Appendix E
U.S. Nuclear Waste Technical Review Board Correspondence with U.S. Department of Energy

In addition to published reports, the Board periodically writes letters to the Director of the U.S. Department of Energy's (DOE) Office of Civilian Radioactive Waste Management (OCRWM). The letters typically provide the OCRWM with the Board's views on specific technical areas earlier than do Board reports. The letters are posted on the Board's Web site after they have been sent to the OCRWM. For archival purposes, the six Board letters written during the period covered by this report are reproduced here.

The OCRWM typically responds to the Board's reports and letters, indicating its plans to respond to the Board's recommendations. Included here are the OCRWM's responses received by the Board during calendar year 2004 and early 2005. Inclusion of these responses does not imply the Board's concurrence.

- Letter from Mark Abkowitz, Chair, Panel on the Waste Management System, to Margaret S. Y. Chu, Director, OCRWM; March 29, 2004.
  Subject: DOE's participation at the Panel on the Waste Management System meeting held January 21, 2004

- Letter from Ronald M. Latanision, Chair, Panel on the Engineered System, to Margaret S. Y. Chu, Director, OCRWM; April 5, 2004.
  Subject: DOE's participation at Panel on the Engineered System meeting held March 9–10, 2004

- Letter from Richard N. Parizek, Chair, Panel on the Natural System, to Margaret S. Y. Chu, Director, OCRWM; May 3, 2004.
  Subject: DOE's participation at Panel on the Natural System meeting held January 20, 2004

- Letter from Margaret S. Y. Chu, Director, OCRWM, to David J. Duquette, Chair, Executive Committee; May 17, 2004.
  Subject: DOE's responses to recommendations in the December 16, 2003 letter

- Letter from Margaret S. Y. Chu, Director, OCRWM, to Mark Abkowitz, Chair, Panel on the Waste Management System; May 28, 2004.
  Subject: DOE's responses to recommendations in the March 29, 2004 letter

- Letter from Margaret S. Y. Chu, Director, OCRWM, to Ronald M. Latanision, Chair, Panel on the Engineered System; July 21, 2004.
  Subject: DOE's responses to recommendations in the April 5, 2004 letter

- Letter from David J. Duquette, Chair, Executive Committee, to Margaret S. Y. Chu, Director, OCRWM; July 28, 2004.
  Subject: DOE's participation at the May Board meeting

- Letter from Margaret S. Y. Chu, Director, OCRWM, to Richard N. Parizek, Chair, Panel on the Natural System; September 10, 2004.
  Subject: DOE's responses to recommendations in the May 3, 2004 letter

- Letter from B. John Garrick to Margaret S. Y. Chu, Director, OCRWM; November 30, 2004.
  Subject: DOE's participation at the September Board meeting

- Letter from B. John Garrick to Margaret S. Y. Chu, Director, OCRWM; December 1, 2004.
  Subject: DOE's participation at the Panel on the Waste Management System meeting held October 13–14, 2004

- Letter from Margaret S. Y. Chu, Director, OCRWM, to B. John Garrick; January 26, 2005.
  Subject: DOE's responses to recommendations in the July 28, 2004 letter

- Letter from Margaret S. Y. Chu, Director, OCRWM, to B. John Garrick; February 1, 2005.
  Subject: DOE's responses to recommendations in the December 1, 2004 letter

- Letter from Theodore J. Garrish, Deputy Director, OCRWM, to B. John Garrick; March 31, 2005.
  Subject: DOE's responses to recommendations in the November 30, 2004 letter

UNITED STATES
NUCLEAR WASTE TECHNICAL REVIEW BOARD
2300 Clarendon Boulevard, Suite 1300
Arlington, VA 22201

March 29, 2004

Dr. Margaret S. Y. Chu
Director
Office of Civilian Radioactive Waste Management
U.S. Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585

Dear Dr. Chu:

Thank you for the Department of Energy's (DOE) support of our January 21 panel meeting on transportation strategic planning. Now that the DOE has received significant funding to develop a transportation system for Yucca Mountain, we anticipate that updates on progress in this area may become a regular feature of our future Board meetings. We also anticipate holding additional panel meetings devoted solely to transportation on a regular basis.

At the January 21 meeting, we heard that there has been significant experience in transporting spent fuel and similar materials safely, both in the United States and abroad, and that the planning and operational issues related to the movement of those materials can readily be identified. Because a Yucca Mountain transportation system would be substantially larger than those used for many previous shipping campaigns in the United States, the challenges in developing such a transportation system and operating it safely and efficiently become magnified. From that perspective, we offer the following comments on information presented at the January 21 meeting.

- The Board believes that proper transportation planning for meeting a 2010 operational start-up is a large and ambitious task. This observation is based on both the current status of Yucca Mountain project transportation planning and a retrospective view of the Waste Isolation Pilot Plant (WIPP) transportation planning and implementation. Consequently, proper strategic planning is vital at this time. Although the release of the DOE's initial strategic plan in November 2003 is commendable, the Board feels that the plan lacks the necessary detail for truly understanding the DOE's intentions and awareness of the complexity and scale of transportation planning. The Board recommends that the DOE develop and produce a Gantt chart (or its equivalent) showing the schedule for transportation planning activities according to each activity's scope, duration, resources required, and relationship to other activities. This will enable the DOE to demonstrate that a systematic approach to transportation planning is being undertaken, identify the activities that are anticipated to occur in sequence or in parallel, and acknowledge what constitute critical-path activities.

- The Board cannot stress enough the importance of collaboration and communication with a diverse set of transportation stakeholders—early and often. This set includes stakeholders at all levels of government. Although the Board believes that the DOE's resumption of transportation planning discussions with regional government organizations represents a positive step, that is not a substitute for the need to engage in constructive dialogue with individual states and affected units of local government. Marginalizing these relationships will not only make the DOE appear disingenuous but will also become problematic when the DOE requests the future cooperation of these entities (e.g., permitting).

- The Board sees waste acceptance emerging as a key strategic planning consideration. There is a compelling need for the DOE and the utility industry to clarify the interpretation of current contract provisions regarding the type of spent fuel that can be shipped and the timetable for doing so, as well as to negotiate any changes to these provisions to satisfy both DOE and utility shipping concerns. Absent these clarifications and negotiations, cask requirements and transport logistics that are compatible with the waste to be shipped will be a formidable, if not impossible, task to define. Although the Board understands that the DOE and the utility industry have been reluctant to discuss these issues because of pending litigation, the Board encourages the DOE to seek a method for facilitating such an exchange, perhaps through the use of an objective, unbiased third party.

- A complete and accurate inventory of rail, truck, and barge access/egress infrastructure for each nuclear power plant and corresponding site interfaces is a critical-path element in the transportation planning process that the DOE needs to address. The feasibility of certain modes for servicing specific facilities and the resources required to upgrade the infrastructure to meet safety and security standards will be important determinants in mode and route decisions as well as in scoping the financial requirements for operating such a system.

- Cask procurement can be a lengthy and expensive activity, especially given the design, testing, certification, and fabrication requirements associated with the production of new cask types. Before the launching of a full-scale development program, the Board advises the DOE to conduct a thorough review of waste inventory and acceptance assumptions; anticipated shipment schedules; the ability to utilize existing cask designs and the flexibility inherent in new designs to handle anticipated waste types, modes, and volumes; interface with the Yucca Mountain surface facility; and effects on ancillary transportation equipment design.

- The DOE should not underestimate its use of truck transport of spent nuclear fuel and high-level radioactive waste, irrespective of whether rail is designated as the primary transport mode. With heavy-haul and super-heavy-haul shipments under consideration, obtaining permits, upgrading or expanding lanes on roadways, and providing enhanced security are just a few of the issues that will need to be addressed. These challenges will be exacerbated by the total reliance on trucking for the final portion of any shipment if

the Yucca Mountain project decides to receive waste shipments before a rail spur into the facility is available.

- For satisfying post-9/11 public expectations, security planning needs to be explicitly considered as part of a comprehensive transportation risk management process. The DOE should give serious consideration to adopting U.S. Nuclear Regulatory Commission security requirements, which a concerned public may view as more effective than similar DOE requirements.

- Emergency response capability is seen by states and local communities as a vital component of shipment safety and security because it ensures that they can participate in protecting the public if a transportation incident occurs. Given that the WIPP transportation program worked with states for seven years to develop community relationships and provide emergency response training before the first shipment, and on the basis of estimates from various counties of the emergency response planning and training resources required, the DOE will need to demonstrate that adequate preparatory time and financial resources will be available.

- The Board observes that the DOE can draw on considerable operational experience on how to transport nuclear waste safely. This is evidenced by previous and ongoing campaigns involving WIPP, foreign research reactor fuel, naval spent fuel, and West Valley spent fuel. However, no formal integration of transportation activities within the agency appears to be taking place. The Board encourages the DOE to establish such a mechanism, perhaps by reestablishing its Senior Executive Transportation Forum.

Thank you again for the DOE's support of our meeting.

Sincerely,

{Signed By}

Mark Abkowitz, Chair
Panel on the Waste Management System

UNITED STATES
NUCLEAR WASTE TECHNICAL REVIEW BOARD
2300 Clarendon Boulevard, Suite 1300
Arlington, VA 22201

April 5, 2004

Dr. Margaret S. Y. Chu
Director
Office of Civilian Radioactive Waste Management
U.S. Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585

Dear Dr. Chu:

The Board's Panel on the Engineered System held a meeting January 20, 2004, in Las Vegas. The theme of the meeting was "Repository Design Update." There were nine presentations at the meeting: five by the staff of your Office of Repository Development, one by a representative of your Office of Strategy and Program Development, two by a representative of Nye County, and one by a representative of the Nuclear Energy Institute. In addition, representatives of OCRWM's Management and Operating Contractor, BSC, were present at the meeting to answer questions. The purpose of this letter is to thank you again for the participation in the meeting by you, your staff, and your contractor and to provide the following Board feedback from the meeting.

- As described at the meeting, the design of the repository surface facilities includes temporary storage for up to 40,000 metric tons of spent fuel. We understand that the current plan is to construct only 1,000 metric tons of storage capacity and that additional storage would be constructed only as needed and only to the extent needed. We also understand that the DOE intends that the entire 40,000 metric tons of storage capacity will be included in the license application. The technical justification for a 40,000 metric ton storage facility is unclear. As pointed out in BSC's February 2002 "Thermal Operating Modes" white paper, a larger surface facilities area with a pad for extended surface aging could affect the analysis of aircraft-crash hazard. The Board recommends that the technical justification for such a large storage facility be explained.

- The Board understands that BSC recently awarded a fixed-price contract to build the first full-scale waste-package prototype. We believe that the technical information obtained during the course of performance of this contract will be very important, and we agree that more waste-package prototypes are needed. We understand that the reasons for building prototypes include reasons other than obtaining technical information. However, we would like more explanation about the technical information that will be obtained by the current plan to build 14 more prototypes.

- While not unprecedented, the stainless-steel perforated plate and stainless-steel bolt system proposed as the ground-support system for emplacement drifts is highly unusual and expensive. We would like to learn more about the technical basis for the selection of stainless steel as the material of construction, particularly for the perforated plate. We also would like to know which other materials were considered for ground support and the technical bases for their rejection. We understand that the emplacement-drift ground-support system is designed for a preclosure service life of 100 years and "not to preclude" a preclosure period of up to 300 years. We would like a description of the planned inspection and maintenance activities — including a description of how those activities would be conducted — for both the first 100 years and the subsequent 200 years.

- The Board notes that changes have been made in the subsurface repository design to increase the radius of each emplacement drift turnout and to move the ventilation control door to the outer end of each turnout. These changes will affect postclosure waste-package temperatures, particularly the temperatures of packages close to the turnouts. In addition, these changes are likely to exacerbate "cold trap" effects near and in the turnouts. We strongly recommend that temperature and relative humidity calculations be revised to reflect the design changes, if that has not been done already.

- The Nye County work on the evolution of chemistry in the engineered barrier system and on the topic of natural ventilation is very interesting. These topics are important because they influence both waste-package corrosion and transport from the engineered barrier system. It is clear that the environment in drifts is not a quasi-static or slowly changing one but a dynamic one driven in part by temperature differences among waste packages and along the drifts. Such differences will always exist but will be greater during the thermal pulse period. A repository at Yucca Mountain will have some degree of natural ventilation or natural circulation regardless of whether it is deliberately engineered into the repository design or not. Models for temperature and relative humidity predictions must take these natural processes into account fully.

