

March 11, 1999

FOR: The Commissioners

FROM: William D. Travers /s/ Executive Director for Operations

SUBJECT: STAFF REVIEW OF U.S. DEPARTMENT OF ENERGY VIABILITY ASSESSMENT FOR A HIGH-LEVEL RADIOACTIVE WASTE REPOSITORY AT YUCCA MOUNTAIN, NEVADA

**PURPOSE:**

In [SRM M990208](#), dated February 16, 1999, the Commission directed the staff to provide a paper on the staff review and comment on the U.S. Department of Energy (DOE) Viability Assessment (VA) of a potential high-level radioactive waste repository sited at Yucca Mountain, Nevada. This paper provides the Commission with staff comments on the VA that, if not addressed by DOE before the license application (LA) is submitted as scheduled in 2002, could cause the LA to be incomplete or lead to a protracted licensing review.

**BACKGROUND:**

The Fiscal Year 1997 Energy and Water Development Appropriations Act (P.L. 104-206) requires DOE to provide the President and Congress with a VA for the Yucca Mountain site. The VA is a management tool that will provide DOE with the basis for making an informed assessment of the feasibility of proceeding with the process of licensing and constructing a repository at Yucca Mountain. Congress required the VA to include the following elements: (1) a preliminary design concept for the critical elements of the repository and waste package; (2) a total system performance assessment (TSPA) based on the design concept and scientific data and analysis available by June 30, 1998, describing the probable behavior of the repository relative to the overall system performance standards; (3) a plan and cost estimate (LA Plan) for the remaining work required to complete an LA; and (4) an estimate of the costs to construct and operate the repository in accordance with the design concept. DOE issued the VA on December 18, 1998, fulfilling its statutory requirement.

In a memorandum dated December 21, 1998, the staff informed the Commission of the scope and approach for its review and committed to providing the Commission with a paper that summarizes DOE's progress and U.S. Nuclear Regulatory Commission (NRC) staff comments, and recommends Commission action. NRC does not have a statutory role with regard to the VA, which is not a licensing document. However, as the agency responsible for reviewing the LA for geologic disposal of spent nuclear fuel and high-level wastes in the proposed geologic repository at Yucca Mountain, NRC has a unique perspective for evaluating the VA and, particularly, the DOE plan for remaining work required for an LA (i.e., the LA Plan). This licensing perspective is likely to be sought by Congress, the President, or others. DOE has also sought NRC input on the VA in terms of preparing a complete and high-quality LA.

In the VA, DOE analyzed the probable performance of a Yucca Mountain repository by using a reference design. DOE used this analysis, evaluations of design alternatives, and estimates of the consequences from disruptive events to make an internal decision on the viability of the Yucca Mountain site. DOE has concluded that the site and design are sufficiently promising for a geologic repository and work should proceed toward a decision on site recommendation.

DOE's conclusions on feasibility are based on estimates of exposures arising from the disposal of radioactive waste at Yucca Mountain, consistent with the reference design and DOE's understanding of the site. Estimates are included for both base case probable performance and repository performance assuming the occurrence of selected disruptive events. In the absence of Environmental Protection Agency standards applicable to Yucca Mountain, DOE assumed a performance measure of 25 mrem/year to an average member of a critical group located 20 km from the repository over the first 10,000 years after closure. The performance measure, exposure pathway, and time frame are consistent with those in proposed 10 CFR Part 63 (64FR8640).

As part of its ongoing preclicensing consultation with DOE, the staff has interacted with DOE on numerous occasions during development of the VA. NRC has been receiving and reviewing the VA supporting documents for over a year to prepare for the VA review. The staff began its formal review of the VA in late December 1998. The focus of the staff review was postclosure performance of the repository. The staff review covered elements (1) - (3) of the VA; element (4), which consists of an estimate of the costs to construct and operate the repository in accordance with the design concept, was not reviewed.

**DISCUSSION:**

The VA documents significant progress in areas such as: data collection; data synthesis; performance assessment modeling; and documentation. One result of this progress is that there is general agreement between DOE and NRC staff that DOE's planned work appears adequate in several technical areas (e.g., mechanical disruption of waste packages, spatial and temporal distribution of flow). In addition, it is also positive to note that in the LA Plan DOE has identified areas where additional data collection or analysis is needed for completing the design of the repository and developing an LA. In other areas, the staff has developed comments on the VA related to the completeness of the data, analysis, or documentation. These comments are organized in succeeding parts of this paper along the organizational lines of the VA, that is: the Preliminary Design Concept; the TSPA; and the LA Plan. The comments developed by the staff are not new in that they have been identified during earlier public interactions with DOE on the VA and were communicated to DOE in written staff documents. The comments are summarized below and described in detail in [Attachment 1](#).

**Preliminary Design Concept**

DOE was directed by Congress to develop "a preliminary design concept for the critical elements of the repository and waste package." As directed, DOE developed a preliminary design concept for the repository, which was used for the TSPA and the cost estimates. However, DOE also presented several major design alternatives that differ from the VA reference design. The consideration of these alternatives is an indication that, currently, DOE is not focused on a single design concept for proceeding to LA. The DOE safety case ultimately will need to be developed around a single reference design. The diversity and ongoing evolution of design concepts currently under consideration may not converge quickly enough for a single design to emerge for an LA in 2002, or may limit the availability of data and analyses in support of the LA design. The NRC staff recognizes DOE's need for flexibility in considering alternate designs to better protect public health and safety, but this must be appropriately balanced against the need for adequate data and analysis to support the design presented in the LA.

