	**Path Forward**
		from the waste causes thermal expansion of the surrounding rock, generating compressive stresses near the drifts and extensional stresses away from them. The zone of compression migrates with time.	of this work.
UZ2	67	2.2.10.05.00 (Thermal-Mechanical Alteration of Rocks Above and Below the Repository) is screened as excluded on the basis of low consequence (CRWMS M&O, 2001b). Thermal-mechanical compression at the repository produces tension-fracturing in the paintbrush nonwelded tuff and other units above the repository. These fractures alter unsaturated zone flow between the surface and the repository. Extreme fracturing may propagate to the surface, affecting infiltration. Thermal fracturing in rocks below the repository affects flow and radionuclide transport to the saturated zone.	DOE planned to analyze the effects of thermal-hydrological-mechanical coupled processes with regard to drainage in the pillars and flow in the vicinity of the drifts and thermal-hydrological/thermal-hydrological-chemical/thermal-hydrological-mechanical analyses to quantify uncertainties in the thermal seepage model. In addition, thermal-hydrological-mechanical continuum modeling will address thermal-mechanical effects in rocks above and below the repository at a mountain scale in an update to the Coupled Thermal-Hydrological-Mechanical Effects on Permeability Analysis and Model Report, ANL–NBS–HS–000037. DOE will clarify the screening arguments in the FEPs in Thermal Hydrology and Coupled Processes, ANL–NBS–MD–000004, on completion of this agreement.
ENG3 UZ2 UZ3 SZ1 SZ2 UZ3	 64 9	2.2.10.06.00 [Thermal-Chemical Alteration (Solubility Speciation, Phase Changes, and Precipitation/Dissolution)] [Near-Field Environment]: Screened as excluded on the basis of low consequence (CRWMS M&O, 2001b). Changes in the groundwater temperature in the farfield, if significant, may change the solubility and speciation of certain radionuclides. This change would have the effect of altering radionuclide transport processes. Relevant processes include volume effects associated with silica phase changes, precipitation and dissolution of fracture-filling minerals (including silica and calcite), and alteration of zeolites and other minerals to clays. [Saturated Zone]: Screened as excluded on the basis of low consequence (CRWMS M&O, 2001e) with reference to the screening argument for 2.2.07.10.00 (Condensation Zone Forms Around Drifts) in (CRWMS M&O, 2001d). The argument that repository thermal effects on saturated zone radionuclide transport will be minimal is based on a to-be-verified assumption (CRWMS M&O, 2001d). There is no explicit technical basis presented that rock alteration or temperature effects on geochemical properties and processes will negligibly affect saturated zone transport. In addition, it is asserted in CRWMS M&O (2001e) that any such effects would be within the bounds of uncertainty ranges established for transport properties such as K_d. However, the relevant analysis and model report (CRWMS M&O, 2000w) does not provide a clear technical basis that this is the case. The DOE current technical justification is considered inadequate. DOE should provide additional technical justification for exclusion. Same comment applies to 2.2.10.08.00 (Thermal-Chemical Alteration of the Saturated Zone). [Unsaturated Zone]: DOE has not provided the technical basis for excluding entrained colloids in the analysis of	[Near-Field Environment]: This issue is addressed by an existing agreement between DOE and NRC (Evolution of the Near-Field Environment Subissue 1, Agreement 3). FEPs in Thermal Hydrology and Coupled Processes, ANL–NBS–MD–000004, will be revised on completion of this work. [Saturated Zone]: DOE agreed to provide clarification of the screening argument in Features, Events, and Processes in SZ Flow and Transport, ANL–NBS–MD–000002, to address the NRC comment. [Unsaturated Zone]: At the Evolution of the Near-Field Environment Technical Exchange, DOE agreed to provide the technical basis for excluding entrained colloids in the analysis of 2.2.10.06.00 (Thermal-Chemical Alteration) or an alternative features, events, and processes (Evolution of the Near-Field Environment Subissue 1, Agreement 6). DOE will provide the technical basis for screening entrained colloids in the analysis of 2.2.10.06.00 (Thermal-Chemical Alteration) in a future revision of Features, Events, and Processes in SZ Flow and Transport, ANL–NBS–MD–000001, expected to be available in fiscal year 2002.

Table B–1. NRC Comments on Features, Events, and Processes and Path Forward for Resolution Including, DOE and NRC Agreements (continued)			
Integrated Subissue	**Technical Exchange**	**Comment**	**Path Forward**
		2.2.10.06.00 [Thermo-Chemical Alteration (Solubility Speciation, Phase Changes, and Precipitation/Dissolution)] or an alternative database entry (CRWMS M&O, 2001d). DOE has not considered possible entrainment of colloids and particulates in convecting/advecting boiling fluids or by otherwise vigorous water movement in the drift.	
UZ3	J-13	2.2.10.06.00 [Thermal-Chemical Alteration (Solubility, Speciation, Phase Changes, Precipitation/Dissolution)] is excluded from the Total System Performance Assessment–Site Recommendation abstraction of radionuclide transport in the unsaturated zone on the basis of low consequence (CRWMS M&O, 2000d, 2001d). Thermal effects on chemistry at the mountain scale are expected to be low, based on near-field coupled thermal-hydrological-chemical models that indicate the thermal effects of the repository result in only small changes in major hydrochemical constituents and limited changes in mineralogy, however, model results in the cited report (CRWMS M&O, 2000x) only consider a few components in hydrochemistry important to container life (e.g., pH, total carbon, and calcium). The model is limited to calcite precipitation/dissolution and addresses only seepage water chemistry. Thermal-chemical effects on transport beneath the repository, which could reflect the influence of the engineered barrier subsystem and waste form materials, are not considered. In addition, although the assumption that far-field changes are likely to be less than near-field changes is reasonable, it has not been verified (CRWMS M&O, 2001d). The technical basis is not sufficient at this time to demonstrate low consequence. The evaluation of this exclusion will depend in part on the verification of Assumption 11 that far-field changes to radionuclide transport in the unsaturated zone will be less than the calculated near-field changes (CRWMS M&O, 2001d).	This issue is addressed by existing agreements between DOE and NRC (Evolution of the Near-Field Environment Subissue 1 Agreement 4, and Subissue 4 Agreements 3 and 4, and Radionuclide Transport Subissue 1 Agreement 5). Features, Events, and Processes in UZ Flow and Transport, ANL–NBS–MD–000001, will be revised on completion of this work.
UZ2 UZ3	J-14	2.2.10.07.00 (Thermal-Chemical Alteration of the Calico Hills Unit) is excluded from the Total System Performance Assessment–Site Recommendation abstraction of radionuclide transport in the unsaturated zone on the basis of low consequence (CRWMS M&O, 2001d). The screening argument is based on the prediction of small changes in aqueous geochemistry and mineralogy in response to coupled thermal-hydrological-chemical processes in the near field (CRWMS M&O, 2000x). Thermal-chemical changes in the far field, including the Calico Hills unit, will be even less significant (CRWMS M&O, 2001d; Assumption 11). The screening argument indicates that temperatures in the zeolite-bearing Calico Hills unit, will not be high enough to cause significant zeolite alteration. Because the radionuclide transport abstraction assumes no retardation in fractures, this exclusion may be appropriate (however, see next paragraph). Again, final evaluation of this exclusion will depend, in part, on the verification of Assumption 11 that far-field changes to radionuclide transport in the unsaturated zone will be less than the calculated near-field changes (CRWMS M&O, 2001d). Alteration of the uppermost nonwelded layers below the repository could significantly reduce the fraction of	This issue is addressed by existing agreements between DOE and NRC (Evolution of the Near-Field Environment Subissue 1 Agreement 4, and Subissue 4 Agreements 3 and 4, and Radionuclide Transport Subissue 1 Agreement 5). Features, Events, and Processes in UZ Flow and Transport, ANL–NBS–MD–000001, will be revised on completion of this work. DOE also stated that alteration of vitric rock has not been addressed and will need to be included in the overall thermal-hydrological-chemical analyses.