We would like to thank you again for your participation in the meeting and for the assistance of your staff in preparing for the meeting. We particularly appreciate the technical coordination assistance provided by Claudia Newbury and the excellent presentations on repository design by Paul Harrington.

Sincerely,

{Signed By}

Ronald M. Latanision
Chair, Panel on the
Engineered System

UNITED STATES
NUCLEAR WASTE TECHNICAL REVIEW BOARD
2300 Clarendon Boulevard, Suite 1300
Arlington, VA 22201

May 3, 2004

Dr. Margaret S. Y. Chu
Director
Office of Civilian Radioactive Waste Management
U.S. Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585

Dear Dr. Chu:

On behalf of the Nuclear Waste Technical Review Board's Panel on the Natural System, I would like to express our appreciation to you and to the rest of the Yucca Mountain Project team for participating in our March 9-10, 2004, meeting in Las Vegas and for the subsequent Board field trip to Yucca Mountain on March 11. The purpose of the meeting and field trip was to investigate the fundamental scientific and technical basis for estimates of the potential performance of the natural barriers to radionuclide transport under conditions not disturbed by repository heating. The presentations at the meeting were clear, substantive, and helpful. The Board's observations and recommendations from the meeting are presented below.

Increasing Fundamental Understanding

Field and laboratory observations and analyses presented by the Department of Energy (DOE) and others suggest that the natural system provides an effective barrier to migration of some radionuclides over time periods that may be comparable to the regulatory period. However, several key hydrogeologic features or processes that may significantly affect fluid flow and radionuclide transport are presently not well understood, are constrained by limited or poor data, or both.

The DOE often deals with uncertain features and processes by making conservative estimates of their effects on radionuclide transport. Such conservativisms regarding the performance of the natural system tend to emphasize more-rapid advective transport processes. More realistic estimates that might arise from further evaluation of some features and processes could lead to slower transport predictions for some radionuclides. However, there is a possibility that some other poorly understood features or processes may lead to faster radionuclide transport. Therefore, it is important that the DOE develop a better fundamental understanding of the overall behavior of the natural system.

In the following paragraphs, the Board identifies some areas where additional work might increase basic understanding, narrow the wide range of predicted radionuclide transport times, and increase confidence in predictions of the performance of the natural barriers. An enhanced

technical basis for the performance of the natural barriers is an important part of an overall repository strategy that uses multiple barriers to provide defense-in-depth.

Technical and Scientific Recommendations

Increases in fundamental understanding of the behavior of the natural system could result from scientific investigations conducted in the following three areas. First, although the hydraulic properties of major block-bounding faults, such as the Solitario Canyon fault, never have been field-tested, it seems clear that these faults can influence fluid flow and radionuclide transport substantially. Large-scale hydraulic tests of those major faults are therefore needed. Second, improvements in the characterization of the spatial distribution and sedimentary architecture of the saturated alluvium could substantially enhance fundamental understanding of groundwater flow and radionuclide transport along Fortymile Wash south of Yucca Mountain. For example, the recent sonic log drilled by Nye County is an excellent source of data for supporting studies of sorption of radionuclides in alluvial sediment; additional logs from locations where uncertainties are high have the potential to yield similar benefits. Deeply weathered cobbles from that geologic log suggest the potential for delays in radionuclide transport due to diffusion that could be demonstrated if the DOE conducts field-scale long-term tracer studies (for example, at the Alluvial Testing Complex). These studies should be done. Third, depending on rock properties such as fracture frequency and thin coatings on the fracture faces, matrix diffusion could either increase or decrease current estimates of radionuclide transport time by thousands of years. For this reason, a better empirical basis for predicting matrix diffusion is needed.

Three other areas — colloid-facilitated transport, the active fracture modeling approach, and boundary fluxes on the site-scale saturated zone model — are significant elements of DOE analyses that have substantial unresolved uncertainty. First, evidence from a nuclear weapons test site suggests that some water-borne colloids can lead to rapid radionuclide transport in the saturated zone. Laboratory and computer studies conducted by the DOE show that other colloids might substantially slow radionuclide migration. Consequently, understanding of this phenomenon should be improved by field, laboratory, and modeling studies. Second, for unsaturated zone fluid flow and radionuclide transport, predictions are influenced significantly by assumptions inherent in the formulation of the active fracture model (AFM). The AFM needs to be tested and evaluated to establish a technical basis for using this approach. Third, in the saturated zone, the technical basis for the DOE's site-scale flow model would be stronger if the model were more consistent with the most recent regional model calculations of flow across the site-scale model boundaries. Updating the DOE's model on the basis of these calculations could affect predictions of radionuclide transport times.

Multiple Lines of Evidence

The Board continues to believe that an integrated explanation is needed of how elements of the repository act as a system to isolate waste. Such an explanation should rest on a fundamental understanding of the system as discussed in previous paragraphs and on multiple lines of evidence. Multiple lines of evidence and argument can be used to supplement and evaluate the conceptual understanding of the natural systems at the site, the models used to represent those concepts, and the scenarios predicted by those models. The Peña Blanca analogue site in Chihuahua, Mexico, having many similarities to Yucca Mountain, provides a good opportunity to evaluate, for example, whether consideration of secondary mineralization

processes may reduce overall system dose estimates substantially and what effect alpha decay of radionuclides in minerals may have on mobility. The Board commends the Science and Technology program for its plans to test Yucca Mountain modeling approaches at the Peña Blanca analogue site. Naturally occurring radioisotopes at Yucca Mountain provide another valuable line of evidence for flow and transport. Additional isotopic data, such as carbon-14 measurements, collected from discrete zones in the flow path from Yucca Mountain, could be used to test and evaluate DOE models and predictions and to constrain recharge rates in the model domain. In summary, the validity of model forecasts can be evaluated better in the presence of a list of independent physical and chemical lines of evidence that support or challenge the forecasts.

Concluding Comments

At a May 2002 meeting of the Board, you stated your intention to devote attention to aspects of the natural system, and we are encouraged by your interest in this important work. Observations during our field trip to Yucca Mountain demonstrated two things in particular: (1) better understanding the behavior of the natural barriers at Yucca Mountain is challenging because of the complexity of the geologic system, and (2) based on recent progress in characterizing the natural system, enhanced understanding of the natural system is attainable. The Board believes strongly that the important work you have done in this area should be continued.

Again, we thank you, your staff, and your scientists very much for an excellent meeting and field trip.

Sincerely,

Richard R. Parizek
Chair, Panel on the Natural System

Department of Energy
Washington, DC 20585

May 17, 2004

David J. Duquette, Ph.D.
Acting Chairman
Nuclear Waste Technical Review Board
2300 Clarendon Boulevard
Arlington, VA 22201-3367

Dear Dr. Duquette:

We have received the December 16, 2003, letter from the Nuclear Waste Technical Review Board (Board) providing the Board's initial reactions to the information presented by the U.S. Department of Energy (DOE) at the Board's September 2003 meeting in Amargosa Valley, Nevada. The DOE's responses to the views expressed by the Board are provided in the enclosure to this letter.

The DOE appreciates the Board's continuing review of our activities as we work to complete the analyses and documentation to support the license application for a repository at Yucca Mountain, Nevada, scheduled to be completed in December.

Sincerely,

Margaret S.Y. Chu, Ph.D.
Director
Office of Civilian Radioactive
Waste Management

Enclosure

U.S. Department of Energy Responses to Observations from the Nuclear Waste Technical Review Board on the September 2003 Full Board Meeting

Issues Relating to Natural Characteristics of Yucca Mountain

1. Igneous scenarios.

According to the DOE's estimates, igneous scenarios may dominate the risk to humans from a Yucca Mountain repository. To date, it appears that the DOE intends to pursue only one of the three recommendations made by the Board in its June 30, 2003, letter—study of aeromagnetic anomalies near the Yucca Mountain site. The Board repeats its recommendation that the DOE also conduct modeling studies of compressible fluids and studies of waste package-magma interaction and waste entrainment.

Response:

Further to our letter of October 10, 2003, the Department of Energy (DOE) has evaluated the Board's recommendations to conduct modeling of compressible fluids and studies of waste package-magma interaction and waste entrainment. A model is being developed to bound the behavior of magma flow within a fissure and within a drift. This modeling would also address the likelihood of a "dog-leg" occurring under these bounding flow conditions, and the sustainability of a "dog-leg."

The DOE acknowledges that additional analyses and laboratory and field experiments could lead to a better understanding of the effects of waste package-magma interaction and waste entrainment in magma. It may be possible to gain some insights from experiments and analyses that could be performed over the next couple of years. These analyses and experiments, if conducted, would be used to build confidence in our conclusions and would not be included in our Total System Performance Assessment for the License Application. These analyses and experiments could lead to a reduction in uncertainties associated with waste package-magma interaction.

2. Enhanced borehole studies.

As plans are developed for drilling aeromagnetic anomalies near Yucca Mountain, the Board encourages the DOE to consider additional development of those boreholes as monitoring wells to obtain hydraulic head, water chemistry, and related hydrogeologic data at relatively small additional cost. Additional hydrogeologic data from these areas may resolve differing hypotheses regarding the direction of water flow in the saturated zone and may provide additional information about the ability of the saturated zone to function as a barrier to migration of radioactive materials.

Response:

The DOE agrees that collection of additional hydrologic data is worthy of consideration in those cases where the boreholes are within or adjacent to flow paths from the Yucca Mountain repository to the compliance boundary. The DOE will evaluate the possibility of completing those boreholes as monitoring wells in order to collect hydrologic information if the water table is encountered. The additional cost to construct wells may not be small because the DOE would have to increase the diameter of the holes and install surface and/or intermediate casing in addition to the completion string. Well development via pumping would also be required to prepare the wells for water level measurement and water sample collection. In addition, obtaining permits from the State of Nevada to pump from such wells has not been successful.

Based on the information currently available, additional hydrologic data from drilling the anomalies in the Crater Flat area would not appear to be relevant to assessing radionuclide migration from the Yucca Mountain repository to the compliance boundary. The DOE does not intend to complete any of these holes as monitoring wells, but will record the approximate depth to water if the water table is encountered. We will continue to share our plans with the Board as those plans are developed.

3. Chlorine-36.

The Board encourages the DOE to resolve discrepancies in chlorine-36 studies and agrees with the decision to commission a third-party review that includes integrated chlorine-36 and other bomb-pulse data to help address inconsistencies. Such an integrated methodology should include the measurement of tritium. If an accepted integrated methodology could be developed, it could enhance understanding of hydrogeologic controls on fast-path flows into the repository and yield a conceptual model consistent with both chlorine-36 and other bomb-pulse data. The Board believes that resolving chlorine-36 discrepancies will require a "root cause" analysis that lays out each step in the procedure, how the discrepancies were addressed by each of the two analytical groups, and what each set of measurements has in common as well as what differences exist and the potential reasons for these differences and actions for resolving them.

Response:

The DOE appreciates the Board's support of our third party approach, utilizing researchers from the University and Community College System of Nevada (UCCSN), to continue the Cl-36 work and the general approach of using a suite of bomb-pulse isotopes (Cl-36, I-129/127, and Tc-99).

The DOE notes the Board's recommendation that tritium measurements be included as part of the integrated approach. Additional tritium measurements are not part of the UCCSN Cl-36 study; however, the U.S. Geological Survey – Los Alamos National Laboratory (USGS-LANL) Cl-36 validation team and the UCCSN team will evaluate the tritium data in concert with the other isotopic data with the goal of developing a conceptual model consistent with all of the data. The DOE also notes the Board's recommendation that resolving the discrepancies will require

a "root cause" analysis. The summary report being developed by the USGS-LANL Cl-36 validation team will contain a discussion that lays out potential "root causes" for the Cl-36 discrepancies. In addition, the methodology and approach outlined by the UCCSN researchers has a reasonable chance of satisfactorily resolving the discrepancies and getting at the root cause. Interested members of the Board and staff are invited to the quarterly meetings on Cl-36 at University of Nevada in Las Vegas to participate in the discussions and offer their opinions and insights. The DOE will keep the Board informed of the schedule for quarterly meetings and of significant developments resulting from the Cl-36 study.

Issues Relating to Potential Waste Package Corrosion

1. Microbial activity.

Decreasing nitrate concentrations with depth, as shown in one of Bo Bodvarsson's slides, suggest microbial activity. A waste package design that relies on nitrate to reduce the likelihood of localized corrosion must take into account the effects of microbial activity on nitrate concentrations both before and during the thermal pulse.