#### **Total System Performance Assessment - VA**

DOE was directed by Congress to prepare a TSPA based on the design concept and scientific data and analyses available at the time. As directed, DOE performed a TSPA and presented the results for the probable behavior of the repository relative to an overall system performance standard. Probable behavior is defined by DOE as the behavior specified by a base case. Limited consideration of disruptive events (e.g., volcanism) was done separately. DOE estimated the peak annual dose in 10,000 years between 0.04 and 0.1 mrem/year for the base case.

The staff believes that DOE's TSPA-VA represents an advancement over earlier efforts in that it is more comprehensive. In conducting its review, the staff compared DOE conclusions with an independent analysis using the Total systems Performance Assessment (TPA) code jointly developed by NRC and the Center for Nuclear Waste Regulatory Analyses. In general, the comparison was favorable with many areas of agreement between the two analyses (e.g., waste package lifetimes greater than 10,000 years, consideration of infiltration). Preliminary results from the staff's independent analysis with the TPA provide an estimate of approximately 0.6 mrem/yr for the peak expected dose in 10,000 years. With the current set of assumptions used in the TPA code, the dominant contributor to peak expected dose in the first 10,000 years was volcanism, because long waste package lifetimes limited doses from other pathways. Although the staff's and DOE's results are within approximately an order of magnitude, it should be noted that the expected annual dose value calculated by the staff is a different performance calculation than the "expected peak dose" used by DOE in the TSPA-VA and the results are not directly comparable.

There are areas where NRC's and DOE's assessments of repository performance differ significantly, and, therefore warrant additional data collection and analysis. The performance of the waste package over long time periods, the estimation of the quantity and chemistry of water contacting the waste package as it affects waste package corrosion and waste form dissolution, the consequences of igneous activity, and how radionuclides are transported in the saturated zone including how concentrations are calculated, represent key areas where the staff believes further work is needed prior to LA, and for which the staff has developed comments in [Attachment 1](#).

#### **License Application Plan**

Congress directed DOE to prepare a plan and cost estimate (LA Plan) for the remaining work required to complete an LA. As directed, DOE developed a plan and cost estimate for the remaining work required to complete an LA and an estimate of the costs to construct and operate the repository. The staff has commented on specific areas of the DOE LA Plan where additional work appears required to prepare the LA. The staff did not review DOE's estimates for the costs to construct and operate the repository.

Implementation of the DOE Quality Assurance (QA) program is a long-standing item of importance to the staff. DOE audits have identified that some data in the Management and Operations Contractor technical database have been determined to be not traceable to their origins and inadequately technically reviewed under DOE's own QA program. DOE recognizes the need to implement an overall data qualification strategy and has developed a management plan to direct this work. The staff is conducting a review of the management plan, and will continue to provide oversight of DOE's activities to effectively implement its QA program.

#### **CONCLUSIONS:**

NRC staff's evaluation of the VA indicates that the analyses presented are adequate to allow for an informed decision to be made regarding continuation of site characterization of Yucca Mountain and the staff agrees with DOE's decision to proceed. The staff has identified a number of comments on aspects of the reference design, total system performance calculation, and the LA Plan. The staff considers these to be significant subjects that require: 1) successful implementation of plans already in place (e.g., QA program); 2) timely DOE decisions (e.g., waste package design); or 3) additional work not identified in the LA Plan (e.g., quantity and chemistry of the water contacting the waste package and waste form) for DOE to have a high-quality LA by 2002. As described in a December 21, 1998, memorandum to the Commission, the staff will follow up on specific technical issues through periodic revisions to the Issue Resolution Status Reports (IRSRs). The staff intends to inform DOE of its comments and possible actions to address them. A draft letter to DOE is attached.

In the LA Plan, DOE has outlined a strategy for conducting additional site characterization, improving its performance assessment, qualifying models and data, and developing a design for the LA. Through a set of workshops, DOE is developing detailed plans to implement the LA Plan. These workshops may result in work plans that could address NRC staff's concerns, if the work is completed. NRC staff will continue to observe these workshops and continue its preclicensing consultation with DOE.

#### **RECOMMENDATIONS:**

That the Commission approve sending the letter transmitting NRC comments on the VA to DOE.

#### **COORDINATION:**

The Office of the General Counsel has reviewed this paper and has no legal objections. There are no resource, information management, or information technology impacts associated with this paper.

original /s/ by  
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Executive Director for Operations

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Attachments: 1. [Letter to DOE with Staff Evaluation of Significant Concerns](#)  
2. [SRM M990208B](#)

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ATTACHMENT 1

Mr. Lake H. Barrett, Acting Director  
Office of Civilian Radioactive Waste Management  
U.S. Department of Energy, Headquarters  
1000 Independence Avenue, S.W.  
Washington, DC 20585

SUBJECT: NRC STAFF REVIEW OF THE U.S. DEPARTMENT OF ENERGY VIABILITY ASSESSMENT FOR A HIGH-LEVEL RADIOACTIVE WASTE REPOSITORY AT YUCCA MOUNTAIN, NEVADA

Dear Mr. Barrett:

In December 1998, the U.S. Department of Energy (DOE) completed its viability assessment (VA) for a potential high-level radioactive waste repository at Yucca Mountain, Nevada. Although the VA is a management tool to provide DOE with a basis for making an informed assessment of the feasibility of proceeding with site characterization and the process of potential licensing and construction of a repository at Yucca Mountain, the U.S. Nuclear Regulatory Commission (NRC) staff has reviewed the VA as part of its prelicensing consultation with DOE under the Nuclear Waste Policy Act of 1982 (NWPA). It is believed that the results of the review will facilitate DOE's development of a complete and high-quality license application (LA). NRC staff believes that DOE's analyses are adequate to make an informed decision whether to continue with site characterization of Yucca Mountain in anticipation of a potential site recommendation, and staff agrees with DOE's decision to continue site characterization.