Table B–1. NRC Comments on Features, Events, and Processes and Path Forward for Resolution Including, DOE and NRC Agreements (continued)			
Integrated Subissue	**Technical Exchange**	**Comment**	**Path Forward**
		matrix flow below the repository. Nonwelded vitric horizons, either basal Topopah Springs vitrophyre or the uppermost Calico Hills unit, cover nearly half the repository. In the southwestern portion of the repository footprint, the nonwelded, nonaltered tuffs lie as little as 45 m [147.64 ft] below the repository. The screening argument (CRWMS M&O, 2001d) includes the assertion that temperatures in the Calico Hills unit will remain below 70 °C [158 °F], which is not high enough to cause significant zeolite alteration. According to the cited reference, however, it appears temperatures can exceed 70 °C [158 °F] {up to 85 °C [185 °F]} is estimated from figures in the cited section of CRWMS M&O, 2000z} where the nonwelded, nonaltered tuff is closest to the repository.	
SZ1 SZ2	9	2.2.10.08.00 (Thermal-Chemical Alteration of the Saturated Zone). See comment on 2.2.10.06.00 [Thermal-Chemical alteration (solubility speciacion, phase changes, precipitation/dissolution)].	See comment on 2.2.10.06.00 [Thermal-Chemical Alteration (solubility speciacion, phase changes, precipitation/dissolution)].
UZ2 UZ3	J-15	2.2.10.09.00 (Thermal-Chemical Alteration of the Topopah Spring Basal Vitrophyre) is excluded from the Total System Performance Assessment–Site Recommendation abstraction of radionuclide transport in the unsaturated zone on the basis of low consequence (CRWMS M&O, 2000d, 2001d). The screening argument is based on predicting small changes in aqueous geochemistry and mineralogy in response to coupled thermal-hydrological-chemical processes in the near field (CRWMS M&O, 2000x). Thermal-chemical changes in the far field, including the Topopah Spring basal vitrophyre, are expected to be even less significant (CRWMS M&O, 2001d). Although the assumption that far-field changes are likely to be less than near-field changes (Assumption 11) is reasonable, this assumption has not been verified (CRWMS M&O, 2001d). It is important to note that the near-field analyses (CRWMS M&O, 2000x) focus on seepage chemistry and how it might affect container life, rather than considering thermal effects on radionuclide transport. The technical basis is not sufficient to demonstrate low consequence to radionuclide transport. Because the Total System Performance Assessment–Site Recommendation radionuclide transport abstraction assumes no retardation in fractures, this exclusion may be appropriate. Final evaluation of this exclusion will depend on verification of Assumption 11 that far-field changes to radionuclide transport in the unsaturated zone will be less than the calculated near-field changes (CRWMS M&O, 2001d). Alteration of the uppermost nonwelded layers below the repository could significantly reduce the fraction of matrix flow below the repository. Nonwelded vitric horizons, either basal Topopah Spring vitrophyre or the uppermost Calico Hills unit, cover nearly half the repository. In the southwestern portion of the repository footprint, the nonwelded, nonaltered tuffs lie as little as 45 m [147.64 ft] below the repository. The screening argument for 2.2.10.07.00 (CRWMS M&O, 2001d) includes the assertion that temperatures in the Calico Hills unit will remain below 70°C [158 °F] which is not high enough to cause significant zeolite alteration. According to the cited reference, however, it	This issue is addressed by existing agreements between DOE and NRC (Evolution of the Near-Field Environment Subissue 1 Agreement 4, and Subissue 4 Agreements 3 and 4, and Radionuclide Transport Subissue 1 Agreement 5). Features, Events, and Processes in UZ Flow and Transport, ANL–NBS–MD–000001, will be revised on completion of this work.