Response:

The DOE agrees that a waste package design that relies on nitrate to reduce the likelihood of localized corrosion must take into account the potential effects of microbial activity on nitrate concentrations. Decreasing nitrate concentrations with depth in one borehole, SD-9 (Slide 22, Bodvarsson and Tsang 2003[1]), have alternative explanations, such as complex hydrologic structure, spatial variability within single hydrologic units, pore water chemistry record of temporal changes, or microbial denitrification. For example, the profile of water compositions sampled with depth, such as that from borehole SD-9, is likely influenced by pre-Holocene hydrologic conditions. The concentration of chloride decreases significantly below the non-welded PTn unit, which has been interpreted, using chloride mass balance relationships, to show that more recent infiltration is more concentrated. The deposition and production of nitrate near the ground surface were likely limited during pre-Holocene conditions, similar to the deposition of chloride. The DOE will update the Board on the evaluation of nitrate inventory in the unsaturated zone at future Board meetings.

2. Gas pressure.

The maximum temperature at which brines can exist on waste package surfaces is a strong function of gas pressure. Elevated pressures allow brines to exist at higher temperatures, increasing the likelihood that corrosion will be initiated. Even transient elevated pressures could be important. The DOE should provide a careful and complete explanation of gas pressures during the thermal pulse within the drift environment.

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[1] Bodvarsson, Gudmundur and Tsang, Yvonne 2003. *Flow and Transport in the Unsaturated Zone*. Presentation to the Nuclear Waste Technical Review Board, September 16, 2003.

Response:

Gas pressure within the emplacement drifts is expected to increase only a few tens of pascals during the thermal period, an increase that will have only negligible effect on the temperature range of aqueous solution stability. Athough the 2-D coupled process models generally show a pressure increase of one- or two-hundred pascals, this artifact almost disappears when the "near-infinite" equivalent permeability of the drifts is considered within 3-dimensional models. In the more realistic 3-D models, the pressure rise is generally only a few tens of pascals.

This very small pressure increase (tens of pascals) is negligible for all practical purposes. The pressure rise is due to boiling in the rock matrix blocks close to the drifts and the very small limitations on the overall capacity of the system to move the increased mass of gas away from the source (i.e., similar to the pressure increase that forces the generated steam to flow from the rock matrix into adjacent fractures). The gas pressure is also slightly elevated in the fractures, and this slight pressure increase propagates into the emplacement drifts as an imposed condition of the geosphere within the boiling zone. Some of the steam flows from the fractures into the drifts, and this causes a significant reduction in the mass fraction of air in the gas phase within the drifts. The slight pressure increase within the emplacement drifts goes away near the end of the thermal period, after about 1,000 years.

The pressure increases given above are miniscule compared to the ambient pressure at the site and have negligible effect on the boiling point of water. Such temperature adjustments are minor compared to the effect on boiling temperature due to the elevation of the repository. A pressure increase of 10 pascals is one-ten thousandth of a bar. The site elevation is such that it is at an ambient pressure of roughly 0.9 bar. This represents a decrease of one-tenth bar, and it produces a drop of about 4°C in the boiling point of water[2]. Given that the pressure changes we are discussing are about 1/1000 of this elevation related pressure difference, the temperature effect on the boiling point is roughly 0.004°C, which is clearly much smaller than the uncertainty on temperatures in post closure. Similarly, such a slight pressure increase is negligible relative to its ability to raise the boiling temperature of aqueous solutions (or conversely the deliquescence temperature of brines).

Issues Relating to Management and Communication

1. Quality/schedule tradeoffs.

The Board appreciates John Arthur's assurance that the license application schedule is not constraining the quality of work within the Yucca Mountain project. The Board strongly agrees with the DOE that a license application should be filed only when appropriate quality standards have been met. A schedule-driven approach to quality management can potentially compromise

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[2] BSC (Bechtel SAIC Company) 2002. *Thermal Testing Measurements Report.* ANL-NBS-HS-000041 REV 00. Las Vegas, Nevada: Bechtel SAIC Company.

the safety culture surrounding the preparation of the license application, thereby making the project vulnerable to poor decision-making. The Board emphasizes the importance and inherent long-term efficiency in "taking the time to do it right."

Response:

The DOE agrees that a license application should only be filed when the appropriate quality standards have been met. The DOE will not submit a license application to the U.S. Nuclear Regulatory Commission (NRC) until we are satisfied that we have met the necessary quality and regulatory requirements.

2. Repository performance confirmation.

With an operational period that may extend beyond repository closure, it appears that performance confirmation may be a component of the DOE's proposed radioactive waste disposal system that will span licensing, construction, and possibly operation. Thus, performance confirmation holds the possibility of enhancing confidence in repository prediction not only by "confirming" DOE models but also by testing the underlying conceptual, physical, and mathematical bases of those models. The Board encourages the DOE to have a clear understanding of what it means by performance confirmation and integrate it thoroughly with performance assessment and repository design. This includes the need to establish formal management practices that ensure that appropriate interactions occur between these system components. Moreover, the Board believes that the performance confirmation program can benefit significantly from the input of the interested public and affected parties.

Response:

The Board is correct in noting that the performance confirmation program will continue through initial licensing, repository construction, and repository operation until permanent closure. The program must satisfy NRC licensing requirements in 10 CFR Part 63[3], including the requirement to continue performance confirmation testing until permanent closure.

The DOE's license application will provide sufficient information to enable NRC to reach a finding that there is reasonable expectation that waste can be disposed at the repository without unreasonable risk to the health and safety of the public. If the NRC authorizes construction of a repository at Yucca Mountain, the performance confirmation program will continue, focusing on testing the adequacy of assumptions, data, and analyses presented in the license application to support the NRC reasonable expectation finding.

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[3] 10 CFR 63. Energy: Disposal of High-Level Radioactive Wastes in a Geologic Repository at Yucca Mountain, Nevada. Readily available.

10 CFR Part 63 specifies the types of testing required for performance confirmation, including tests to evaluate:

- Subsurface conditions, including geotechnical and design parameters
- Functions of the natural and engineered barriers
- Waste package condition
- Effectiveness of any design features added after construction authorization, such as borehole seals

Additional testing may be undertaken to enhance confidence in repository performance by testing the underlying conceptual, physical, and mathematical bases of models.

The DOE's formal management procedures will ensure appropriate integration of the performance confirmation program with performance assessment and repository design.

3. Program integration and communication.

The Board believes that the technical basis documents being developed for the Yucca Mountain Project have significant potential for improving program integration and enhancing program communication with the wider technical community as well as the general public. For gaining the maximum benefit from these documents, integrating their most important conclusions into a concise description of the safety case for a Yucca Mountain repository will be important. However, if the documents are not well integrated or if they contain technical errors, then communication of the safety case to the broad scientific and public audiences will be weakened. Where appropriate, the discussion of relevant analogs can be used as a line of evidence and enhance the DOE's communication.

Response:

The DOE appreciates that the Board recognizes the potential of the technical basis documents both in enhancing technical integration, and in informing the wider scientific community as well as the general public. The DOE also agrees that the most important conclusions need to be integrated into a concise description of the performance of the repository system in the postclosure timeframe. Chapter 2 of the Safety Analysis Report in the license application will include a comprehensive discussion of the technical basis for the evaluation of postclosure performance. The technical basis will be supported by relevant analogs when appropriate. The DOE will draw on the technical basis documents along with other technical references in developing this chapter of the Safety Analysis Report. This chapter will include a concise overview of repository safety after permanent closure, including a description of the multiple barriers that contribute to postclosure performance of the repository.

The DOE has scheduled in-depth reviews of the technical conclusions that will be provided in the license application. These reviews will focus on quality and integration of the technical basis for the conclusions on the postclosure performance of the repository system.

The DOE recognizes that a broad-audience document that presents a clear description of the safety case would be desirable. Its function would be to explain to non-specialists why we

believe that there is a basis for confidence in the safety of the proposed system. Such a document is being considered, but its production must await the content of the license application, to assure that the two documents are consistent and to avoid any confusion as to the DOE's position.

Department of Energy
Washington, DC 20585
MAY 2 8 2004

Dr. Mark Abkowitz
Chairman
Panel on the Waste Management System
United States Nuclear Waste Technical
Review Board
2300 Clarendon Boulevard, Suite 1300
Arlington, VA 22201

Dear Dr. Abkowitz:

Thank you for your March 29, 2004, letter in which you provided comments on information presented by the Department of Energy's (DOE) Office of Civilian Radioactive Waste Management (OCRWM). That information was presented during the January 21, 2004, Waste Management System Panel Meeting on transportation strategic planning.

We appreciate your interest in OCRWM's approach to transportation planning. Your questions regarding interaction with stakeholders, waste acceptance, transportation infrastructure and interfaces, cask procurement, security planning, emergency preparedness, and operational lessons learned from previous and ongoing DOE shipment campaigns are all important. We are incorporating many of your comments and concerns as we continue to develop the transportation system.

Some of the issues you've raised are being addressed in a comprehensive fashion currently. Others will be addressed comprehensively after critical milestones are achieved that support subsequent detailed planning. We believe our discussions during the Board's Spring Meeting in Washington, D.C., on May 18-19, 2004 were useful for us, and hope you found them helpful as well. We believe that our presentation at that meeting described the areas where we are able to do detailed planning, as well as the areas where we are managing to milestones prior to having detailed project scope, schedules and resources identified. We believe those discussions addressed most of the comments made in your letter. As we proceed with our planning for transportation, we will be interested in the Technical Review Board's views on the technical issues we will be addressing.

OCRWM places a great emphasis on working with our stakeholders, including the Technical Review Board, collaboratively throughout the planning process. We are looking forward to more productive discussions at the fall Transportation Panel Meeting in Salt Lake City. In the meantime, please contact Gary Lanthrum, my transportation Office Director, to discuss that meeting, or other technical aspects of transportation system development.

Sincerely,

Margaret S.Y. Chu, Ph.D.
Director
Office of Civilian Radioactive
Waste Management

Department of Energy
Washington, DC 20585

QA: N/A

July 21, 2004

Ronald M. Latanison, Ph.D.
Chair, Panel on the Engineered System
Nuclear Waste Technical Review Board
2300 Clarendon Boulevard
Arlington, VA 22201-3367

Dear Dr. Latanison:

Thank you for your letter of April 5, 2004, providing the Nuclear Waste Technical Review Board's (Board) response to the information presented by the U.S. Department of Energy (Department) on repository design at the January 20, 2004, meeting of the Board's panel on the engineered system. The Department appreciates the Board's continuing review of our activities as we work to develop and document the technical basis for the License Application for a repository at Yucca Mountain, Nevada. Our responses to the Board's views and recommendations are summarized in the enclosure to this letter.

The Department continues to benefit from the constructive views of the Board, and we look forward to further dialog on our repository design and related issues.

Sincerely,

Margaret S.Y. Chu, Ph.D.
Director
Office of Civilian Radioactive
Waste Management

Enclosure:
U.S. Department of Energy (Department) Responses to the April 5, 2004, Letter from the Nuclear Waste Technical Review Board (Board)

Ronald M. Latanison, Ph.D. -2-

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ENCLOSURE

U.S. DEPARTMENT OF ENERGY (DOE) RESPONSES TO THE APRIL 5, 2004, LETTER FROM THE NUCLEAR WASTE TECHNICAL REVIEW BOARD (BOARD)

1. SPENT FUEL AGING FACILITY AT THE REPOSITORY

1.1 RECOMMENDATION

As described at the meeting, the design of the repository surface facilities includes temporary storage for up to 40,000 tons of spent fuel. We understand that the current plan is to construct only 1,000 metric tons of storage capacity and that additional storage would be constructed only as needed. We also understand that the DOE intends that the entire 40,000 metric tons of storage capacity will be included in the license application. The technical justification for a 40,000 metric ton storage facility is unclear. As pointed out in BSC's February 2002 "Thermal Operating Modes" white paper, a larger surface facilities area with a pad for extended surface aging could affect the analysis of aircraft–crash hazard. The Board recommends that the technical justification for such a large storage facility be explained.

1.2 RESPONSE

The Final Environmental Impact Statement (DOE 2002) for the repository considered up to 40,000 MTHM of aging capacity to address the potential need to age commercial spent nuclear fuel and to stage DOE spent nuclear fuel and high-level radioactive waste. In the license application (LA), the Aging Facility being designed as part of the repository surface facilities has the capacity for 21,000 metric tons of heavy metal (MTHM) and contingency to expand to 40,000 MTHM. This facility provides sufficient capacity to allow efficient loading of emplacement drifts with the required combination of DOE waste and commercial spent nuclear fuel to meet thermal management goals. It will also allow DOE to stage spent nuclear fuel and high-level radioactive waste so that the rates for waste receipt and emplacement can be decoupled, if necessary.