Staff interactions with DOE over the past 18 months have facilitated the NRC staff review of the VA. These interactions focused on elements of DOE's ongoing work that formed the basis for the VA. The VA reflects substantial progress by DOE in focusing its program on the issues that need to be addressed prior to a licensing decision. It describes significant DOE progress in areas such as data collection, data synthesis, performance assessment modeling, and documentation of results. There is general agreement that DOE's planned work appears adequate in several technical areas including: mechanical disruption of waste packages; spatial and temporal distribution of flow; distribution of mass flux between fracture and matrix; and dilution of radionuclides in soil.

Staff comments on the VA are intended to facilitate DOE's efforts to focus its program and develop a high-quality LA. The staff reviewed the preliminary design concept, total system performance assessment (TSPA), and LA Plan. Supporting documents such as the TSPA-VA Technical Basis Document were also examined. In formulating comments, the staff took into account supporting information, importance to performance or licensing, and DOE's plans for addressing these topics, as documented in the LA Plan. The comments developed by the staff are not new and have been the subject of earlier public meetings and NRC staff documents.

The staff comments in the enclosure cover the reference design, technical topics related to the data or models associated with several aspects of DOE's TSPA (i.e., performance of the waste package, seepage into the drifts, saturated zone flow, and analysis of the consequences of volcanism), and the LA plan. More detailed comments on the VA will be provided to DOE through updates to Issue Resolution Status Reports, interactions, and correspondence, as appropriate. The staff will continue to evaluate these topics, interact with DOE, and provide timely feedback. It is important for the prelicensing consultations to proceed in order for a possible LA to be of sufficient quality that the staff will be able to complete its review in the time frame required by the NWPA.

Sincerely,  
Carl J. Paperiello  
Director  
Office of Nuclear Material Safety and Safeguards

cc w/encl: See attached list

Letter to L. Barrett from C. Paperiello dated: \_\_\_\_\_

cc: R. Loux, State of Nevada  
S. Frishman, State of Nevada  
A. Brownstein, DOE/Wash, DC  
S. Hanauer, DOE/Wash, DC  
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S. Rousso, DOE/Wash, DC  
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R. Dyer, YMPO  
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B. Price, Nevada Legislative Committee  
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D. Bechtel, Clark County, NV  
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J. Lyznicky, AMA  
R. Clark, EPA  
F. Marcinowski, EPA  
R. Anderson, NEI  
R. McCullum, NEI  
S. Kraft, NEI  
J. Kessler, EPRI

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U.S. Nuclear Regulatory Commission's Staff Evaluation of  
U.S. Department of Energy's Viability Assessment

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- Repository Design
  - *Comment:*
  - *Importance:*
  - *Status of Resolution:*
  - *Additional Background:*
  - *Basis:*
  - *References:*
- Waste Package Corrosion
  - *Comment:*
  - *Importance:*
  - *Status of Resolution:*
  - *Additional Background:*
  - *Basis:*
  - *References:*
- Quantity and Chemistry of Water Contacting Waste Packages and Waste Forms
  - *Comment:*
  - *Importance:*
  - *Status of Resolution:*
  - *Additional Background:*
  - *Basis:*
  - *References:*
- Saturated Zone Flow and Transport

- *Comment:*
- *Importance:*
- *Status of Resolution:*
- *Additional Background:*
- *Basis:*
- *References:*
- Volcanic Disruption of the Waste Package
  - *Comment:*
  - *Importance:*
  - *Status of Resolution:*
  - *Additional Background:*
  - *Basis:*
  - *References:*
- Quality Assurance
  - *Comment:*
  - *Importance:*
  - *Status of Resolution:*
  - *Additional Background:*
  - *Basis:*
  - *References:*

The U.S. Nuclear Regulatory Commission (NRC) staff reviewed the U.S. Department of Energy's (DOE's) Viability Assessment (VA) for a potential high-level radioactive waste (HLW) repository sited at Yucca Mountain, Nevada (YM). This review was conducted as part of the staff's precicensing activities and included the preliminary design, total system performance assessment (TSPA), and License Application (LA) Plan. Based on this review, the staff identified several challenges for DOE to assemble a complete and high-quality LA within the time frame envisioned in the LA Plan.

The review of the VA indicates that DOE has made significant progress in a number of areas such as: data collection, data synthesis, performance assessment (PA) modeling, and documentation. However, additional work will be needed in order for DOE to be able to prepare a complete and high-quality LA. The LA Plan provides a high-level description of where DOE believes progress is required and the priority that DOE is assigning to particular objectives.

The TSPA will be an important element in DOE's LA. The staff conducted concurrent reviews of the TSPA-VA and the LA Plan. Through these reviews, the staff identified a set of technical comments regarding the supporting data and models within the TSPA. These comments address key elements of DOE's PA, and -- based on the review of the LA Plan -- may represent challenges for DOE to develop a complete and acceptable LA. There are areas where the staff does not have major comments at this time. These areas include: mechanical disruption of waste packages (WPs); radionuclide release rates and solubility limits; spatial and temporal distribution of flow in the unsaturated zone (UZ); distribution of mass flux between fracture and matrix in the UZ; retardation in fractures in the UZ; retardation in water-production zones and alluvium; dilution of radionuclides in groundwater from well pumping; airborne transport of radionuclides; dilution of radionuclides in soil; and location and lifestyle of the critical group. The most significant staff comments are summarized below.

## Repository Design

### **COMMENT:**

The reference repository design presented in VA keeps open numerous options such that the overall concept remains fluid. Significant changes in the repository design may affect the timely availability of data to be used for repository PA that is necessary for developing a complete and defensible LA. Although appreciating the importance and need for flexibility in design, the lack of a more focused design may not permit DOE sufficient time to address all pertinent issues and prepare a complete LA within its current schedule.