Table B–1. NRC Comments on Features, Events, and Processes and Path Forward for Resolution Including, DOE and NRC Agreements (continued)			
Integrated Subissue	**Technical Exchange**	**Comment**	**Path Forward**
		appears temperatures can exceed 70°C [158 °F] {up to 85°C [185 °F] is estimated from figures in the cited section of CRWMS M&O (2000z)} where the nonwelded, nonaltered tuff is closest to the repository. Temperatures would be higher in the overlying Topopah Spring basal vitrophyre than in Calico Hills.	
UZ1 UZ2	61	2.2.10.12.00 (Geosphere Dryout Due to Waste Heat). It is necessary to develop a screening argument for this item as part of the scope of the analysis and model report (CRWMS M&O, 2001d). Elevated thermal effects on shallow infiltration from changes in soil water content were not addressed for 2.2.10.12.00 (Geosphere Dryout Due to Waste Heat). The DOE study of a natural thermal gradient on Yucca Mountain addresses this item (CRWMS M&O, 1998b). 2.2.10.12.00 (Geosphere Dryout Due to Waste Heat) is screened as included in CRWMS M&O (2001b) for issues related to the near-field environment, but does not address the effects on infiltration.	DOE agreed to provide the technical basis for the screening argument in Features, Events, and Processes in UZ Flow and Transport, ANL–NBS–MD–000001, to address the NRC comment.
UZ2 SZ1 SZ2	12	2.2.10.13.00 [Density-Driven Groundwater Flow (Thermal)]. The analysis and model report (CRWMS M&O, 2001e) addresses this item in two parts: repository-induced effects (excluded, low consequence) and natural geothermal effects (included). Exclusion of repository effects on flow based on the DOE analyses is accepted. Natural effects are included only to the extent that the natural geothermal gradient is applied in the saturated zone flow and transport model. However, changes in thermal gradients are excluded on the basis of low consequence, with reference to 1.2.06.00.00 (Hydrothermal Activity) and 1.2.10.02.00 (Hydrologic Response to Igneous Activity) (CRWMS M&O, 2001e). A clear technical basis is not provided for these items that all possible changes in thermal gradients will be localized. The screening argument for 1.2.06.00.00 (Hydrothermal Activity) focuses on geochemical effects (see separate entry), whereas 1.2.10.02.00 (Hydrologic Response to Igneous Activity) is focused on highly localized igneous intrusions. How these arguments apply to 2.2.10.13.00 [Density-Driven Groundwater Flow (Thermal)] is not entirely clear.	This issue is addressed by an existing DOE and NRC agreement (Unsaturated and Saturated Flow Under Isothermal Conditions Subissue 5, Agreement 13). Features, Events, and Processes in SZ Flow and Transport, ANL–NBS–MD–000002, will be updated to clarify the screening argument and to reflect the results of this existing agreement.
UZ2	J-21	2.2.11.02.00 (Gas Pressure Effects) is excluded based on low consequence and low probability (CRWMS M&O, 2001d). Consistency is needed in the screening arguments. Buildup of water vapor pressure within rock matrix blocks from waste heat has not been considered. Gas pressure can build up within matrix blocks that have low permeability. This condition can increase the boiling point and keep water in the liquid phase at higher temperatures. Flashing to vapor as liquid water leaves the matrix block can result in mineral deposition that can later affect flow pathways.	This issue is addressed by existing agreements between DOE and NRC (Evolution of the Near-Field Environment Subissue 1 Agreements 5 and 7, and Subissue 4 Agreement 3). Features, Events, and Processes in UZ Flow and Transport, ANL–NBS–MD–000001, will be revised on completion of this work.
SZ1 SZ2 Dose1 Dose2 Dose3	10	2.3.11.04.00 (Groundwater Discharge to Surface) is excluded on the basis of low consequence (CRWMS M&O, 2001e). Modeling shows that spring discharge within the 20-km [12.4-mi] radius is not likely, yet past discharges occurred within the 20-km [12.4-mi] radius (e.g., paleospring deposits at 9S and 1S). See discussion of 1.3.07.02.00 (Water Table Rise). Any screening argument that spring discharges are outside the proposed compliance area is insufficient.	DOE agreed to provide clarification of the screening argument in Features, Events, and Processes in SZ Flow and Transport, ANL–NBS–MD–000002, to address the NRC comment.

Table B–1. NRC Comments on Features, Events, and Processes and Path Forward for Resolution Including, DOE and NRC Agreements (continued)

Integrated Subissue	Technical Exchange	Comment	Path Forward
		Additional technical justification is required to fully exclude 2.3.11.04.00 (Groundwater Discharge to Surface).	
Dose3 Dose2	21	2.3.13.01.00 (Biosphere Characteristics) screening argument indicates the Yucca Mountain region lacks permanent surface water (CRWMS M&O, 2001a). It is not clear this statement is consistent with the geologic record of past climate change in the area.	DOE agreed to provide clarification of the screening argument in Evaluation of the Applicability of Biosphere-Related Features, Events, and Processes (FEP), ANL–MGR–MD–000011, to address the NRC comment.
Dose3	24	2.3.13.02.00 (Biosphere Transport) contains only two secondary entries related to surface water, gas, and biogeochemical transport processes (CRWMS M&O, 2001a). The Yucca Mountain Project feature, event, and process description and the originator description are different and question whether the focus is transport processes, alterations during transport, or both.	DOE agreed to clarify the description of the primary features, events, and processes in Evaluation of the Applicability of Biosphere-Related Features, Events, and Processes (FEP), ANL–MGR–MD–000011, to address the NRC comment.
Dose3	25	2.4.07.00.00 (Dwellings) includes a secondary entry, household cooling, which has an inappropriate screening argument (CRWMS M&O, 2001a). The screening argument indicates that because use of an evaporative cooler would only increase inhalation and direct exposure pathways, and these pathways are only minor contributors to the current dose conversion factors, the use of evaporative coolers can be screened. However, the direct exposure and inhalation dose from evaporative coolers is the result of significantly different processes than the direct exposure and inhalation dose from radionuclides deposited on soils and, hence, could have a more significant dose impact.	DOE agreed to provide the technical basis for the screening argument in Evaluation of the Applicability of Biosphere-Related Features, Events, and Processes (FEP), ANL–MGR–MD–000011, to address the NRC comment.
Dose3 Dose2 Direct2	26	The analysis and model report (CRWMS M&O, 2001a) states that 3.3.08.00.00 (Radon and Daughter Exposure) is screened as excluded on the basis the parent radionuclide (Th-230) will not reach the critical group in 10,000 years in the basecase scenario (CRWMS M&O, 2000aa, 2001a). This rationale, however, does not apply to the direct release scenario, where transport times are much shorter.	DOE agreed to provide the technical basis for the screening argument in Evaluation of the Applicability of Biosphere-Related Features, Events, and Processes (FEP), ANL–MGR–MD–000011, to address the NRC comment.

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GLOSSARY

This Glossary is provided for information and is not exhaustive.

absorption: The process of taking up by capillary, osmotic, solvent, or chemical action of molecules (e.g., absorption of gas by water) as distinguished from adsorption.

abstracted model: A model that reproduces, or bounds, the essential elements of a more detailed process model and captures uncertainty and variability in what is often, but not always, a simplified or idealized form. See *abstraction*.

abstraction: Representation of the essential components of a process model into a suitable form for use in a total system performance assessment. Model abstraction is intended to maximize the use of limited computational resources while allowing a sufficient range of sensitivity and uncertainty analyses.

adsorb: To collect a gas, liquid, or dissolved substance on a surface as a condensed layer.

adsorption: The adhesion by chemical or physical forces of molecules or ions (as of gases or liquids) to the surface of solid bodies. For example, the transfer of solute mass, such as radionuclides, in groundwater to the solid geologic surfaces with which it comes in contact. The term *sorption* is sometimes used interchangeably with this term.

advection: The process in which solutes, particles, or molecules are transported by the motion of flowing fluid. For example, advection in combination with dispersion controls flux into and out of the elemental volumes of the flow domain in groundwater transport models.

air mass fraction: The mass of air divided by the total mass of gas (typically air plus water vapor) in the gas phase. This expression gives a measure of the "dryness" of the gas phase, which is important in waste package corrosion models.