The Aging Facility would be constructed on an as-needed basis. Our preliminary throughput analyses support an operational need for an Aging Facility capacity from 15,000 to 17,000 MTHM. That capacity was increased to the 21,000 MTHM value to allow some margin for the early throughput estimate. The DOE intends to construct a small pad for aging up to 1,000 MTHM as part of the surface facilities needed for initial repository operations. The rest of the planned Aging Facility is designed as a series of four modules, each with a capacity of 5,000 MTHM. Our current estimates show that the 21,000 MTHM capacity of the Aging Facility will be sufficient to address all the necessary aging and staging requirements for the repository. As we approach the point where we will be receiving fuel, formal material receipt assessments will be performed to assure compliance with Nuclear Regulatory Commission (NRC) licensing specifications for both subsurface emplacement and surface aging. Locations for three additional 5,000 MTHM modules and one 4,000 MTHM module have been identified as a contingency to bring the total capacity to 40,000 MTHM should it be required. This

approach will provide the regulatory basis and the flexibility to construct additional aging capacity, should it be required to support future operational needs.

The preclosure safety analysis conducted for the LA will also evaluate the consequences of various potential external hazards, including aircraft crashes, and the relevant event sequences associated with the maximum anticipated surface-aging facility size. This analysis is intended to provide the basis for the NRC to determine, with reasonable assurance, that a repository with surface-aging capacity of at least 21,000 MTHM, with potential expansion to 40,000 MTHM, will not represent an unreasonable risk to the health and safety of the public during the preclosure operating period.

2. WASTE PACKAGE PROTOTYPES

2.1 RECOMMENDATION

The Board understands that BSC recently awarded a fixed-price contract to build the first full-scale waste-package prototype. We believe that the technical information obtained during the course of performance of this contract will be very important, and we agree that more waste-package prototypes are needed. We understand that the reasons for building prototypes include reasons other than obtaining technical information. However, we would like more explanation about the technical information that will be obtained by the current plan to build 14 more prototypes.

2.2 RESPONSE

The waste-package prototype testing-program is designed to provide information regarding:

- Manufacturing process variability (fabricator to fabricator)
- Impact of transportation effects on waste packages
- Waste package weld-preparation performance
- Nondestructive examination (NDE) process confirmation and process improvement
- Confirmation of residual stress states (interaction effects, transport effects, etc.)
- Metallurgical analyses (phase-transformation data), confirmation of mechanical properties (as necessary)
- Mechanical testing related to postulated accident scenarios or credible event sequences.

2.2.1 Testing to Confirm As-Built Conditions

This testing program, described below, will aid in establishing a baseline for acceptance of production waste packages during the operation of the repository.

2.2.1.1 Nondestructive Testing

Manufacturing Process Variability - It is anticipated that multiple vendors will be required to fabricate the approximately 11,000 waste packages needed for the Yucca Mountain Project (YMP). The various fabrication processes used by the fabricators (especially solution heat-treatment and quenching), although guided by procurement requirements, industry codes and standards, and technical and quality requirements, may not be completely uniform from one fabricator to the next. Process differences between fabricators may impact the ultimate performance of the waste package. A prudent way to identify and evaluate these potential differences is to evaluate waste package prototypes from various fabricators before actual manufacture of production waste packages begins. The variability between fabricators and processes can then be identified and potentially significant differences, if any, can be addressed as early as possible in order to develop appropriate mitigation measures.

Transportation Effects on Waste Packages - The waste packages will likely be transported several thousands of miles from the fabricators' facilities to YMP facilities. Transportation over these distances could impact waste package geometry, surface condition, and, potentially, other conditions. The geometry (ovality) of the waste packages will be measured after transport. The as-built information from the fabricator before transport will be compared to the condition of the waste packages upon arrival at the YMP facilities. In addition, the waste packages will be inspected to determine if any alteration to the surface condition has occurred during transport. This information will be used to establish and refine specifications for shipping the waste packages and to address any related waste package closure issues at the repository.

Waste Package Weld Preparation Performance - When a waste package is filled with fuel, it will begin to heat up rapidly. As the waste package heats up, it may distort physically. Although the amount of distortion is expected to be small, the potential impact on weld preparation and the "fit up" to the closure lids must be confirmed as distortion; and small variations in waste package ovality may be critical to successful completion of the final closure welds. The evaluation of this potential problem will involve simulated heating of a waste package prototype and measurement of the distortion. In addition, information regarding the sufficiency of the gap between the inner vessel and the outer corrosion barrier, as well as confirmation of the interpass welding temperature, will be obtained by conducting this test.

NDE of the Outer Lid Closure Weld - The postclosure performance of the waste package will, in part, be determined by the condition of the outer corrosion-barrier closure weld. Accordingly, this weld will be nondestructively examined. Current plans include visual inspection, ultrasonic examination, and eddy-current testing. Visual inspection will provide information on the surface character of the weld, ultrasonic examination will provide volumetric data regarding the quality of the weld, and eddy-current testing will provide data regarding the surface condition (e.g., surface-breaking flaws). NDE of the waste package prototypes will be used to establish parameters for NDE during repository operations.

2.2.1.2 Destructive Testing

The following destructive tests will be performed using waste package prototypes. Depending on the extent of destructive testing, the prototypes used for these tests may be available for certain operational testing, such as demonstration of mechanical handling operations, but current planning reserves these prototypes for destructive testing only.

Confirmation of Residual Stresses of the Outer Corrosion Barrier - The current manufacturing process to control residual stresses in the outer corrosion barrier of the waste package is solution heat-treatment and subsequent quenching following completion of the fabrication process. Although this stress-mitigation process is included in the manufacture of the waste packages, subsequent destructive testing is required to verify that the solution heat-treatment and quench accomplish what was intended and to determine if any tensile stresses develop on the surface of the outer corrosion barrier during transportation.

Although nondestructive X-ray diffraction can give a general idea of what the stress state is on the surface, it cannot be used to determine the through-wall stress state of the plate material, nor can it be effectively used on welds because of the large grain sizes within the welds themselves. Only destructive testing can realistically provide the required information regarding the magnitude and depth of stress in the plate material and in the weld areas.

One destructive testing process involves the use of strain gauges affixed to the surface being examined and the use of sensitive measuring equipment. The material is either machined or chemically etched away, and the stress relaxation is measured by the strain gauge instrumentation. A set of residual stress values as a function of depth is then developed.

Destructive X-ray diffraction will be used to determine the depth and magnitude of residual stresses. This test involves measuring the surface of the material and then removing a small layer of material and repeating the X-ray measurement. This process is repeated until the stresses have been measured to the depth of interest.

Metallographic Analyses – Metallography is an analytical testing method used to evaluate the structure of metals. This destructive testing method will enable the evaluation of phase precipitation and grain size changes as a result of heating, provide assurance that the general appearance of the metallography meets the specification #SB-575 of the American Society of Mechanical Engineers (constituents based on chemical composition), and confirm other characteristics that are dependent upon material composition. Metallography will also be used to confirm that the outer corrosion barrier of the waste package has been successfully stress mitigated. In addition, weld-flaw data collected during this testing program will be combined and compared with data from a 2003 weld-flaw analysis study, and a data resource will be compiled for statistical analysis.

2.2.2 Demonstration of Fabricability

The waste package prototype strategy provides for the demonstration of fabrication processes well before manufacture of the production waste packages. This strategy is necessary to ensure

that the waste packages can be manufactured as designed in an efficient, effective, and quality manner. Experience has shown that it is likely that fabrication of the prototypes will identify problems. If problems are encountered during the prototype manufacturing process, design changes can be implemented as necessary before committing funds for the actual production waste packages. Manufacturing process reviews and feedback to subcontractors will serve to improve the fabrication processes and, hence, the quality of the final product. Demonstration of fabricability will be the primary focus of at least the first two waste package prototypes. In addition, the demonstration of fabricability will be a secondary function of all other waste package prototypes.

2.2.3 Operational Testing (Verification of Process Operations)

Operational testing includes such activities as verification of mechanical handling equipment operability, fuel loading activities, subsurface handling and emplacement activities, and waste package closure activities. In addition, it will be necessary to complete an operational readiness review prior to actual operations. All of these operational testing activities will require the use of waste package prototypes.

2.2.4 Number of Waste Package Prototypes

A total of 15 waste package prototypes are planned to support the program outlined here. Table 1 provides a summary of the potential uses of the prototypes, along with the estimated number of prototypes necessary to support design, testing, start-up, and pre-operations. In Table 1, *P* indicates a primary function of a prototype, and *S* indicates a secondary function. Each waste package prototype has only one primary function but may have several secondary functions.

Table 1. Estimated Number of Waste Package Prototypes

Prototype Number (not necessarily order of fabrication)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Configuration → / Activity ↓	21 PWR AP	21 PWR AP	21 PWR AP	21 PWR AP	5 DHLWDOE Co. long	Naval Long	44 BWR	5 DHLWDOE Co. short	5 DHLWDOE Co. long	5 DHLWDOE Co. short	Not Yet Determined	Not Yet Determined	Not Yet Determined	Not Yet Determined	Not Yet Determined
Demonstrate Fabricability/Variability	P	P	P	P	S	S	S	S	S	S	S	S	S	S	S
Develop Cadre of Qualified Vendors	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
Verification of Process Operations															
Mechanical Handling Verification								P	P			P			
Fuel Loading Verification				S	P	P	P	S				S			
Closure Cell Process Verification	S	S	S					S	S	S	S	S	P	P	S
Operator Training				S	S	S	S	S				S			
Nondestructive Testing	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
Destructive Testing	S	S	S						S	S	P				
Mechanical Properties Testing	S	S	S							P	S				
Drop Testing (if required)															P
# Potential Uses per Prototype	6	6	6	5	5	5	5	7	6	6	6	7	4	4	5

P Primary Function of Prototype
S Secondary Function of Prototype
Configuration not yet determined

3. EMPLACEMENT DRIFT GROUND SUPPORT

3.1 RECOMMENDATION

While not unprecedented, the stainless-steel perforated plate and stainless-steel bolt system proposed as the ground-support system for emplacement drifts is highly unusual and expensive. We would like to learn more about the technical basis for the selection of stainless steel as the material of construction, particularly for the perforated plate. We also would like to know which other materials were considered for ground support and the technical bases for their rejection. We understand that the emplacement-drift ground-support system is designed for a preclosure service life of 100 years and "not to preclude" a preclosure period of up to 300 years. We would like a description of the planned inspection and maintenance activities – including a description of how those activities would be conducted – for both the first 100 years and the subsequent 200 years.

3.2 RESPONSE

Although the use of stainless steel ground support components is not typical in mining and tunneling applications, it is not unprecedented as numerous mines operating in high-sulfide ore bodies with low pH seepage waters have used stainless-steel rock bolts for ground support for their superior corrosion resistance. Both Atlas Copco and Ingersol Rand (now International Rollforms, Inc.) supply stainless-steel rock bolts as standard items.

3.2.1 Rock Mass Description

The rock types comprising the repository host horizon include nonlithophysal rock (a typical, fractured volcanic) and lithophysal rock (same matrix as nonlithophysal rock but with lithophysal void porosity as high as approximately 25 percent). The matrix of the lower lithophysal unit (about 85 percent of the repository emplacement area) is also heavily fractured, with average fracture spacings of less than 10 cm. Extensive fracture mapping studies have been conducted in both of these rock units, and detailed panel mapping of lithophysae has been conducted in the Enhanced Characterization of the Repository Block cross drift. Modeling analyses, reported in *Drift Degradation Analysis* (BSC 2004a), show that the median block sizes created in the nonlithophysal rock are around 0.15 MT (0.06 m^3). Observation of fracture spacing as well as particle sizes from coring in the lower lithophysal unit indicates that the rock fragments expected during failure are small, being on the order of the fracture and lithophysae spacing.

During the preclosure period, the combined in situ, thermal, and seismic loading to the rock mass is relatively small. Although failure is not expected, the value engineering team assembled to evaluate this issue agreed that the most likely potential failure mechanism to occur within the lithophysal rock mass would be a "raveling" mode, characterized by loosening of the rock surface and gravity-driven fall of small rock fragments. In the nonlithophysal rock mass, the potential failure mode would be formation of relatively small "key-block" or wedge-type

failures, a small number of which occurred during excavation and scaling of the existing tunnels[1]. Based on the potential failure modes, particularly the raveling of small rock fragments, the preferred support method is use of a continuous-type of surface covering that "knits" the rock surface together and provides sufficient confinement to prevent loosening and raveling.