### **IMPORTANCE:**

Many aspects related to the repository design, especially the thermal load and temperature alternatives; option for backfilling the emplacement drifts and its timing; ground support options and maintenance of underground facility; selection of emplacement stratum; and ventilation alternatives may be important to understanding repository performance. Design alternatives being considered by DOE could result in substantially different approaches than the current reference design. Design options being considered (U.S. Department of Energy, 1998) include different thermal loads, backfilling of the emplacement drifts, continuous pre-closure ventilation, timing of repository closure, type of ground support systems, near-field rock treatment, and repository horizon elevation. Additional enhancement features such as drip shields and Richard's barrier are also being studied. Adequate documentation of design development and traceability of design changes are very important to the completeness and defensibility of the DOE LA. It is important to establish that the data being gathered and the suite of analyses being performed are sufficient to cover all the design alternatives under consideration. It is equally important to develop analytical tools that can make quantitative comparisons of alternatives so that the preference of one over the rest could be established on a rational basis.

### **STATUS OF RESOLUTION:**

The NRC staff has to date concentrated on the design control process being employed by the DOE to document designs and design changes. However, the staff has yet to review the DOE process for the design of the repository. The staff has been observing many DOE meetings and workshops where design alternatives are being discussed and compared based mostly on engineering judgement or qualitative criteria. DOE plans to complete the selection of the LA design in May 1999 and the final design in November 2000 (US Department of Energy, 1998).

**ADDITIONAL BACKGROUND:**

None.

**BASIS:**

DOE presented its first conceptual design for the proposed repository at Yucca Mountain in its Environmental Assessment (in 1984) and then again in its Site Characterization Plan (in 1987). Over the years, the initial design concepts have undergone several iterations with many minor and some major changes to reflect newly acquired information as well as to respond to comments raised by oversight and regulatory bodies. At present, DOE is considering several design alternatives and design options that could significantly affect the repository performance; generate new demands for data and model development; and raise associated uncertainties. For example, depending on the thermal load option selected for final consideration, the technical issues that need to be addressed by DOE and evaluated by NRC could be different. Backfilling the emplacement drifts can change the WP degradation and disruption scenarios to a large extent. Considering the current DOE schedules for addressing the issue of design alternatives, there is a risk that data, models, and analysis results will not be sufficient for a complete and high-quality LA. This might result in NRC requesting additional information at the time of LA review and thus prolong the review period.

**REFERENCES:**

McKenzie, III, D.G. 1998. Alternative repository designs. Presented to the *Drift Stability Workshop*. North Las Vegas, NV: U.S. Department of Energy, Office of Civilian Radioactive Waste Management.

U.S. Department of Energy. 1998. *Viability Assessment of a Repository at Yucca Mountain, Volume 4: License Application Plan and Costs*. North Las Vegas, NV: U.S. Department of Energy, Office of Civilian Radioactive Waste Management.

**Waste Package Corrosion****COMMENT:**

It is unclear whether DOE will be able to acquire sufficient data, applicable to conditions at the proposed repository, in time to demonstrate compliance with NRC requirements. This comment is applicable to the VA design of the waste package (WP) and other aspects of the Engineered Barrier System (EBS).

**IMPORTANCE:**

Container life is an important factor in limiting the dose to the critical group and in providing defense-in-depth for the repository system. For example, DOE sensitivity analyses in the TSPA-VA show that by decreasing the corrosion rate of the inner overpack material by a factor of 60, the annual dose at 10,000 years decreases from 2 mrem to less than  $10^3$  mrem. The corrosion rate of the inner overpack material is one of the many WP parameters affecting the prediction of WP lifetime in the TSPA-VA. Several WP parameters have been defined based on expert elicitation rather than long-term test data, especially those for the corrosion-resistant material (CRM). Even if the design were fixed today, only very limited data will be available to substantiate the adequacy of the waste package design for LA.

The continued consideration of alternate designs (in all areas including the EBS and repository) further complicates this subject. It will be even more difficult to gather sufficient and applicable data in the far shorter time-frame between the next design decision (May 1999) and LA. In addition to the time required for testing new materials and concepts, and developing the appropriate modeling when different failure modes may be involved, fabrication issues -- including the problem of closure welding -- will require time for development and evaluation prior to completing the LA.

**STATUS OF RESOLUTION:**

DOE has testing programs in place for many WP parameters, particularly those relating to the CRM. NRC and DOE staff have had ongoing discussions and interactions regarding these programs and the validity of the values selected by expert elicitation. DOE has described an ambitious testing program in the LA Plan.

DOE has continued the evaluation of alternative designs for waste packages, and a decision is expected in May 1999. One alternative to the current design includes the use of Alloy-22 as an outer barrier and titanium Grade 7 or 16 as an inner barrier. Other options include a three-wall design in which nuclear grade stainless steel (i.e., 316 NG) will be used to provide structural integrity. The reverse design of that proposed in VA, consisting of Alloy-22 as an outer barrier and the steel as an inner barrier providing structural integrity, is also being considered. The issues related to the performance of the alternate designs, including data collection and fabrication issues, are currently being reviewed by NRC and will be addressed in the next revision of the Issue Resolution Status Report (IRSR) on Container Life and Source Term (CLST).