Alloy 22: A nickel-base corrosion resistant alloy containing approximately 22 weight percent chromium, 13 weight percent molybdenum, and 3 weight percent tungsten as major alloying elements and that may be used as the outer container material in a waste package design (see *outer barrier*).

alluvium: Detrital deposits made by streams on river beds, flood plains, and alluvial fans; especially a deposit of silt or silty clay laid down during time of flood. The term applies to stream deposits of recent time. It does not include subaqueous sediments of seas and lakes.

alternative: Plausible interpretations or designs based on assumptions other than those used in the base case that could also fit or be applicable, based on the available scientific information. When propagated through a quantitative tool such as performance assessment, alternative interpretations can illustrate the significance of the uncertainty in the base case interpretation chosen to represent the repository's probable behavior.

ambient: Undisturbed, natural conditions such as ambient temperature caused by climate or natural subsurface thermal gradients, and other surrounding conditions.

anisotropy: The condition that physical properties vary when measured in different directions or along different axes. For example, in layered rock the permeability is often greater within the horizontal layers than across the horizontal layers.

annual frequency: The number of occurrences of an event expected in one year.

aqueous: Pertaining to water, such as aqueous phase, aqueous species, or aqueous transport.

aquifer: A subsurface, saturated rock unit (formation, group of formations, or part of a formation) of sufficient permeability to transmit groundwater and yield water of sufficient quality and quantity for an intended beneficial use.

ash: Bits of volcanic rock that would be broken-up during an eruption to less than 2 mm [0.08 inches] in diameter.

basalt: A type of igneous rock that forms black, rubbly lavas and black-to-red tephras of the type commonly used as lava rocks for barbecues.

borosilicate glass: A predominantly noncrystalline, relatively homogenous glass formed by melting silica and boric oxide together with other constituents such as alkali oxides. A high-level radioactive waste matrix material in which boron takes the place of the lime used in ordinary glass mixtures.

boundary condition: For a model, the establishment of a set condition, often at the geometric edge of the model, for a given variable. An example is using a specified groundwater flux from net infiltration as a boundary condition for an unsaturated flow model.

bound: An analysis or selection of parameter values that yields pessimistic results, such that any actual result is certain to be no worse or could be worse only with an extremely small likelihood.

breach: A penetration in the waste package caused by failure of the outer and inner containers or barriers that allows the spent nuclear fuel or the high-level radioactive waste to be exposed to the external aqueous environment and eventually permits radionuclide release.

burnup: A measure of nuclear reactor fuel consumption expressed either as the percentage of fuel atoms that have undergone fission or as the amount of energy produced per unit weight of fuel.

calibration: (1)The process of comparing the conditions, processes, and parameter values used in a model against actual data points or interpolations (e.g., contour maps) from measurements at or close to the site to ensure that the model is compatible with reality, to the extent feasible. (2) For tools used for field or lab measurements, the process of taking instrument readings on standards known to produce a certain response, to check the accuracy and precision of the instrument.

canister: A cylindrical metal receptacle that facilitates handling, transportation, storage, and/or disposal of high-level radioactive waste. It may serve as (1) a pour mold and container for

vitrified high-level radioactive waste or (2) a container for loose or damaged fuel rods, non-fuel components and assemblies, and other debris containing radionuclides.

carbon steel: A steel made of carbon up to about 2 weight percent and only residual quantities of other elements. Carbon steel is a tough but ductile and malleable material used as baskets to maintain the spent fuel assemblies in fixed positions in the current waste package design.

Category 1 event sequences: Those event sequences that are expected to occur one or more times before permanent closure of a geologic repository.

Category 2 event sequences: Event sequences other than Category 1 event sequences that have at least one chance in 10,000 of occurring before permanent closure.

Center for Nuclear Waste Regulatory Analyses: A Federally funded research and development center in San Antonio, Texas, sponsored by the U.S. Nuclear Regulatory Commission, to provide the U.S. Nuclear Regulatory Commission with technical assistance for the repository program.

chain reaction: A continuing series of nuclear fission events that takes place within the fuel of a nuclear reactor. Neutrons produced by a split nucleus collide with and split other nuclei causing a chain of fission events.

cladding: The metal outer sheath of a fuel rod generally made of a zirconium alloy, and in the early nuclear power reactors of stainless steel, intended to protect the uranium dioxide pellets, which are the nuclear fuel, from dissolution by exposure to high temperature water under operating conditions in a reactor.

climate: Weather conditions including temperature, wind velocity, precipitation, and other factors, that prevail in a region.

climate states: Representations of climate conditions.

code (computer): The set of commands used to solve a mathematical model on a computer.

colloid: As applied to radionuclide migration, a colloidal system is a group of large molecules or small particles, having at least one dimension with the size range of 10^{-9} to 10^{-6} meters that are suspended in a solvent. Naturally occurring colloids in groundwater arise from clay minerals such as smectites and illites. Colloids that are transported in groundwater can be filtered out of the water in small pore spaces or very narrow fractures because of the large size of the colloids.

Colloid-Facilitated, Radionuclide Transport Model: A model that represents the enhanced transport of radionuclides by particles that are colloids.

commercial spent nuclear fuel: Nuclear fuel rods, forming a fuel assembly, that have been removed from a nuclear power plant after reaching the specified burnup.

common cause failure: Two or more failures that result from a single event or circumstance.

conceptual model: A set of qualitative assumptions used to describe a system or subsystem for a given purpose. Assumptions for the model are compatible with one another and fit the existing data within the context of the given purpose of the model.

consequence: A measurable outcome of an event or process that, when combined with the probability of occurrence, gives risk.

conservative: A condition of an analysis or a parameter value such that its use provides a pessimistic result, which is worse than the actual result expected.

continuum model: A model that represents fluid flow through numerous individual fractures and matrix blocks by approximating it as continuous flow fields.

corrosion: The deterioration of a material, usually a metal, as a result of a chemical or electrochemical reaction with its environment.

corrosion model: A theoretical representation of a corrosion process based on the application of a combination of fundamental electrochemical (chemical) and thermodynamic principles (or laws) with empirical parameters resulting from experiments, field measurements, or data obtained through industrial experience. Models can describe the penetration of a pit or a crack through a container wall as a function of time.