3.2.2 Value Engineering Process

The specification of the ground support was developed using the value engineering process.

A group of engineers, geologists, and performance assessment specialists, both internal and external to the YMP, were assembled to perform the initial design evaluation. External consultants included Dr. Nick Barton, Barton and Associates; George Yoggy, Master Builders; and Patrick Andrieux, Itasca Canada (formerly Noranda Mining).

A number of criteria for the ground support were established for the evaluation, based on repository performance requirements and operational and safety considerations. The criteria of greatest importance included:

1. The ground support methods must not have a significant negative impact on the capabilities of natural or engineered barriers.

2. The ground support must support the regulatory waste retrieval requirement.

3. The design of the ground support should result in the need for little or no maintenance over the entire preclosure period (taken to be approximately 100 years, with the potential to maintain the repository in an open condition for up to 300 years)[2].

4. The ground support should not impede the rock mass drying effect from forced ventilation air.

5. Personnel safety during all aspects of ground support installation and maintenance is of highest priority.

Ground support alternatives developed and evaluated by the team included standard support methods such as concrete and shotcrete linings, grouted rock bolts, wire mesh or steel plates, thin organic or cement-based spray-on linings, steel sets, and full-tube conduit-type linings. In all deliberations, the attempt was made to develop support methods with standard materials and components and to use off-the-shelf hardware, where possible.

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[1] No significant ground instabilities or ground falls have occurred since the excavations were completed.

[2] The ground support has been classified as not important to safety. Studies for unsupported tunnels, conducted as part of the preclosure safety assessment, examined rockfall potential when subjected to preclosure in situ, thermal, and seismic loading. The rockfall was found to have insufficient mass to result in a credible nuclear safety scenario.

From a purely geotechnical and mining perspective, the preferred ground support method for all excavations was the use of standard fiber-reinforced shotcrete and grouted rock bolts. However, uncertainties exist regarding the potential impact of cementitious and organic surface coatings on the chemistry of seepage waters. This uncertainty leads to greater uncertainties regarding drip shield and waste package corrosion, and near-field environment radionuclide transport mechanisms. It was determined that this uncertainty currently rules out the use of either cementitious or organic materials from ground support in emplacement drifts.

Consequently, it was determined that only steel components would be used for ground support. This determination results in the use of friction-type rock bolts (either Swellex or Split Set were considered) for general ground-reinforcement. To provide the surface confinement desired to eliminate raveling of small rock fragments, Bernold-style perforated steel sheeting was chosen for use. This type of surface support consists of thin steel sheets that are rolled to the tunnel radius and punched to create slots that allow air circulation behind the sheet. The punching process also corrugates the sheet, which results in significant structural stiffness. These sheets are overlapped for connection and predrilled for rock bolt installation. The bolts are installed through the sheets and pulled tight to the rock surface, preventing loosening and raveling. The slot dimensions can be custom designed to prevent loss of small rock fragments. A 240° coverage of the tunnel periphery is used to minimize rockfall onto the invert rail system. It is envisioned that a highly mechanized rail-based system will be developed for installation of this support system. A single piece of equipment for lifting and holding the steel sheets to the rock surface, followed by drilling of radial boltholes and installation of friction bolts, could be developed relatively easily.

3.2.3 Ground Support Materials Selection

The most effective corrosion control practice is selection of a suitable metal or alloy for the service time in a particular environment. The total service life for the ground support system is currently established at 100 years, which encompasses the NRC requirement that the waste be retrievable starting at any time up to 50 years after the start of waste emplacement operations.

Candidate steel ground-support materials, including carbon steel, high-strength low-alloy steel, and stainless steel were considered in the corrosion evaluation for the longevity of ground support materials for the LA. The potential corrosion mechanisms that may be expected in the repository environment include dry oxidation; humid-air corrosion; aqueous, pitting, or crevice corrosion; stress corrosion cracking; hydrogen embrittlement; and microbiologically influenced corrosion.

The following conclusions were reached based on the corrosion evaluation for the candidate ground-support materials in Section 7.3 of the report *Longevity of Emplacement Drift Ground Support Materials for LA* (BSC 2003a):

- The impact of dry oxidation on the performance of carbon steel and stainless steel is insignificant or negligible.

- For humid-air corrosion, ground-support components made of carbon steel will fail after a service life of 30 years, whereas a rock bolt made of high-strength, low-alloy steel will not fail for a service life of 100 years. Ground-support components made of stainless steel 316 will not fail for a service life of 100 years.

- Carbon steel and high-strength, low-alloy steel will fail because of aqueous corrosion within 10 years, whereas stainless steel 316 will not fail for 100 years of service life.

- Stainless steel 316 indicates superior performance against pitting and crevice corrosion. The potential effect of higher temperatures on general and localized corrosion for stainless steel 316 is insignificant.

- Based on the stress level, temperature, and ground water conditions, it is expected that stress corrosion cracking of friction-type rock bolts will probably not occur during preclosure. The potential impact of hydrogen embrittlement on friction-type rock bolts is minimal or insignificant.

- The effect of microbiologically influenced corrosion is significant on carbon steel, whereas it is insignificant on stainless steel 316.

The following paragraph is cited from Section 7.4 of the report *Longevity of Emplacement Drift Ground Support Materials for LA* (BSC 2003)

> . . . for a service life of 100 years during the preclosure, both the friction-type rock bolts (Split Sets and/or Swellex bolts) and the perforated steel sheets need to be made of stainless steel, such as 316 (equivalent or better), from the viewpoint of corrosion control. This result confirms the current design on materials for rock bolts and perforated sheets in emplacement drifts. Rock bolts and perforated steel sheets made of stainless steel with thickness of 3 mm will not fail due to corrosion for a service life of 100 years. Furthermore, Swellex bolts may perform better than Split Sets in terms of corrosion attack due to its tubing configuration. Among all friction-type rock bolts, Super Swellex bolts have the highest holding capacity, which is desirable from the viewpoint of structural stability. Moreover, the Super Swellex bolt has a larger tube thickness compared with others, which is also desirable from the viewpoint of minimizing the effects of corrosion.

3.2.4 Maintenance and Cost

The ground support has been classified as not important to safety. Examination of potential preclosure rockfall size shows that waste package breach is not credible. To facilitate waste package retrieval, should it be required, emplacement drift stability will be monitored during the 100-year design-basis preclosure period from the initiation of waste emplacement. A preliminary observation and ground-support maintenance plan has been developed, however, the details of this plan can only be developed as the subsurface design proceeds. The specific observation equipment and intervals have not been determined, but the current thinking is that observation of the ground support will be performed using remote-controlled video cameras. Observations will center on examination of areas of deformation that would indicate extensive

yield behind the ground-support system. A determination of the need to maintain the support in that area will be made on a case-by-case basis based on an evaluation of the significance of the changes in the affected ground support. Although the repository design will include provisions that support deferral of closure for up to 200 years beyond the end of the design-basis preclosure period, the monitoring and maintenance program for this contingency is not needed at this time.

A primary objective for the use of full tunnel-support coverage and stainless steel components with an expected service life in excess of 100 years was to eliminate or minimize the need for maintenance. Although the initial cost of the planned stainless-steel ground support system is higher than for standard carbon-steel components, the added cost is outweighed by the cost and potential worker safety issues that would be associated with moving waste packages for reentry into emplacement drifts to maintain ground support.

4. "COLD TRAP" EFFECTS IN THE EMPLACEMENT DRIFT TURNOUTS

4.1 RECOMMENDATION

The Board notes that changes have been made in the subsurface repository design to increase the radius of each emplacement drift turnout and to move the ventilation control door to the outer end of each turnout. These changes will affect the postclosure waste package temperatures, particularly the temperature of packages close to the turnouts. In addition, these changes are likely to exacerbate "cold trap" effects near and in the turnouts. We strongly recommend that temperature and relative humidity calculations be revised to reflect the design changes, if that has not been done already.

4.2 RESPONSE

The DOE agrees that changes in the subsurface repository design, specifically the increase in the radius of the emplacement-drift turnout and relocation of the ventilation control door, need to be evaluated as to the effect on predictions of temperature and relative humidity inside the drift, especially in the postclosure time frame. The YMP has recently modeled the natural convection and condensation of in-drift moisture during the postclosure period and the associated redistribution of energy, documenting the results in the forthcoming analysis and model report on in-drift natural convection and condensation. This model reflects the recent design changes and provides predictions of temperature, moisture content, and condensation patterns. This analysis and model report will be completed in the near future.

In general, a longer turnout and relocated ventilation door provide additional, cooler rock surfaces outside of the emplacement section of the drifts and on which condensation of moisture may occur (cold trap effect). The warm, moist air that moves from the emplacement drifts into the turnouts as a result of natural convection processes will be depleted of most of its vapor content by condensation on the cooler rock-surfaces. At the same time, relatively dry air circulates back toward the emplacement sections of the drifts, thereby reducing the vapor mass and the relative humidity in these areas. The energy transport associated with the movement of in-drift air also affects the waste package temperatures, particularly those close to the turnouts. However, compared to the reduction in relative humidity, the changes in temperature are rather small.

5. NATURAL VENTILATION AND DRIFT ENVIRONMENT

5.1 RECOMMENDATION

The Nye County work on the evolution of chemistry in the engineered barrier system and on the topic of natural ventilation is very interesting. These topics are important because they influence both waste package corrosion and transport from the engineered barrier system. It is clear that the environment in drifts is not a quasistatic or slowly changing one but a dynamic one driven in part by temperature differences among waste packages and along the drifts. Such differences will always exist but will be greater during the thermal pulse period. A repository at Yucca Mountain will have some degree of natural ventilation or natural circulation regardless of whether it is deliberately engineered into the repository design or not. Models for temperature and relative humidity predictions must take these natural processes into account fully.

5.2 RESPONSE

Nye County's work on the in-drift chemical environment and natural ventilation are undoubtedly important alternative concepts enriching the knowledge base that supports DOE's analyses of the performance of the repository system.

During the preclosure period, a large volume of air will move through the drifts at high velocity due to active ventilation. During the postclosure period, the volume and velocity of air moving through the drifts will drop substantially because only intrinsic natural circulation augmented by temperature differences along the drifts will sustain air movement. YMP models take air and moisture exchange between the fracture system and the in-drift environment into account. The only way that temperature differences along the length of the drift and between waste packages could increase or become more uneven following closure is if there was an impediment to the flow of heat, such as backfill cover. There could also be some advection of moisture (inevitably carrying some heat) from the rock into the drift caused by fluctuations in barometric pressure. However such moisture movement would be limited and would decrease with time, because of the continued increase in the size of the dry-out zone surrounding each emplacement drift during the thermal pulse.

6. REFERENCES

6.1 DOCUMENTS CITED

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DOE 2002. *Final Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada.*

DOE/EIS-0250. Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management.

6.2 CODES, STANDARDS, REGULATIONS, AND PROCEDURES

10 CFR 63. Energy: Disposal of High-Level Radioactive Wastes in a Geologic Repository at Yucca Mountain, Nevada.

UNITED STATES
NUCLEAR WASTE TECHNICAL REVIEW BOARD
2300 Clarendon Boulevard, Suite 1300
Arlington, VA 22201

July 28, 2004

Dr. Margaret S. Y. Chu, Director
Office of Civilian Radioactive Waste Management
U.S. Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585

Dear Dr. Chu:

On behalf of the Nuclear Waste Technical Review Board, I thank you, your staff from the Department of Energy (DOE), and your contractor team for participating in the Board's spring meeting on May 18-19, 2004, in Washington, D.C. The Board appreciates your responsiveness to our recent letters and report on the potential for corrosion of the Alloy 22 waste packages during the thermal pulse.* The hard work that went into preparing the meeting presentations was evident and worthwhile; the presentations provided important new information and analyses. We want to note in particular the excellent technical coordination and assistance provided by Bob Andrews, Claudia Newbury, and Mark Peters.

Corrosion Issues

In its October 21, 2003, letter and in its November 25, 2003, letter and report, the Board concluded that, given the information presented by the DOE and others at the Board's January 2003 and May 2003 meetings, deliquescence-induced crevice corrosion would be likely to initiate during the higher-temperature period of the thermal pulse. That conclusion was based particularly on corrosion tests conducted in an aqueous environment rich in calcium chloride. Test results showed clearly that corrosion would take place in that environment when temperatures ranged roughly between 140°C and 160°C. The results also suggested that the expected mitigating effect of the presence of nitrate ions might not be sufficient to inhibit the corrosion process fully.