**ADDITIONAL BACKGROUND:**

There are a number of ancillary subjects associated with data collection. In addition to data sufficiency and applicability to the repository environment, there are issues associated with the qualification of data. Another issue is the appropriate role of data collected during the performance confirmation period, relative to data available at the time of Construction Authorization. Although it is appropriate for DOE and NRC to take into consideration more long-term data at later times (i.e., license to receive and possess, repository closure), sufficient data must be available to support the LA. Finally, the bulk of the long-term data used in the TSPA is gathered from expert elicitations and literature reviews, rather than measured under the environmental conditions at Yucca Mountain; including water chemistry, gamma radiation, and the variation of temperature with time.

**BASIS:**

Sensitivity analyses indicate that the lifetime of the WPs has a significant effect on dose to the receptor group. Consequently, corrosion performance of the WPs is a critical factor that may be affected by detrimental interactions between different materials and/or prompted by a specific fabrication process. Additional testing may be required to provide support for any new design. In particular, DOE has recognized in VA that "the primary weakness of the [waste package] model is the overall reliance on expert elicitation rather than on long-term test data of corrosion rates for corrosion-resistant material."

**REFERENCES:**

U.S. Nuclear Regulatory Commission, *Issue Resolution Status Report (Key Technical Issue: Container Life and Source Term, Revision 0)*, Washington DC: U.S. Nuclear Regulatory Commission, 1998a.

**Quantity and Chemistry of Water Contacting Waste Packages and Waste Forms****COMMENT:**

The data and models used in the VA to calculate the quantity and chemistry of water dripping on WPs are inadequate to describe the process and extent of potential dripping under ambient and thermally-altered conditions. This is an issue because both DOE and NRC PA analyses indicate that the fraction of WPs contacted by water is the most important factor affecting dose for the groundwater pathway. Further, NRC staff considers that the current DOE testing and modeling plans are not sufficient to resolve the issue prior to LA. There are activities that DOE could complete prior to LA that would provide additional support for addressing this issue.

**IMPORTANCE:**

The quantity and chemistry of water contacting the WP are the major factors in determining the lifetime of the WP. Radionuclide release rates from breached WPs are also dependent on the quantity and chemistry of water contacting the WPs and, subsequently, the waste forms. Degradation of WPs by corrosion and alteration of waste forms is accelerated in the presence of water and certain dissolved aqueous species. Differences in the amount of seepage into the emplacement drifts and onto WPs lead to calculated radionuclide releases that vary by several orders of magnitude.

**STATUS OF RESOLUTION:**

DOE recognizes that there are few data -- and the need for additional data -- regarding seepage into drifts, the effects of heat and excavation on flow at the drift scale dripping onto WPs, and the chemistry of water on WPs. In addition, DOE has recognized that its current PA models do not adequately capture the effects of coupled processes on the quantity and chemistry of water contacting WPs. DOE has assigned a high priority to both the data collection and modeling efforts, and is conducting a peer review on drift seepage to guide its pre-licensing scientific activities. The range of activities outlined in the LA Plan are unlikely to provide an adequate licensing basis for assessing the quantity and chemistry of water contacting WPs and waste forms. For instance, it was noted at the Drift Seepage Peer Review Meeting on January 11-13, 1999, that the niche studies that have been conducted and proposed to be completed prior to license application, do not provide an adequate basis to support the seepage abstraction (Hughson, 1999). However, two activities were suggested by members of the peer review panel (Hughson, 1999). It is likely that they could be completed prior to LA and would lead to a more defensible approach for addressing the quantity and chemistry of water contacting the WPs and waste forms. First, systematic air permeability measurements conducted in horizontal boreholes in the three repository host rock units could provide data on the scales of variability and heterogeneity in rock properties that are necessary to describe seepage. Second, additional model development efforts should focus on explaining the observed patterns of seepage in the niche experiments.

**ADDITIONAL BACKGROUND:**

The data and processes necessary to describe the quantity and chemistry of water contacting the WPs and waste forms through abstraction in a PA have been addressed in several IRSRs (U.S. Nuclear Regulatory Commission, 1998a, 1998b, 1998c, and 1998d). In addition, the importance of characterizing thermal perturbations to UZ flow fields during the heating phase and considering coupled thermal-hydrologic-chemical-mechanical processes in PAs was raised in letters to DOE (U.S. Nuclear Regulatory Commission, 1997, 1998e).

**BASIS:**

An ongoing peer review of the DOE drift seepage approach has identified inadequacies in the data, experiments used to collect the data, the models used to describe the seepage process, and the methods used to abstract seepage into performance assessments (Hughson, 1999). Both laboratory scale heater tests and analog site heater tests have indicated the potential for liquid water to contact a heat source under heterogenous or transient boiling conditions. Both: (1) the potential for gravity-driven refluxing during the thermal period and other coupled processes; and (2) the importance of these processes for adequately describing WP performance has been presented to DOE (U.S. Nuclear Regulatory Commission, 1997, 1998c). Drift collapse may also significantly alter effective parameters describing moisture retention characteristics of the fracture continuum, and thus result in more seepage for a given percolation flux. On the very small scale of a drift wall, the presence of surface irregularities and conducting fractures that dead-end at the drift crown will result in less capillarity and thus less diversion of percolation flux around the drift (Hughson, 1999). Many alteration products of tuff and engineered materials are likely to affect the chemistry of water contacting WPs, which in turn can affect corrosion rates, waste form alteration rates, and radionuclide solubility and speciation (U.S. Nuclear Regulatory Commission, 1998d). Although an effort was made to address this subject, there are many limitations in the data used and the extent of phases considered. Additional data and analysis of seepage under both isothermal and thermal conditions will be required for a complete LA. The amount of data required for the LA, and the need to confirm expected performance of the evolving repository system, will depend on the importance of the quantity and chemistry of water contacting WPs and waste forms to the DOE safety case.

**REFERENCES:**

Hughson, D., *Drift Seepage Peer Review*, Trip Report, Las Vegas, Nevada, January 11-13, 1999, Center for Nuclear Waste Regulatory Analyses, San Antonio, TX, 1999.