corrosion resistant alloy: An alloy that exhibits extremely high resistance to general or uniform corrosion in a given environment as a result of the formation of a protective film on its surface. Alloy 22, and other similar nickel-chromium-molybdenum alloys, are considered corrosion resistant alloys because they are extremely resistant to general corrosion in severe aqueous environments (e.g., high temperature brines containing acidic sulfur species).

coupling: The ability to assemble separate analyses or parameters in a performance assessment so that information can be passed among them to develop an overall analysis of system performance.

crevice corrosion: Localized corrosion of a metal surface at, or immediately adjacent to, an area that is shielded from full exposure to the environment because of close proximity between the metal and the surface of another material.

critical event: See *criticality*.

criticality: (1) A condition that would require the original waste form, which is part of the waste package, to be exposed to degradation, followed by conditions that would allow concentration of sufficient nuclear fuel, the presence of neutron moderators, the absence of neutron absorbers, and favorable geometry. (2) The condition in which nuclear fuel sustains a chain reaction. It occurs when the number of neutrons present in one generation cycle equals the number generated in the previous cycle. The state is considered critical when a self-sustaining nuclear chain reaction is ongoing.

criticality accident: The release of energy as a result of accidental production of a self-sustaining or divergent neutron chain reaction.

data: Facts or figures measured or derived from site characteristics or standard references from which conclusions may be drawn. Parameters that have been derived from raw data are sometimes, themselves, considered to be data.

U.S. Department of Energy: A Cabinet-level agency of the U.S. federal government charged with the responsibilities of energy security, national security, and environmental quality.

design concept: An idea of how to design and operate the above-ground and below-ground portions of a repository.

diffusion: (1) The spreading or dissemination of a substance caused by concentration gradients. (2) The gradual mixing of the molecules of two or more substances because of random thermal motion.

diffusive transport: Movement of solutes because of their concentration gradient. The process in which substances carried in groundwater move through the subsurface by means of diffusion because of a concentration gradient.

dike: A tabular body of igneous rock that cuts across the structure of adjacent rocks or cuts massive rocks.

dimensionality: Modeling in one, two, or three dimensions.

direct exposure: The manner in which an individual receives dose from being in close proximity to a source of radiation. Direct exposures present an external dose pathway.

dispersion (hydrodynamic dispersion): (1) The tendency of a solute (substance dissolved in groundwater) to spread out from the path it is expected to follow if only the bulk motion of the flowing fluid were to move it. The tortuous path the solute follows through openings (pores and fractures) causes part of the dispersion effect in the rock. (2) The macroscopic outcome of the actual movement of individual solute particles through a porous medium. Dispersion causes dilution of solutes, including radionuclides, in groundwater, and is usually an important mechanism for spreading contaminants in low flow velocities.

disposal container: A cylindrical metal receptacle designed to contain spent nuclear fuel and high-level radioactive waste that will become an integral part of the waste package when loaded with spent nuclear fuel or high-level radioactive waste. In the current waste package design, the inner container will have spacing structures or baskets to maintain fuel assemblies, shielding components, and neutron absorbing materials in position to control the possibility of criticality.

disruptive event: An unexpected event that, in the case of the potential repository, includes volcanic activity, seismic activity, and nuclear criticality. Disruptive events have two possible effects: (1) direct release of radioactivity to the surface, or (2) alteration of the nominal behavior of the system. For the purposes of screening features, events, and processes for the total system performance assessment, a disruptive event is defined as an event that has a significant effect on the expected annual dose and that has a probability of occurrence during the 10,000-year period of performance less than 1.0, but greater than a cutoff of 0.0001.

disruptive event scenario class: The scenario, or set of related scenarios, that describes the behavior of the system if perturbed by disruptive events. The disruptive scenarios contain all disruptive features, events, and processes that have been retained for analysis.

dissolution: (1) Change from a solid to a liquid state. (2) Dissolving a substance in a solvent.

distribution: The overall scatter of values for a set of observed data. A term used synonymously with frequency distribution or probability distribution function. Distributions have structures that are the probability that a given value occurs in the set.

drift: From mining terminology, a horizontal underground passage. The nearly horizontal underground passageways from the shaft(s) to the alcoves and rooms. Drifts include excavations for emplacement (emplacement drifts) and access (access mains).

drift scale: The scale of an emplacement drift, or approximately 5 meters in diameter.

Drift-Scale Heater Test: A test being conducted in the Exploratory Studies Facility to investigate thermal-hydrologic, thermal-chemical, and thermal-mechanical processes.

drip shield: A metallic structure placed along the extension of the emplacement drifts and above the waste packages to prevent seepage water from directly dripping onto the waste package outer surface.

edge effects: Conditions at the edges of the potential repository that are cooler and wetter because heat dissipates more quickly there than at the center of the repository.

effective porosity: The fraction of a porous medium volume available for fluid flow and/or solute storage, as in the saturated zone. Effective porosity is less than or equal to the total void space (porosity).

empirical: Reliance on experience or experiment rather than on an understanding of the fundamental processes as related to the laws of nature.

emplacement drift: See *drift*.

enrichment: The act of increasing the concentration of ^{235}U from its value in natural uranium. The enrichment (typically reported in atom percent) is a characteristic of nuclear fuel.

equilibrium: The state of a chemical system in which the phases do not undergo any spontaneous change in properties or proportions with time; a dynamic balance.

events: (1) Occurrences that have a specific starting time and, usually, a duration shorter than the time being simulated in a model. (2) uncertain occurrences that take place within a short time relative to the time frame of the model. For the purposes of screening features, events, and processes for the total system performance assessment, an event is defined to be a natural or human-caused phenomenon that has a potential to affect disposal system performance and that occurs during an interval that is short compared with the period of performance.

event tree: A modeling tool that illustrates the logical sequence of events that follow an initiating event.

expert elicitation: A formal process through which expert judgment is obtained.