Based primarily on information presented at the Board's May 2004 meeting, it appears unlikely that dusts that accumulate on waste package surfaces during the preclosure period would contain significant amounts of calcium chloride or that significant amounts of calcium chloride would evolve on waste package surfaces during the thermal pulse. Consequently, the calcium chloride-rich environment selected for corrosion tests does not appear representative of the conditions that can be expected on waste package surfaces in a Yucca Mountain repository. If calcium chloride is not present, calcium chloride-rich brines will not form by deliquescence, and crevice corrosion due to the presence of such brines in the temperature range of roughly 140°C to 160°C will not occur. Thus, the Board concludes that deliquescence-induced localized corrosion during the higher-temperature period of the thermal pulse is unlikely.

*The thermal pulse is the period of approximately 1,000 years after repository closure when temperatures in repository tunnels would be above the boiling point of water.

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Ideally, corrosion tests should be carried out both in environments that closely approximate the various conditions to which the waste package alloy will be exposed and in environments that reasonably bound those conditions. The extent to which the DOE has characterized accurately the likely waste package environments (i.e., temperature, relative humidity, and chemical species present) is unclear at this point. Accurate characterization of probable waste package environments and the corrosion response of the waste package alloy to those environments will continue to be a major focus of the Board's technical and scientific review.

Several corrosion issues that require additional analysis were discussed at the May 2004 Board meeting. First, the DOE raised the possibility that when temperatures in repository tunnels fall below boiling, localized corrosion could occur in concentrated sodium chloride solutions with low concentrations of inhibitors. The Board believes that further investigation of the possibilities for localized corrosion at below-boiling temperatures is warranted and that such an investigation should focus on (1) possible mechanisms that might create environments that would facilitate localized corrosion and (2) the likelihood that such environments could exist. Second, the presence of ammonium ion and the implications of its presence for corrosion or other performance aspects need to be explained. Third, the State of Nevada suggested that nitrates could be aggressive corrodents in some circumstances. The Board believes that it would be worthwhile to review existing corrosion data to determine whether they bound nitrate-containing environments that reasonably could be anticipated at Yucca Mountain.

Integration

DOE contractors have been performing corrosion tests at high-temperatures in high-chloride brines for several years, presumably because it was thought that the test conditions might occur at Yucca Mountain or might reasonably bound actual conditions. However, as became clear as a result of presentations at the May 2004 meeting, geochemical considerations preclude high-temperature, high-chloride brine conditions at Yucca Mountain, rendering the corrosion tests of limited relevance. This situation underscores the need for thorough integration and close cooperation among diverse technical disciplines, particularly when "coupled" processes are involved. For example, excellent integration among geochemists and corrosion scientists/engineers was evident at the meeting and helped bring clarity to an extremely important corrosion issue. Continuing integration will be necessary for resolving other issues associated with the DOE's current repository design.

Hydrology and Thermohydrology Issues

In its November 2003 report, the Board indicated that it agreed with the DOE that boiling during the thermal pulse and capillarity during and following the thermal pulse would significantly reduce the seepage of water into repository drifts but that the pervasiveness of these barriers throughout repository tunnels is not assured. At the May 2004 meeting, the DOE presented detailed descriptions of numerous field and computer investigations—many of which are at the leading edge of science—that form the basis for the DOE's high level of confidence in the effectiveness of vaporization and capillary barriers in its current repository design. In particular, the DOE maintains that there would be no seepage during the period when repository rocks are above boiling and that seepage would be limited at lower temperatures.

After reviewing the information presented at the May 2004 meeting, the Board continues to question the pervasiveness of vaporization and capillary barriers because of persistent uncertainties related to the expected repository tunnel environments. Examples of uncertainties include (1) the conceptual basis for the drift-scale thermohydrologic seepage analysis, including the axial convective transport of water vapor, air, and thermal energy in drifts; (2) the source of liquid water observed in the bulkheaded part of the cross drift; (3) the effects of drift degradation on the waste package environment; and (4) potentially unrealistic combinations of parameters used in the performance-assessment calculations of seepage.

The Board understands that significant scientific challenges are associated with analyzing the complex hydrology at Yucca Mountain, especially when the repository is subject to a large thermal perturbation. However, the Board believes that addressing uncertainties such as those noted above could create a more solid technical basis for determining whether the DOE's high confidence in the effectiveness of capillary and vaporization barriers is warranted.

Seismic Update

We were very pleased to learn from the update at the May 2004 meeting that the DOE has initiated a program aimed at deriving more realistic estimates of seismic hazard at the Yucca Mountain site. In its June 27, 2003, letter to you, the Board indicated its concern about what may be physically unrealizable estimates of very low-probability (annual probabilities of exceedance of 10^{-6} or less) seismic ground motion being calculated for Yucca Mountain by the DOE and its contractors. The new program appears to be a thoughtful first step. It is based on using the extent of fracturing observed in the tunnels at Yucca Mountain to limit the ground motions that could have taken place at the site during the last 10 million years. We look forward to reading the written report on these initial efforts when it becomes available and to learning more about subsequent analyses. As discussed in our June 2003 letter, deriving limits to low-probability ground motions will be challenging. We therefore urge the DOE to implement an external peer review of these efforts.

Transportation Planning

Information presented at the May 2004 meeting indicates that real progress is being made in planning a transportation system for a Yucca Mountain repository. The timelines that the DOE presented at the meeting identify several important milestones that your Office of National Transportation plans to develop further into detailed project plans with cost, schedule, and technical baselines. The Board's Panel on the Waste Management System has tentatively scheduled a meeting for October 13-14, 2004, in Salt Lake City, Utah. We look forward to a more detailed review of progress in transportation planning at that time. We also would like to discuss aircraft hazard and public perceptions of transportation risk at the panel meeting.

Concluding Comments

Once again, thank you for participating in our spring meeting and for the contributions of your staff and contractors. From the Board's perspective, the meeting met its objective: to provide a forum for the free and open exchange of views and information on the potential for corrosion during the thermal pulse. Success in achieving this objective was due in large part to the leadership you provided and to the effort that you and your staff and contractors put into conducting new studies, integrating information, and developing presentations. We also were pleased that the Nuclear Regulatory Commission, the Electric Power Research Institute, and the State of Nevada contributed their insights at the meeting. The Board looks forward to future exchanges of this kind.

Sincerely,

David J. Duquette
Chair, Executive Committee

djd006vh

Department of Energy
Washington, DC 20585

QA: N/A

September 10, 2004

Richard R. Parizek, Ph.D.
Chair, Panel on the Natural System
U.S. Nuclear Waste Technical Review Board
2300 Clarendon Boulevard, Suite 1300
Arlington, VA 22201-3367

Dear Dr. Parizek:

Thank you for your letter of May 3, 2004, providing the Nuclear Waste Technical Review Board's (Board) response to the information presented by the U.S. Department of Energy (Department) at the March 9-10, 2004, meeting of the Board's Panel on the Natural System (Panel). The Department appreciates the Board's continuing review of our activities as we work to develop and document the technical basis for the license application for a repository at Yucca Mountain. Our responses to the Panel's views and recommendations are summarized in the enclosure to this letter.

The Department looks forward to further dialog on the Natural System and related issues.

Sincerely,

Margaret S.Y. Chu, Ph.D.
Director
Office of Civilian Radioactive
Waste Management

Enclosure

ENCLOSURE

U.S. DEPARTMENT OF ENERGY (DOE) RESPONSES TO THE MAY 3, 2004, LETTER FROM THE NUCLEAR WASTE TECHNICAL REVIEW BOARD (BOARD) PANEL ON THE NATURAL SYSTEM

1.0 INCREASING FUNDAMENTAL UNDERSTANDING

1.1 RECOMMENDATION

Field and laboratory observations and analyses presented by the Department of Energy (DOE) and others suggest that the natural system provides an effective barrier to migration of some radionuclides over time periods that may be comparable to the regulatory period. However, several key hydrogeologic features or processes that may significantly affect fluid flow and radionuclide transport are presently not well understood, are constrained by limited or poor data, or both.

The DOE often deals with uncertain features and processes by making conservative estimates of their effects on radionuclide transport. Such conservativisms regarding the performance of the natural system tend to emphasize more-rapid advective transport processes. More realistic estimates that might arise from further evaluation of some features and processes could lead to slower transport predictions for some radionuclides. However, there is a possibility that some other poorly understood features or processes may lead to faster radionuclide transport. Therefore, it is important that the DOE develop a better fundamental understanding of the overall behavior of the natural system.

1.1.1 RESPONSE

We concur that some aspects of fluid flow and radionuclide transport are uncertain. The most significant uncertainties that affect performance of these natural barriers in affecting radionuclide transport have been included in the performance assessment. Although in some cases, conservative approximations have been utilized, this can be acceptable in a licensing analysis.

In Fiscal Year (FY) 2002, the DOE defined a technical work plan that focused on improving confidence in the models for the repository system, including specific testing and analyses aimed at increasing the fundamental understanding of the natural system. This plan was presented to the Board in May 2002[1]. We are in the process of documenting the results of these activities as part of the comprehensive technical basis in a license application that will be submitted to the

[1] Swift, P. 2002. Project Plans for Fiscal Year 2002-2003: Performance Assessment. Presentation to the Nuclear Waste Technical Review Board, May 8, 2002.

Nuclear Regulatory Commission later this year. The DOE believes that the fundamental understanding of key hydrogeologic processes that may significantly affect fluid flow and radionuclide transport is adequate to support the licensing basis for the Yucca Mountain site.

The DOE will continue to evaluate fluid flow and radionuclide transport to the extent that these processes are important to overall system performance through our Performance Confirmation Program. Activities in the Performance Confirmation Program will evaluate the adequacy of assumptions, data, and analyses that may lead to the findings that permit construction of the repository and subsequent emplacement of wastes. Key parameters that evaluate barrier capability will be monitored and/or tested to evaluate conditions assumed in the license application that may affect compliance with the performance objectives of 10 CFR Part 63[2], as discussed in the following responses to comments on specific testing needs.

The DOE is also initiating work to further investigate some of the key conservatisms in the natural system models and to enhance our understanding of repository performance[3]. This work includes efforts to more completely understand processes involving fracture-matrix interaction, drift shadow, saturated zone groundwater movement, retardation, site-scale hydrologic parameters, and scaling effects in hydrologic parameter estimation. Results could lead to potential modifications of the technical basis at future stages of the licensing process.

2.0 TECHNICAL AND SCIENTIFIC RECOMMENDATIONS

2.1 RECOMMENDATION: HYDRAULIC PROPERTIES OF MAJOR BLOCK-BOUNDING FAULTS

First, although the hydraulic properties of major block-bounding faults, such as the Solitario Canyon fault, never have been field-tested, it seems clear that these faults can influence fluid flow and radionuclide transport substantially. Large-scale hydraulic tests of those major faults are therefore needed.

2.1.1 RESPONSE

In the past two decades, significant amounts of data (geologic, hydrologic, and geochemical) have been collected from the Yucca Mountain site. In the unsaturated zone, the DOE has completed air injection testing in the Bow Ridge fault and the southern Ghost Dance fault and hydrologic testing to determine air permeability, porosity, and gaseous tracer transport characteristics (transport porosity and longitudinal dispersivity) in the northern Ghost Dance fault. Although data on water flow in faults are relatively limited in the unsaturated zone, faults are explicitly incorporated in models using the dual-permeability conceptual model. Hydraulic properties for the fractures in fault zones were separately calibrated to account for differences in

[2] 10 CFR 63. Energy: Disposal of High-Level Radioactive Wastes in a Geologic Repository at Yucca Mountain, Nevada. Readily available.

[3] Budnitz, R. 2004. Update on OCRWM's Science and Technology Program. Presentation to the Nuclear Waste Technical Review Board, January 20, 2004.

fracture properties as compared to fractures outside of fault zones. Flow and transport parameters for the matrix of fault zones were assumed to be identical to the matrix outside of fault zones. Various model simulations have been completed to capture the uncertainties that result from data limitations and the complexity of unsaturated zone flow. Additional testing of faults in the unsaturated zone is not planned at this time.

Although faults were not directly tested in the saturated zone, the results of testing at the C-wells complex provided insight into the role of faults in the saturated zone. Numerous fault traces (e.g., Midway Valley Fault, Paintbrush Canyon Fault, Bow Ridge Fault, and Fran Ridge Fault) traverse between the pumping well and the distant monitoring wells. The measured drawdown during testing at the C-wells complex indicated the existence of connected fault anisotropy. Test results also indicate that the flow system behaved like an equivalent continuum or as a dual porosity system over large scales.