U.S. Nuclear Regulatory Commission, *Comments on the Department of Energy Thermohydrology Testing and Modeling Program*, letter dated January 23, 1997, from M.J. Bell, U.S. Nuclear Regulatory Commission, to S.J. Brocoum, U.S. Department of Energy, 1997.

U.S. Nuclear Regulatory Commission, *Issue Resolution Status Report (Key Technical Issue: Total System Performance Assessment and Integration, Revision 1)*, enclosure to letter dated December 8, 1998, from M.J. Bell, U.S. Nuclear Regulatory Commission, to S.J. Brocoum, U.S. Department of Energy, 1998a.

U.S. Nuclear Regulatory Commission, *Issue Resolution Status Report (Key Technical Issue: Unsaturated and Saturated Flow Under Isothermal Conditions, Revision 1)*, enclosure to letter dated October 7, 1998, from M.J. Bell, U.S. Nuclear Regulatory Commission, to S.J. Brocoum, U.S.

Department of Energy, 1998b.

U.S. Nuclear Regulatory Commission, *Issue Resolution Status Report (Key Technical Issue: Thermal Effects on Flow, Revision 1)*, enclosure to letter dated October 1, 1998, from M.J. Bell, U.S. Nuclear Regulatory Commission, to S.J. Brocoum, U.S. Department of Energy, 1998c.

U.S. Nuclear Regulatory Commission, *Issue Resolution Status Report (Key Technical Issue: Evolution of the Near-Field Environment, Revision 1)*, enclosure to letter dated August 28, 1998, from N.K. Stablein, U.S. Nuclear Regulatory Commission, to S.J. Brocoum, U.S. Department of Energy, 1998d.

U.S. Nuclear Regulatory Commission, *U.S. Nuclear Regulatory Commission Comments on the U.S. Department of Energy Total System Performance Assessment*, letter dated July 6, 1998, from M.J. Bell, U.S. Nuclear Regulatory Commission, to S.J. Brocoum, U.S. Department of Energy, 1998e.

## Saturated Zone Flow and Transport

### **COMMENT:**

In NRC sensitivity studies, flow in the saturated zone has been shown to be an important component of the natural barrier. At this time, the saturated zone (SZ) has not been sufficiently characterized from the repository out to the proposed 20-km receptor location to adequately assess its contribution to performance. This is an issue because it creates uncertainty about the SZ flow and transport models and the SZ representation in the TSPA. Furthermore, it may render the LA incomplete because the SZ remains an integral part of the DOE repository safety strategy.

### **IMPORTANCE:**

The SZ is the primary pathway for radionuclide transport from the repository to the receptor location, and is an integral part of the DOE repository safety strategy. The SZ has been identified in the TSPA-VA as one of 19 "principal factors" affecting postclosure performance. In its 1998 report to Congress, the Nuclear Waste Technical Review Board (NWTRB) stated that it believes that the SZ "is an essential natural component of a defense-in-depth repository design for Yucca Mountain" (NWTRB, 1998, PP 45).

DOE indicates that radionuclide travel time in the SZ constitutes a significant fraction of the 10,000 year compliance period (DOE, 1998a: Vol 3, pp 6-16). In addition, sensitivity analyses performed by DOE (DOE, 1998a: Vol 3, pp 4-71-80; 5-40-43) indicate that all three SZ attributes examined in the analyses (SZ dilution, method of combining flow in the SZ flowtube model, and the alluvium fraction in the SZ flow path) have some measure of importance to repository performance, and that SZ dilution is an important parameter affecting the calculated dose for the 10,000-year simulation. Sensitivity analyses by NRC and Center for Nuclear Waste Regulatory Analyses (CNWRA) staff suggest that the SZ is a relatively important subsystem for overall repository performance (Jarzemba et al., 1998).

### **STATUS OF RESOLUTION:**

DOE has low "current confidence" and a low "confidence goal" in the SZ flow and transport representation in the TSPA (DOE, 1998a: Volume 4, pp 2-20, 2-38). DOE plans to conduct additional SZ work activities to improve confidence in the SZ representation in the TSPA for the LA (DOE, 1998a: Vol 4, pp 2-47; pp 3-15, 3-16). In cooperation with DOE, Nye County will implement an "Early Warning Drilling Program," involving installation and testing of shallow and deep wells downgradient of the repository. These wells are expected to provide data about the hydraulic and transport properties of the aquifers along the flow path downgradient from the repository. The scope of the drilling program is limited, however, and may not adequately characterize the SZ, especially the alluvial aquifer. According to DOE (DOE, 1998a: Volume 4, pp 2-39, 3-13), the scope of the planned SZ work was constrained by the available time before the site recommendation (SR) decision and the LA submittal. Furthermore, DOE has assigned a relatively low priority to the planned SZ work (DOE, 1998a: Volume 4, pp 2-20, 2-39).

In addition, some of the planned work activities will extend beyond the cutoff dates for the planned refinement and update of the site-scale and regional SZ flow models. These include (DOE, 1998: Vol 4, pp 3-16): (1) downgradient alluvial hydraulic and tracer testing; (2)  $K_d$  determination of alluvium samples obtained from the Nye County wells; and (3) downgradient hydraulic and tracer testing of the volcanic rocks in the area between 5 and 20 km from the repository. DOE states that data obtained from the first two activities and early data from the third activity will be available for use in the TSPA for the LA, but it is not clear how this will be achieved.

It may be possible for DOE to implement, in a relatively short time prior to the LA, some additional field work independent of the Nye County drilling program, possibly including exploratory drilling and surface geophysical investigations to specifically delineate and characterize the alluvium along the flowpath downgradient from the repository. However, DOE currently has no plans to address this.