Exploratory Studies Facility: An underground laboratory at Yucca Mountain that includes a 7.9-kilometer [4.9-mile] main loop (tunnel); a 2.8-kilometer [1.75-mile] cross-drift; and a research alcove system constructed for performing underground studies during site characterization. The data collected will contribute toward determining the suitability of the Yucca Mountain site for a repository. Some or all of the Exploratory Studies Facility may eventually be incorporated into the potential repository.

fault (geologic): A planar or gently curved fracture across which there has been displacement parallel to the fracture surface.

fault tree: A graphical logic model that depicts the combinations of events that result in the occurrence of an undesired event.

features: Physical, chemical, thermal, or temporal characteristics of the site or potential repository system. For the purposes of screening features, events, and processes for the total system performance assessment, a feature is defined to be an object, structure, or condition that has a potential to affect disposal system performance.

ferritic steel: A subclass of carbon steels characterized by a relatively low strength but good ductility as a result of the ferrite microstructure. A type of ferritic steel, mild steel, or low-carbon steel containing up to about 0.1 weight percent carbon is the metallic material most commonly used for construction purposes.

film flow: Movement of water as a film along a surface such as a fracture plane.

finite element analysis: A commonly used numerical method for solving mechanical deformation problems. A technique in which algebraic equations are used to approximate the partial differential equations that comprise mathematical models to produce a form of the problem that can be solved on a computer. For this type of approximation, the area being modeled is formed into a grid with irregularly shaped blocks. This method provides an advantage in handling irregularly shaped boundaries, internal features such as faults, and surfaces of engineered materials. Values for parameters are frequently calculated at nodes for convenience, but are defined everywhere in the blocks by means of interpolation functions.

flow: The movement of a fluid such as air, water, or magma. Flow and transport are processes that can move radionuclides from the proposed repository to the receptor group location.

flow pathway: The subsurface course that water or a solute (including radionuclides) would follow in a given groundwater velocity field, governed principally by the hydraulic gradient.

fracture: A planar discontinuity in rock along which loss of cohesion has occurred. It is often caused by the stresses that cause folding and faulting. A fracture along which there has been displacement of the sides relative to one another is called a fault. A fracture along which no

appreciable movement has occurred is called a joint. Fractures may act as fast paths for groundwater movement.

fracture aperture: The space that separates the sides of a fracture, and the measured width of the space separating the sides of a fracture.

fracture permeability: The capacity of a rock to transmit fluid that is related to fractures in the rock.

frequency: The number of occurrences of an observed or predicted event during a specific time period.

galvanic: Pertains to an electrochemical process in which two dissimilar electronic conductors are in contact with each other and with an electrolyte, or in which two similar electronic conductors are in contact with each other and with dissimilar electrolytes.

galvanic corrosion: Accelerated corrosion of a metal resulting from electrical contact with a more noble metal or non metallic conductor in a corrosive electrolyte.

geochemical: The distribution and amounts of the chemical elements in minerals, ores, rocks, soils, water, and the atmosphere; and the movement of the elements in nature on the basis of their properties.

geologic-framework model: A digital, scaled, geometrically congruent , three-dimensional model of the geologic system.

groundwater: Water contained in pores or fractures in either the unsaturated or saturated zones below ground level.

half-life: The time required for a radioactive substance to lose have its activity due to radioactive decay. At the end of one half-life, 50 percent of the original radioactive material has decayed.

heterogeneity: The condition of being composed of parts or elements of different kinds. A condition in which the value of a parameter such as porosity, which is an attribute of an entity of interest such as the tuff rock containing the potential repository, varies over the space an entity occupies, such as the area around the repository, or with the passage of time.

high-level radioactive waste glass: A waste form produced by melting a mixture of high-level radioactive waste and components of borosilicate glass at a high temperature (approximately 1,100 degrees centigrade).

hydrologic: Pertaining to the properties, distribution, and circulation of water on the surface of the land, in the soil and underlying rocks, and in the atmosphere.

igneous: (1) A type of rock that has formed from a molten, or partially molten, material. (2) A type of activity related to the formation and movement of molten rock either in the subsurface (intrusive) or on the surface (volcanic).

infiltration: The process of water entering the soil at the ground surface. Infiltration becomes percolation when water has moved below the depth at which it can be removed (to return to the atmosphere) by evaporation or transpiration. See *net infiltration*.

inner barrier: The inner container in the current design of the waste package. Type 316NG stainless steel is the DOE preferred material of construction.

invert: A constructed surface that would provide a level drift floor and enable transport and support of the waste packages.

isothermal: Having a constant temperature.

license application: An application, to the U.S. Nuclear Regulatory Commission for a license to construct and operate a repository.

localized corrosion: Corrosion at discrete sites (e.g., pitting and crevice corrosion).

magma: Molten or partially molten rock that is naturally occurring and is generated within the earth. Magma may contain crystals along with dissolved gasses.

Mathematical Model: A mathematical description of a conceptual model.

matrix: Tuff rock material and its pore space exclusive of fractures. As applied to Yucca Mountain tuff, the ground mass of an igneous rock that contains larger crystals.

matrix diffusion: As used in the Total System Performance Assessment for the Site Recommendation conceptual models, the process by which molecular or ionic solutes, such as radionuclides in groundwater, move from areas of higher concentration to areas of lower concentration. This movement is through the pore spaces of the rock material as opposed to movement through the fractures.

matrix permeability: The capability of the matrix to transmit fluid.

mean (arithmetic): For a statistical data set, the sum of the values divided by the number of items in the set. The arithmetic average.

mechanical disruption: Damage to the drip shield or waste package because of external forces.

median: A value such that one-half of the observations are less than that value and one-half are greater than the value.

meteorology: The study of climatic conditions such as precipitation, wind, temperature, and relative humidity.

microbe: An organism too small to be viewed with the unaided eye. Examples of microbes are bacteria, protozoa, and some fungi and algae.

microbial influenced corrosion: Deterioration of metals as a result of the metabolic activity of microorganisms.

migration: Radionuclide movement from one location to another within the engineered barrier system or the environment.

mineral model: A description of the kinds and relative abundances of minerals that is used to approximate the true mineralogical system.

mineralogical: Of or relating to the chemical and physical properties of minerals, their occurrence, and their classification.

model: A depiction of a system, phenomenon, or process, including any hypotheses required to describe the system or explain the phenomenon or process.

near field: The area and conditions within the potential repository including the drifts and waste packages and the rock immediately surrounding the drifts. The region around the potential repository where the natural hydrogeologic system has been significantly impacted by the excavation of the repository and the emplacement of waste.

net infiltration: The amount of infiltration that escapes the zone of evapotranspiration, which is generally the zone below the zone of plant roots. See *infiltration*.

nominal behavior: (1) Expected behavior of the system as perturbed only by the presence of the potential repository. (2) Behavior of the system in the absence of disruptive events.

nominal features, events, and processes: Those features, events, and processes expected, given the site conditions as described from current site characterization information.

nominal scenario class: The scenario, or set of related scenarios, that describes the expected or nominal behavior of the system as perturbed only by the presence of the potential repository. The nominal scenarios contain all expected features, events, and processes that have been retained for analysis.

nuclear criticality safety: Protection against the consequences of a criticality accident, preferably by prevention of the accident.