Major faults in the saturated zone are conceptualized as zones of enhanced permeability that simulate preferential flow in faults with gridblocks that are nominally 500-by-500 m in a horizontal direction. Representing faults by 500-by-500 m gridblocks accounts for uncertainties in their geographic location. While the precise flow regime within a fault may not be representative when using volume-averaged representations of faults, the overall flow through the system, particularly at the model boundaries, is not significantly affected by the volume averaging approach. The impact of grid cell averaging is expected to be minimal at the scale of the site-scale flow model and is implicitly included in the specific discharge uncertainty, as applied to the saturated zone transport abstraction model. Hydraulic and tracer testing of fault zone hydrologic characteristics, including anisotropy, is planned to evaluate and test these modeling results in the Performance Confirmation Program. This testing will evaluate fault zone hydraulic conductivity (permeability), porosity, dispersivity, and anisotropy in fractured rock along the flow path from the repository. Quantified results from these tests will be compared to values used in the saturated zone flow and transport models.

Therefore, the relevant effects of faults on groundwater flow paths and rates of radionuclide transport have been included in the performance assessment, as has the uncertainty associated with these faults.

2.2 RECOMMENDATION: SPATIAL DISTRIBUTION AND SEDIMENTARY ARCHITECTURE OF ALLUVIUM

Second, improvements in the characterization of the spatial distribution and sedimentary architecture of the saturated alluvium could substantially enhance fundamental understanding of groundwater flow and radionuclide transport along Fortymile Wash south of Yucca Mountain. For example, the recent sonic log drilled by Nye County is an excellent source of data for supporting studies of sorption of radionuclides in alluvial sediment; additional logs from locations where uncertainties are high have the potential to yield similar benefits. Deeply weathered cobbles from that geologic log suggest the potential for delays in radionuclide transport due to diffusion that could be demonstrated if the DOE conducts field-scale long-term tracer studies (for example, at the Alluvial Testing Complex). These studies should be done.

2.2.1 RESPONSE

As you know, the testing at the Alluvial Testing Complex (ATC) was suspended during site characterization when a permit to withdraw and inject water was denied by the State of Nevada. Before the testing was terminated, single-hole hydraulic and tracer testing and multiple well hydraulic tests were conducted at the ATC. The results of these tests were used to develop estimates of groundwater specific discharge in the alluvium. The DOE plans to restart testing at the ATC, pending resolution of permitting issues with the State of Nevada, using multiple borehole tracer testing as part of the Performance Confirmation Program. Cross-hole pump and tracer transport tests are planned to evaluate conceptual and numerical models for flow and transport in the alluvium south of Yucca Mountain. In addition, Nye County is planning a multi-well test in the alluvium as part of the Early Warning Drilling Program and has plans to investigate the geometry of the alluvium-tuff interface geophysically.

2.3 RECOMMENDATION: MATRIX DIFFUSION

Third, depending on rock properties such as fracture frequency and thin coatings on the fracture faces, matrix diffusion could either increase or decrease current estimates of radionuclide transport time by thousands of years. For this reason, a better empirical basis for predicting matrix diffusion is needed.

2.3.1 RESPONSE

The drift-to drift liquid release and tracer tests (Alcove 8-Niche 3) provide information on seepage, matrix diffusion, and transport over spatial scales in the range of 20 meters in the vicinity of a near-vertical fault[4]. Alcove 8 is located in the upper lithophysal tuff of the Topopah Spring directly above Niche 3, located in the middle nonlithophysal tuff of the Topopah Spring. The role of matrix diffusion is examined by comparing the experimental observations collected from Alcove 8-Niche 3 and results of tracer tests in Alcove 1 with model predictions. The results support conceptual models of unsaturated zone flow and transport and confirm that numerical approaches used in the models adequately represent physical processes controlling unsaturated zone flow[5].

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[4] BSC (Bechtel SAIC Company) 2003. In Situ Field Testing of Processes. ANL-NBS-HS-000005 REV 02. Las Vegas, Nevada: Bechtel SAIC Company. ACC: DOC.20031208.00001.

[5] BSC (Bechtel SAIC Company) 2004. UZ Flow Models and Submodels. MDL-NBS-HS-000006 REV 02. Las Vegas, Nevada: Bechtel SAIC Company.

Similar tracer behavior with different diffusion coefficients was observed by Reimus et al. in tracer experiments in fractured volcanic tuff at the C-wells site[6]. This consistency suggests that similar transport processes (advection and matrix diffusion) are at work in the unsaturated and saturated zone barriers in the fractured tuffs of low matrix permeability.

Laboratory and field tests have demonstrated that matrix diffusion occurs in fractured volcanic tuffs near Yucca Mountain and provide a basis for quantifying the effect of matrix diffusion on radionuclide migration through the fractured tuff of the saturated zone. An empirical relationship relating matrix diffusion coefficients to matrix porosity and permeability has been developed from laboratory experiments of diffusion coefficients in intact volcanic tuff matrices and from corresponding matrix porosity and permeability measurements. In the field, the observed tracer breakthrough curves in multiple tracer tests at the C-wells can be explained and interpreted only using transport models incorporating matrix diffusion.

Three additional projects are underway on the subject of matrix diffusion, including a laboratory study to determine the effect of pore connectivity and episodic flow on matrix diffusion, a field study of isotopic disequilibrium as an indicator of in-situ matrix diffusion, and a study to verify the scale-dependence of matrix diffusion parameters. Further, the 2-km natural gradient tracer test, in the saturated zone, will provide a better empirical basis for predicting matrix diffusion.

2.4 RECOMMENDATION: COLLOID-FACILITATED TRANSPORT

. . . evidence from a nuclear weapons test site suggests that some water-borne colloids can lead to rapid radionuclide transport in the saturated zone. Laboratory and computer studies conducted by the DOE show that other colloids might substantially slow radionuclide migration. Consequently, understanding of this phenomenon should be improved by field, laboratory, and modeling studies.

2.4.1 RESPONSE

Colloid filtration rate constants and retardation factors for colloidal transport in fractured volcanic rocks and alluvium have been estimated from a number of laboratory and field experiments. These experiments suggest that the longer the colloids have to travel through saturated medium, the higher the probability that they will be reversibly or irreversibly filtered by the rock phase.

Field and laboratory experiments using both natural and surrogate colloids indicate that most colloids will be filtered by the volcanic rock and the alluvium, and that only a small percentage will remain unretarded (mobile) during migration in the saturated zone. Attachment rate constants and detachment rate constants of colloids to the rock matrix have been measured, and

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[6] Reimus, P.W.; Haga, M.J.; Adams, A.I.; Callahan, T.J.; Turin, H.J.; and Counce, D.A. 2003. "Testing and Parameterizing a Conceptual Solute Transport Model in Saturated Fractured Tuff Using Sorbing and Nonsorbing Tracers in Cross-Hole Tracer Tests." Journal of Contaminant Hydrology, 62-63, 613-636. New York, New York: Elsevier. TIC: 254205.

separate uncertainty distributions of colloid retardation factors have been developed for the fractured volcanic rocks and alluvium.

There are uncertainties associated with the colloid retardation factors obtained for the volcanic rocks and alluvium. These uncertainties are accounted for in the DOE's technical basis for the license application.

The DOE requested that the University of Nevada, Las Vegas, propose an integrated, multi-disciplinary, multi-organizational effort to provide more understanding of the role of colloids in radionuclide movement. Initiative of that work is on hold pending resolution of budget issues.

2.5 RECOMMENDATION: ACTIVE FRACTURE MODEL

. . . for unsaturated zone fluid flow and radionuclide transport, predictions are influenced significantly by assumptions inherent in the formulation of the active fracture model (AFM). The AFM needs to be tested and evaluated to establish a technical basis for using this approach.

2.5.1 RESPONSE

The active fracture model is important for unsaturated zone flow and transport calculations. This model is supported by comparisons of transport simulations with field data, such as carbon-14 measurements and mineral fracture coating data. Because field data are relatively sparse and only indirectly support the active fracture model, total system performance assessment (TSPA) analyses use a range of active fracture model parameters from three infiltration scenarios. The implementation of the active fracture model in the abstraction model (finite element heat and mass particle tracker) was shown to reproduce the qualitative features of the breakthrough curves documented in the unsaturated zone transport process model reports on which the abstraction was based[7]. Thus, the abstraction has been compared with the full complexity of the unsaturated zone model and was found to represent the system robustly for the entire range of parameters and conceptual models required.

Further, testing in a cubic meter block from the lower lithophysal unit, planned for FY 2005, is specifically designed to verify the van-Genuchten parameters of the characteristic curves for the fractured tuff, and to validate the active fracture model.

2.6 RECOMMENDATION: SITE-SCALE MODEL BOUNDARIES

Third, in the saturated zone, the technical basis for the DOE's site-scale flow model would be stronger if the model were more consistent with the most recent regional model calculations of flow across the site-scale model boundaries. Updating the DOE's model on the basis of these calculations could affect predictions of radionuclide transport times.

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[7] BSC. 2004. Particle Tracking Model and Abstraction of Transport Processes. MDL-NBS-HS-000020 REV 00. Las Vegas, Nevada: Bechtel SAIC Company. ACC: DOC.20040120.0001.

2.6.1 RESPONSE

The DOE is in the process of revising the *Site-Scale Saturated Zone Flow Model [Analysis Model Report] AMR* to document an alternative conceptual model, using the updated hydrologic framework model and boundary fluxes derived from the 2002 regional flow model. This analysis will consider:

1) Additional water-level data from Phase 2 of the Nye County Drilling Program,
2) A reinterpreted Hydrologic Framework Model,
3) Revised recharge distribution from the 2002 Regional Model and the 2003 Unsaturated Zone Model,
4) Updated boundary fluxes from the 2002 Regional Model,
5) Additional permeability data, and
6) Fifteen new Nye County head targets for calibrations.

The analysis will evaluate the potential impacts of the resulting flow fields (flow paths and specific discharge) on transport calculations and breakthrough curves. The analysis will also include additional evaluation of alternative conceptual models, such as an alternative representation of the Solitario Canyon fault and the large hydraulic gradient. Work initiated recently seeks to optimize the interface between site and regional groundwater models and will incorporate up-to-date versions of each.

3.0 MULTIPLE LINES OF EVIDENCE

3.1 RECOMMENDATION

Multiple lines of evidence and argument can be used to supplement and evaluate the conceptual understanding of the natural systems at the site, the models used to represent those concepts, and the scenarios predicted by those models. The Peña Blanca analogue site in Chihuahua, Mexico, having many similarities to Yucca Mountain, provides a good opportunity to evaluate, for example, whether consideration of secondary mineralization processes may reduce overall system dose estimates substantially and what effect alpha decay of radionuclides in minerals may have on mobility. The Board commends the Science and Technology program for its plans to test Yucca Mountain modeling approaches at the Peña Blanca analogue site. Naturally occurring radioisotopes at Yucca Mountain provide another valuable line of evidence for flow and transport. Additional isotopic data, such as carbon-14 measurements, collected from discrete zones in the flow path from Yucca Mountain, could be used to test and evaluate DOE models and predictions and to constrain recharge rates in the model domain. In summary, the validity of model forecasts can be evaluated better in the presence of a list of independent physical and chemical lines of evidence that support or challenge the forecasts.

3.1.1 RESPONSE

The DOE agrees with the Board that multiple lines of evidence can be used to supplement and evaluate the conceptual understanding of the natural system at Yucca Mountain. The

Peña Blanca analogue site provides an opportunity to evaluate models of the Yucca Mountain site by testing against field observations and process modeling of these observations at the Peña Blanca site. The ongoing work at Peña Blanca is evaluating fracture-matrix interactions, transport behavior, and colloidal transport.

One of the few methods to investigate transport processes over the spatial and temporal scale of interest to repository performance is the use of naturally occurring radioisotopes, such as carbon-14. The DOE has used observations of carbon and other isotopes to test and evaluate transport properties developed at smaller scales in the saturated zone. Although uncertainty and variability exists in these observations, they generally indicate advective transport times of unretarded species that range from a few hundred to a few thousand years along likely flow paths in the tuff and alluvial aquifers. These advective travel times are similar to those that result from the saturated zone flow and transport model. The DOE has also used isotopic data, along with hydrochemical data, to provide bounds on the magnitude and timing of recharge in the saturated zone at the regional scale. New methods of interpreting carbon-14 and carbon-13 analyses together provide an independent line of evidence related to saturated zone processes, for example, advective transport of natural tracers.