### **ADDITIONAL BACKGROUND:**

The M&O (1998) and DOE (1998a) suggest that the SZ flow system in the YM vicinity has not been adequately characterized. There are very limited field data to characterize the SZ flow between about 5 km and 20 km downgradient from the repository (DOE, 1998a: Volume 4, pp2-38), and limited data to define the SZ transport along the SZ flow path from the repository to the receptor location (DOE, 1998a: Vol 3, pp6-36). In addition, conceptual uncertainties associated with SZ flow and transport have also been reported by the U.S. Geological Survey and others (Luckey et. al., 1996; Czarnecki et., el., 1997; D'Agnes, et., al., 1997; DOE: 1998b; Geomatrix Consultants, Inc., 1998; Gelhar, 1998; and NWTRB, 1998).

The uncertainties about SZ flow and transport at YM have been documented in two IRSRs (NRC, 1998a,b). The flow rate in water production zones has been identified by NRC staff as a key element of subsystem abstraction (KESA) in the TSPA models, and the acceptance criteria are in the Unsaturated and Saturated Flow Under Isothermal Conditions IRSR (NRC 1998a,b).

### **BASIS:**

The presence of alluvium along the SZ flow path is expected to significantly delay the arrival of radionuclides at the receptor location due to enhanced sorption and dilution; however, the location of the water table transition from tuffs to alluvium is not yet reasonably characterized. There is uncertainty as to where SZ flow enters the alluvium along the flowpath from the repository or even if flow occurs within the alluvium within 20 km (DOE, 1998a:



Volume 3, pp 6-24). This is especially important considering the potentially higher sorption coefficients of some radionuclides which are key contributors to dose, such as neptunium in the alluvium (DOE, 1998a: Volume 3, pp 6-24 - 6-25).

The flow rate in water production zones is affected by the basin scale groundwater flow and may, therefore, be controlled by high permeability features or channelized flow pathways in the aquifer. The presence of preferential and/or fast pathways, due to geologic structural controls, could significantly reduce the transport time. In the YM vicinity, the faults locally control groundwater flow and may represent pathways for upward flow from the deeper carbonate aquifer (Fridrich et al., 1994; Bredehoeft, 1997; Geomatrix Consultants, 1998). Such flow channeling along preferred pathways is common in fractured and faulted rock (Tsang and Neretnieks, 1998). Interpretation of aquifer borehole tests indicate that permeability at YM is anisotropic (Geldon, 1996). The anisotropic permeability due to structural features downgradient of YM may result in more southerly-directed flow paths than currently modeled by the DOE. The radionuclides in this southerly flow path could remain in the volcanic tuff aquifer all the way to the receptor location at 20 km, since there is no alluvium or a much reduced alluvium fraction in this direction (Frizzel and Shulters, 1990).

DOE has characterized the uncertainties in SZ flow and transport to the TSPA as "moderate", but states that the uncertainty could increase as the model more realistically accounts for processes that reduce radionuclide concentration (DOE, 1998a: Volume 4, pp 2-38). Furthermore, a "moderate" ranking of the SZ uncertainties appears inconsistent with the results of the sensitivity analyses performed by either DOE or NRC/CNWRA.

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U.S. Department of Energy. 1998b. *Peer Review of the Total System Performance Assessment-Viability Assessment: Third Interim Report, June 1998*. Las Vegas, NV: U.S. Department of Energy, Office of the Civilian Radioactive Waste Management.

## Volcanic Disruption of the Waste Package

### **COMMENT:**

DOE concludes in the TSPA-VA that there are no risks from volcanism during a 10,000 yr post closure period, based on models assuming waste package resilience and limited HLW entrainment during a volcanic eruption (CRWMS M&O, 1998). NRC staff review concludes (i) these analyses are based on assumptions of physical conditions that are not representative of Yucca Mountain basaltic volcanism, (ii) data are insufficient to evaluate waste package and HLW behavior under appropriate physical conditions, and (iii) model assumptions are incongruent with those used elsewhere in the TSPA-VA, for example, in enhanced source-term analyses.

### **IMPORTANCE:**

TSPA-VA analyses may underestimate the contribution to risk associated with future igneous activity at the proposed repository site. Current NRC calculations suggest that the probability-weighted risk from volcanic disruption of the proposed repository is low (on the order of 1 mrem), however this value has sizeable model and parameter uncertainty. DOE has not identified in the VA plans to conduct additional investigations necessary to support igneous activity risk assessment. Unavailability of acceptable consequence models to support igneous activity risk assessment is an issue, in that a process with a potential to be an important contributor to total system risk would not be supported adequately in the LA.

### **STATUS OF RESOLUTION:**

While the VA License Application Plan (DOE, 1998b) indicates no planned activities to resolve these issues, recent informal staff interactions, including participation at DOE workshops, suggest that workplans are being developed which, if implemented, could resolve them. These plans are expected to be completed in late March. The staff will review these plans as they become available and discuss their implementation with DOE in future DOE/NRC Technical Exchanges and other interactions (DOE, 1998a, Section 6.5.3.8) to determine if the issues can be resolved at the staff level prior to licensing.

### **ADDITIONAL BACKGROUND:**

The issues associated with the DOE igneous activity program, including the relationship to Total System Performance Assessment modeling, have been raised in comments on DOE study plans 8.3.1.8.1.1 (Holonich, 1994a), 8.3.1.8.1.2 (Holonich, 1994b), 8.3.1.8.5.1 (Holonich, 1994c), numerous interactions with DOE at Technical Exchanges, Appendix 7 Meetings, meetings and workshops with the Advisory Committee on Nuclear Waste and the Nuclear Waste Technical Review Board, interactions associated with the DOE PVHA, and most recently through detailed comments in the Igneous Activity Issue Resolution Status Reports (NRC, 1997, 1998). Acceptance criteria contained in the IA IRSR (NRC, 1998) delineate an acceptable technical basis for evaluating risks associated with future igneous events.