U.S. Nuclear Regulatory Commission: An independent agency, established by the U.S. Congress under the Energy Reorganization Act of 1974, to ensure adequate protection of the public health and safety, the common defense and security, and the environment, in the use of nuclear materials in the United States. The U.S. Nuclear Regulatory Commission scope of responsibility includes regulation of the transport, storage, and disposal of nuclear materials and waste.

Nuclear Waste Policy Act (42 U.S.C. 10101 et seq.): The Federal statute enacted in 1982 that established the Office of Civilian Radioactive Waste Management and defined its mission to develop a federal system for the management, and geologic disposal, of commercial spent nuclear fuel and other high-level radioactive wastes. The Act also: (1) specified other federal responsibilities for nuclear waste management; (2) established the Nuclear Waste Fund to

cover the cost of geologic disposal; (3) authorized interim storage under certain circumstances; and (4) defined interactions between federal agencies and the states, local governments, and Indian tribes. The act was substantially amended in 1987.

Nuclear Waste Policy Amendments Act of 1987: Legislation that amended the Nuclear Waste Policy Act to: (1) limit repository site characterization activities to Yucca Mountain, Nevada; (2) establish the Office of the Nuclear Waste Negotiator to seek a state or Indian tribe willing to host a repository or monitored retrievable storage facility; (3) create the Nuclear Waste Technical Review Board; and (4) increase state and local government participation in the waste management program.

numerical model: An approximate representation of a mathematical model that is constructed using a numerical description method such as finite volumes, finite differences, or finite elements. A numerical model is typically represented by a series of program statements that are executed on a computer.

Office of Civilian Radioactive Waste Management: A U.S. Department of Energy office created by the Nuclear Waste Policy Act of 1982 to implement the responsibilities assigned by the Act.

outer barrier: The outer container in the current design of the waste package. Alloy 22 is the U.S. Department of Energy preferred material of construction.

oxidation: (1) A corrosion reaction in which the corroded metal forms an oxide, usually applied to reaction with a gas containing elemental oxygen, such as air. (2) An electrochemical reaction in which there is an increase in the valence of an element resulting from the loss of electrons.

parameter: Data, or values, such as those that are input to computer codes for a total system performance assessment calculation.

patch: A circumscribed area of a surface. In the DOE modeling of waste package corrosion, it is the minimal surface area of the outer container over which uniform corrosion occurs, as opposed to localized corrosion in pits.

pathway: A potential route by which radionuclides might reach the accessible environment and pose a threat to humans. For example, direct exposure is an external pathway, and inhalation and ingestion are internal pathways.

permeability: The ability of a material to transmit fluid through its pores when subjected to a difference in head (pressure gradient). Permeability depends on the substance transmitted (oil, air, water, etc.) and on the size and shape of the pores, joints, and fractures in the medium and the manner in which they are interconnected.

phase: A physically homogeneous and distinct portion of a material system, such as the gaseous, liquid, and solid phases of a substance. In liquids and solids, single phases may coexist.

phase stability: A measure of the ability of a particular phase to remain without transformation.

pit: A small cavity formed in a solid as a result of localized dissolution.

pitting corrosion: Localized corrosion of a metal surface, confined to a small area, that takes the form of cavities named pits.

porosity: The ratio of openings, or voids, to the total volume of a soil or rock expressed as a decimal fraction or as a percentage. See also *effective porosity*.

pre-startup and startup testing: Activities to evaluate the readiness to receive, possess, process, store, and dispose of high-level radioactive waste.

probabilistic: (1) Based on or subject to probability. (2) Involving a variate, such as temperature or porosity. At each instance of time, the variate may take on any of the values of a specified set with a certain probability. Data from a probabilistic process are an ordered set of observations, each of which is one item from a probability distribution.

probabilistic risk assessment: (1) A systematic process of identifying and quantifying the consequences of scenarios that could cause a release of radioactive materials to the environment. (2) Using predictable behavior to define the performance of natural, geologic, human, and engineered systems for thousands of years into the future including probability distributions to account for uncertainty and variability.

probability: The chance that an outcome will occur from the set of possible outcomes. Statistical probability examines actual events and can be verified by observation or sampling. Knowing the exact probability of an event is usually limited by the inability to know, or compile, the complete set of possible outcomes over time or space.

probability distribution: The set of outcomes (values) and their corresponding probabilities for a random variable.

processes: Phenomena and activities that have gradual, continuous interactions with the system being modeled. For the purposes of screening features, events, and processes for the total system performance assessment, a process is defined as a natural or human-caused phenomenon that has a potential to affect disposal system performance and that operates during all or a significant part of the period of performance.

process model: A depiction or representation of a process, along with any hypotheses required to describe or to explain the process.

radioactive decay: The process in which one radionuclide spontaneously transforms into one or more different radionuclides, which are called daughter radionuclides.

radioactivity: The property possessed by some elements (i.e., uranium) of spontaneously emitting radiation (e.g., alpha particles, beta particles, or gamma rays) by the disintegration of atomic nuclei.

radiolysis: Chemical decomposition by the action of radiation.

radionuclide: Radioactive type of atom with an unstable nucleus that spontaneously decays, usually emitting ionizing radiation in the process. Radioactive elements are characterized by their atomic mass and atomic number.

range (statistics): The numerical difference between the highest and lowest value in any set.

receptor: An individual for whom radiological doses are calculated or measured.

relative permeability: The ability of a material to transmit fluid through its pores when subjected to a pressure gradient under unsaturated conditions. Relative permeability is a function of permeability (has a value between 0 and 1).

repository footprint: The areal extent of the underground repository facility.

retardation: Slowing or stopping radionuclide movement in groundwater by mechanisms that include sorption of radionuclides, diffusion into rock matrix pores and microfractures, and trapping of large colloidal molecules in small pore spaces or dead ends of microfractures.

risk: The probability that an undesirable event will occur, multiplied by the consequences of the undesirable event.

risk assessment: An evaluation of potential consequences or hazards that might be the outcome of an action. This assessment focuses on potential negative impacts on human health or the environment.

rock matrix: See *matrix*.

runoff: Lateral movement of water at the ground surface, such as down steep hillslopes or along channels, that is not able to infiltrate at a specified location. See *runon*.

runon: Lateral movement of water along the ground surface from some upstream location that becomes available for infiltration. See *runoff*.

safety question: A question regarding the adequacy of structures, systems, and components important to safety and engineered or natural barriers important to waste isolation.

scenario: A well-defined, connected sequence of features, events, and processes that can be thought of as an outline of a possible future condition of the potential repository system. Scenarios can be undisturbed, in which case the performance would be the expected, or nominal, behavior for the system. Scenarios can also be disturbed, if altered by disruptive events such as human intrusion or natural phenomena such as volcanism or nuclear criticality.