### **BASIS:**

In the TSPA-VA, it is assumed that a waste package with >50 percent of the original corrosion resistant material thickness (i.e., >1 cm) will not fail when exposed to the extreme physical conditions of a volcanic eruption except through occasional end-cap failure. This assumption precludes any direct HLW entrainment or release from any volcanic event occurring within the first 100,000 yr post-closure (CRWMS M&O, 1998). This assumption is based on extrapolation of limited data from <430 °C to likely magmatic temperatures around 1100 °C. In contrast, similar data are used to conclude that an intact waste package will fail mechanically when exposed to magma intruded into repository drifts (i.e., enhanced source-term analysis), even when temperatures significantly below expected intrusion temperatures are used in the analysis (CRWMS M&O, 1998). The TSPA-VA analysis of waste-package resilience also does not address the dynamic force imposed on a waste package entrained into a volcanic conduit. As outlined in the IA IRSR (NRC, 1998), staff analyses of limited available data conclude waste-package breach is likely under volcanic eruption conditions. Models proposing waste-package resilience during igneous events are nonconservative and will need robust support through analyses and data that examine physical, chemical, and thermal conditions representative of likely future igneous activity in the YM region.

Another key assumption in the TSPA-VA that is not supported by available information is that magma particle sizes or particle velocities are insufficient to entrain HLW fragments (CRWMS M&O, 1998). Although the expansion of dissolved volatiles in ascending magma may be sufficient to form a two-phase flow regime at repository depths, the fragmented particles are still at temperatures around 1100 °C. Particles will be larger average size than observed at completely cooled and fragmented fall deposits, and will impact HLW fragments elastically. In addition, assumed HLW particle sizes do not account for the extreme physical conditions associated with igneous disruption. As outlined in the IA IRSR (NRC, 1998), staff concludes that HLW particle sizes will be reduced substantially when exposed to the physical, thermal, and chemical environment associated with YM igneous events. Models proposing a lack of entrainment in potential repository-penetrating igneous events will need support through analyses and data.

### **REFERENCES:**

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## Quality Assurance

### **COMMENT:**

Although NRC staff has reviewed and accepted the DOE Quality Assurance (QA) program, DOE has consistently had problems implementing the program. Deficiencies identified during DOE audits and surveillance of its suppliers raised the issue of whether the data/products produced by these suppliers will be acceptable and appropriately qualified for licensing. DOE audits have identified that some data in the Management and Operating Contractor's (M&O's) technical data base are not traceable to their origins and could not be ensured to be applicable, correct and technically adequate. The Technical Basis Document, which supports the TSPA-VA, indicates that a major portion of the data supporting VA is not qualified. DOE's LA Plan does not recognize the current situation with regard to implementation of its QA program and the activities needed to address it.

### **IMPORTANCE:**

To obtain authorization to construct a HLW repository, DOE must be able to demonstrate in its LA that data, analysis, and designs of barriers and systems important to safety or waste isolation meet QA requirements of Appendix B to CFR Part 50.

The QA program applies to all systems, structures, and components important to safety and waste isolation, including: design and characterization of barriers important to waste isolation; activities such as site characterization, facility and equipment construction; facility operation; performance confirmation; permanent closure; and decontamination and dismantling of surface facilities. Confidence in the adequacy of data, data analyses, construction activities, and other items and activities associated with the LA is obtained through a QA program.

### **STATUS OF RESOLUTION:**

DOE recognizes the need to improve the implementation process to qualify data, models, and codes and has assigned a high priority to these activities based on questionable data in the M&O technical data base and its associated references. DOE has also issued Yucca Mountain Administration Procedure YAP-S111.1Q, Revision 3, ICNO to improve the process of qualifying unqualified data.

During the NRC/DOE QA meeting of December 9, 1998, DOE committed to the development of an overall data qualification strategy/plan by December 21, 1998. The plan should include: 1) identification of unqualified data sets approved for qualification; 2) methods of qualification and rationale; 3) technical disciplines required; 4) data evaluation criteria including size of sample to be tested, statistical method to be used, and identification of computer codes to be used; 5) criteria for changing data status from "non-qualified" to "qualified;" and 6) a schedule for completing the work. NRC staff is currently reviewing the "Data, Model and Code Qualification/Validation and Control Plan."

Meanwhile, an NRC QA Task Force was formed to conduct an independent and objective review of the DOE HLW QA program and its implementation. A Task Force review of the "DOE Management Plan and Responses to Corrective Action Request (CAR) and Status of Implementation of Corrective Actions" document, dated January 25, 1999, is underway. The Task Force will also review, and formally comment on, the Root Cause Analysis/Corrective Action Report conducted by DOE.

### **ADDITIONAL BACKGROUND:**

None.

### **BASIS:**

The NRC On-Site Representative's reports (ORRs) and Observation Audit Reports (OARs) on the Yucca Mountain Project are documented to alert NRC staff, managers and contractors to information on DOE programs for site characterization, repository design performance assessment, and environmental studies that may be of use in fulfilling NRC's role during pre-licensing consultation. As noted in the ORRs and the OARs, deficiencies have been identified questioning the accuracy, qualification and traceability of data.

### **REFERENCES:**

NUREG-1298 - Generic Technical Position (GTP) on "Qualification of Existing Data for High-Level Nuclear Waste Repositories," dated February 1998.

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