scenario class: A set of related scenarios sharing sufficient similarities that they can usefully be aggregated for the purposes of screening or analysis. The number and breadth of scenario classes depend on the resolution at which scenarios have been defined. Coarsely defined scenarios result in fewer, broad scenario classes, whereas narrowly defined scenarios result in many narrow scenario classes. Scenario classes (and scenarios) should be aggregated at the coarsest level at which a technically sound argument can be made while still retaining adequate detail for the purposes of the analysis.

seepage: The inflow of groundwater moving in fractures or pore spaces of permeable rock to an open space in the rock such as a drift. Seepage rate is the percolation flux that enters the drift. Seepage is an important factor in waste package degradation and mobilization and migration of radionuclides out of the potential repository.

seismic: Pertaining to, characteristic of, or produced by earthquakes or earth vibrations.

shallow infiltration: The amount of infiltration that escapes the root zone and percolates downward into the unsaturated zone. See *net infiltration.*

site recommendation: A recommendation by the Secretary of Energy to the President that the Yucca Mountain site is suitable for development as the Nation's first high-level radioactive waste repository.

sorb: To undergo a process of sorption.

sorption: The binding, on a microscopic scale, of one substance to another. A term that includes both adsorption and absorption. The sorption of dissolved radionuclides onto aquifer solids or waste package materials by means of close-range chemical or physical forces is potentially an important process in a repository. Sorption is a function of the chemistry of the radioisotopes, the fluid in which they are carried, and the mineral material they encounter along the flow path.

sorption coefficient (K_d): Coefficient for a term for the various processes by which one substance binds to another.

source term: Types and amounts of radionuclides that are the source of a potential release.

spatial variability: A measure of how a property, such as rock permeability, varies at different locations in an object such as a rock formation.

speciation: The existence of the elements, such as radionuclides, in different molecular forms in the aqueous phase.

spent nuclear fuel: Fuel that has been withdrawn from a nuclear reactor following irradiation, the constituent elements of which have not been separated by reprocessing. Spent fuel that has been burned (irradiated) in a reactor to the extent that it no longer makes an efficient contribution to a nuclear chain reaction. This fuel is more radioactive than it was before irradiation, and releases significant amounts of heat from the decay of its fission product radionuclides. See *burnup.*

stratigraphy: The science of rock strata. It is concerned with all characters and attributes of rocks as *strata* and their interpretation in terms of mode of origin and geologic history.

stress corrosion cracking: A cracking process that requires the simultaneous action of a corrodent and sustained (residual or applied) tensile stress. Stress corrosion cracking excludes both the fracture of already corroded sections and the localized corrosion processes that can disintegrate an alloy without the action of residual or applied stress.

structure: In geology, the arrangement of the parts of the geologic feature or area of interest such as folds or faults. This includes features such as fractures created by faulting and joints caused by the heating of rock.

tectonic: Pertaining to geologic forms or effects created by deformation of the earth's crust.

tephra: A collective term for all clastic materials ejected from a volcano and transported through the air. It includes volcanic dust, ash, cinders, lapilli, scoria, pumice, bombs, and blocks.

thermal-chemical: Of or pertaining to the effect of heat on chemical conditions and reactions.

thermal-hydrologic: Of or pertaining to changes in groundwater movement due to the effects of changes in temperature.

thermal-hydrologic processes: Processes that are driven by a combination of thermal and hydrologic factors. These processes include evaporation of water near the potential repository when it is hot and subsequent redistribution of fluids by convection, condensation, and drainage.

thermal hydrology: The study of a system that has both thermal and hydrologic processes. A thermal-hydrologic condition, or system, is expected to occur if heat-generating waste packages are placed in the potential repository at Yucca Mountain.

thermal-mechanical: Of or pertaining to changes in mechanical properties of rocks from effects of changes in temperature.

thermodynamics: A branch of physics that deals with the relationship and transformations between work as a mechanical action and heat.

total system performance assessment: A risk assessment that quantitatively estimates how the potential Yucca Mountain repository system will perform in the future under the influence of specific features, events, and processes, incorporating uncertainty in the models and uncertainty and variability of the data.

transparency: The ease of understanding the process by which a study was carried out, which assumptions are driving the results, how they were arrived at, and the rigor of the analyses leading to the results. A logical structure ensures completeness and facilitates in-depth review of the relevant issues. Transparency is achieved when a reader or reviewer has a clear picture of what was done in the analysis, what the outcome was, and why.

transpiration: The removal of water from the ground by vegetation (roots).

transport: A process that allows substances to be carried in a fluid through (1) the physical mechanisms of convection, diffusion, and dispersion; and (2) the chemical mechanisms of sorption, leaching, precipitation, dissolution, and complexation. Types of transport include advective, diffusive, and colloidal.

tuff: A general term for all consolidated pyroclastic rocks. The most abundant type of rock at the Yucca Mountain site.

uncertainty: How much a calculated or measured value varies from the unknown true value.

uniform corrosion: A type of corrosion attack (deterioration) more or less uniformly distributed over a metal surface. Corrosion that proceeds at approximately the same rate over a metal surface. Also called general corrosion.

unsaturated zone flow: The movement of water in the unsaturated zone driven by capillary, viscous, gravitational, inertial, and evaporative forces.

variable: A non-unique property or attribute.

variability (statistical): A measure of how a quantity varies over time or space.

volcanism: Pertaining to volcanic activity.

watershed: The area drained by a river system including the adjacent ridges and hillslopes.

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11. ABSTRACT *(200 words or less)*

This report provides background information on the status of prelicensing inter actions between the U.S. Nuclear Regulatory Commission (NRC) staff and the U.S. Department of Energy (DOE) concerning a pot ential high-level waste geologic repository at Yucca Mountain, Nevada. The NRC staff have, for many years, engaged in exte nsive interactions with DOE and various stakeholders. In recent years, the interactions focused on what the NRC staff termed key technical issues important to repository performance.

This report provides background information pertaining to the recent interactio ns with DOE (to October 2001), particularly the technical bases for the staff's views presented in the public meetings with DOE from August 2000 to September 2001. The report also documents the information staff considered in formulating their vie ws, including the results of the in-depth review of DOE and contractor documents; the independent work of NRC and its contractor, t he Center for Nuclear Waste Regulatory Analyses; published literature; and other publicly available information.

The information in this report may be of value to stakeholders interested in un derstanding the staff technical rationale for identifying certain information which, if provided by DOE, would address the st aff questions concerning the manner in which DOE is addressing the key technical issues.

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