4.0 CONCLUDING COMMENTS

4.1 RECOMMENDATION

At a May 2002 meeting of the Board, you stated your intention to devote attention to aspects of the natural system, and we are encouraged by your interest in this important work. Observations during our field trip to Yucca Mountain demonstrated two things in particular: (1) better understanding the behavior of the natural barriers at Yucca Mountain is challenging because of the complexity of the geologic system, and (2) based on recent progress in characterizing the natural system, enhanced understanding of the natural system is attainable. The Board believes strongly the important work you have done in this area should be continued.

4.1.1 RESPONSE

At the May 2002 Board meeting, I introduced my vision of the Science and Technology Program, noting that one focus of this program would be activities that enhance understanding through continuous improvement in scientific understanding of the Yucca Mountain repository system. This program is managed as a separate activity from the license application. Science and technology projects are not needed to support the license application, but may provide useful information after the initial license application. One of the key focus areas of the Science and Technology Program is the natural system. Results of testing and analyses completed in the Science and Technology Program will be available after license application and can be incorporated at a later stage in the program, as appropriate.

At this same meeting in May 2002, the DOE summarized its plans for additional technical work to support the license application based on a risk-informed prioritization and emphasizing a defensible and sound technical basis for the license application, as noted above. The extensive

testing and modeling program undertaken to understand and characterize flow and transport in the unsaturated and the saturated zones at Yucca Mountain provides a sufficient basis for predicting radionuclide releases at the compliance boundary. While it is clear that enhanced understanding of the natural system is attainable, the DOE believes that the technical basis for a license application is adequate. As noted previously[1], scientific studies of the natural system will be completed in the Performance Confirmation Program to evaluate the adequacy of the technical basis that led to findings that may permit construction of a repository at Yucca Mountain.

UNITED STATES
NUCLEAR WASTE TECHNICAL REVIEW BOARD
2300 Clarendon Boulevard, Suite 1300
Arlington, VA 22201

November 30, 2004

Dr. Margaret S. Y. Chu
Director
Office of Civilian Radioactive Waste Management
U.S. Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585

Dear Dr. Chu:

On behalf of the Nuclear Waste Technical Review Board, I thank you and your team of DOE staff and contractors for participating in the Board's meeting on September 20, 2004, in Las Vegas, Nevada. We appreciated both your program overview and your welcome to the new Board members. The information presented at the meeting was very useful, and the field trip to Yucca Mountain on September 22 was a worthwhile and valuable experience for the new members.

In this letter, the Board provides follow-up comments on the information presented at the meeting.

Waste Management System

The Board believes strongly that waste handling and surface storage at Yucca Mountain should be viewed and analyzed as parts of an integrated waste management system that begins when waste is selected for shipment at reactor and other sites and that ends after placement of the waste in a repository. Because the many elements of a waste management system are interdependent, integrated analyses are needed to understand the viability of the system, identify possible safety and operational concerns, and optimize the system.

Issues raised in the presentation on the design of surface and underground facilities at Yucca Mountain illustrate the vital importance of integrating waste management activities as a part of facility design. For example, under current plans, fuel assemblies could be handled up to four times at Yucca Mountain before being emplaced in the repository. The Board believes that the DOE should analyze ways to minimize the number of times that fuel assemblies are handled. The Board also encourages the DOE to analyze how the aging of spent fuel in surface storage at Yucca Mountain would be used to achieve thermal goals as part of a clearly articulated thermal management strategy. Evaluating the implications of various aging scenarios should be included in this analysis.

bjg004vf

Science and Engineering

Need for Integration. The value of integrating program activities also extends to scientific and engineering activities. In particular, changes in engineering design or operations should be analyzed using Total System Performance Assessment (TSPA) to determine the potential level of significance of the effects of the changes on the overall repository system. For example, as the Board pointed out in its June 30, 2003, letter, if the repository design is modified to mitigate the effects of igneous activity, such modifications should be evaluated for their effects on repository operation and performance.

Increasing Fundamental Understanding. In the past, the DOE has increased its fundamental understanding of Yucca Mountain through a large number of scientific and engineering investigations that were part of the site characterization program. Appropriately, much of this work continues in one form or another to address existing and future scientific and technical issues. In addition, you have established the Science and Technology (S&T) program to increase fundamental understanding and to explore concepts that could improve the waste management system. Because the objectives of the S&T program are so important, the Board believes that sustaining the S&T program at or above its current level is very important.

Because several significant scientific issues remain unresolved, maintaining access to the Exploratory Studies Facility and the Enhanced Characterization of the Repository Block (ECRB) for ongoing scientific and engineering investigations is important. For example, the Drift-Scale Test, which is planned to run for 8 years, is presently in its 4-year cool-down phase. Observations of hydrogeologic changes in response to heat fluxes in this test will be needed to evaluate models that predict repository performance. Similarly, water collected in the ECRB and the possible presence of bomb-pulse chlorine-36 at the repository horizon continue to raise questions about water flow inside Yucca Mountain.

Corrosion Issues. The Electric Power Research Institute (EPRI) reported at the meeting that preliminary short-term tests with synthetic magma indicate that Alloy 22 may have significant corrosion resistance to some magmas. However, the chemical compositions of possible magmas at Yucca Mountain vary widely. Therefore, the Board believes that EPRI's results, although very important as an early indicator, do not provide a sufficient technical basis for determining the corrosion resistance of Alloy 22 in magma.

The possibility of stress corrosion cracking of the titanium drip shield also was mentioned at the meeting. The Board looks forward to receiving more information on the technical basis for the DOE's conclusions that stress corrosion cracks that completely penetrate the drip shield would be rare and that, if they did occur, would be narrow and plugged by mineral precipitates or overcome by capillary forces. We also recommend that the DOE determine the likelihood that conditions necessary for stress corrosion cracking of the drip shield would occur at Yucca Mountain.

These two issues need to be addressed within the context of other corrosion tests that should be carried out in environments that closely approximate the various conditions to which Alloy 22 and titanium will be exposed and in environments that reasonably bound those conditions. For example, the Board's July 28, 2004, letter mentions the need for further investigation of the possibilities of localized corrosion. The extent to which the DOE has characterized likely waste package environments accurately is unclear at this point.

Progress on Ground-Motion Estimates. The seismic update made clear that the program has taken significant steps toward developing realistic estimates of ground motions. The Board encourages the DOE to continue these efforts using sound physical principles to limit the proposed, very low-probability earthquake ground motions. We understand that the DOE's S&T program also is addressing this issue over a longer time frame. Of importance is that all currently planned work is continued and that short- and long-term seismic efforts are well integrated. Because of the challenging nature of the task, the analyses should be submitted to external peer review.

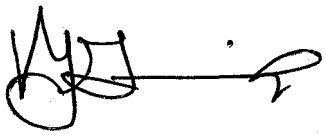
Total System Performance Assessment

The afternoon session of the meeting was devoted primarily to a presentation on TSPA, which provided an overview of significant issues and the TSPA process for the new Board members. The importance of TSPA as a part of the repository safety assessment highlights the critical need to complete the testing and validation of the process computer models and methods that support TSPA.

Within the context of TSPA, the Board has three specific interests for future Board meetings. First, we would like to review the results of the TSPA that will be submitted as part of the license application, i.e., TSPA-LA. Second, we would like to understand better the technical and integration problems associated with TSPA and model validation activities (as indicated by the red zones in the August 2004 Annunicator Panel) and how they are being resolved. Finally, the Board would like to know how TSPA and other technical activities will be affected by the court's decision to vacate the 10,000-year time period associated with the EPA standard.

Once again, I thank you and the DOE's staff and contractors for participating in the Board's September meeting. We look forward with interest to further interactions with the DOE on the topics discussed in this letter.

Sincerely,



B. John Garrick
Chairman

UNITED STATES
NUCLEAR WASTE TECHNICAL REVIEW BOARD
2300 Clarendon Boulevard, Suite 1300
Arlington, VA 22201

December 1, 2004

Dr. Margaret S. Y. Chu
Director
Office of Civilian Radioactive Waste Management
U.S. Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585

Dear Dr. Chu:

On behalf of the Nuclear Waste Technical Review Board and its Waste Management System panel, chaired by Board member Mark Abkowitz, I thank your staff for participating in the panel's meeting on October 13 and 14, 2004, in Salt Lake City, Utah. The Board members found the U.S. Department of Energy (DOE) presentations informative and thought-provoking.

Transportation Planning. The Board commends the DOE on its effort in developing a systematic approach to transportation planning. Attempts to adopt such an approach were evident at the national transportation program level and within specific components of the planning effort (e.g., transportation security risk assessment). The Board believes that developing a successful transportation plan will require significant interactions, both operationally and institutionally. The following are examples of potentially fruitful areas for such interactions.

- Exchange of technical information between the DOE and the railroad industry on equipment design and system operations.
- Dialogue about technical issues between the DOE and the utilities in developing a reliable and credible schedule for the amount and types of spent fuel to be shipped.
- Exchange of technical information with other DOE and private spent-fuel transportation shippers to learn from their planning experiences.

The Board observes that presently there is not an overarching implementation organization that can develop a safe, secure, and efficient transportation system. To ensure successful technical integration, it is important for the DOE to develop specific logistical plans that identify the entity that is responsible for each system component and the key interactions required of each involved entity. A detailed strategic plan for transportation could be used to guide this effort. For example, the DOE needs to focus its attention on the transportation options within Nevada for both rail and truck. In particular, contingency plans need to be developed for higher levels of truck use in case a rail spur is not built or is delayed beyond the initiation of the shipping campaign.

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The Board is concerned that non-technical constraints, such as those related to schedule or budget, may compromise transportation planning. The Board urges the DOE to provide adequate resources for supporting transportation planning issues and to exercise great care in how decisions are made so that the integrity of the planning process is preserved and key technical issues that warrant serious consideration are not overlooked.

The public comment periods at the meeting provided evidence that communication between the DOE and stakeholders could be improved to ensure that the public understands the technical aspects of the program and the DOE's plans. This is particularly important in the context of the presentation on risk perception.

Security and emergency-response planning. The DOE's approach to transportation security risk assessment appears to be organized appropriately. The Board notes, however, that determining the probabilities of potentially disruptive events is very difficult. Development and use of realistic scenarios can enhance the technical basis of the overall analysis and could lead to establishment of an effective response infrastructure. Emphasis on defensive and mitigative actions should be commensurate with the likelihood and consequences of the scenarios. Risk assessment results, as they become available, should be merged into an integrated, all-hazards risk management approach that fully considers both safety and security threats.

The DOE's approach to emergency-response planning through the 180(c) program appears to be based too much on funding formulas and not enough on the underlying objective of ensuring that adequate emergency-response capability exists along all selected routes. The DOE needs to define what constitutes a minimum acceptable level of emergency response along each segment of each transport route and needs to develop a method for verifying that such capability exists. Also important is understanding the general expectations of security provisions—for example, the role of safe havens, notifications, escorts, and emergency personnel, including first responders. Shipments of foreign research-reactor fuel can provide useful information in this regard.

Transportation risk assessment. The DOE's approach to transportation risk assessment has been largely one of applying deterministic models (i.e., RADTRAN). As described at the meeting, RADTRAN appears to include several conservative assumptions. The Board was pleased to learn that version 5 of RADTRAN has the capability (using Latin Hypercube Sampling) to perform uncertainty analysis, thus providing a modeling capability more closely aligned with the Board's desire to see transportation analyses that are more risk-based and realistic. After code testing and validation, we look forward to seeing transportation risk results based on RADTRAN 5.

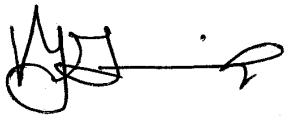
Related to assessing transportation risks is the Package Performance Study being planned by the U.S. Nuclear Regulatory Commission (NRC). The Board would like to be kept informed on the status of the NRC study. We are particularly interested in the technical adequacy of the test program in which the rail cask will be tested and how the tests will be used to validate the models used in other cask designs, such as those used for truck shipments.

Route selection. Evaluation and designation of shipment routes by the DOE is important. This topic is of great interest to stakeholders along selected transportation corridors. Closely related is the decision on using dedicated trains, because a decision not to use dedicated trains could limit the routes available for consideration. The Board believes that it is appropriate to involve state regional groups in establishing routing criteria and recommending preferred routes, although the variation in views of these groups on this issue is evident. Moreover, tribal groups may not be adequately represented in these deliberations. To ensure that the state regional groups are successful in their efforts, this process must be managed carefully and diligently. Of particular importance, the DOE needs to ensure that the technical issues involved in route selection are identified and that sound methods for addressing the issues are developed and applied.

Program integration. The DOE presentations did not demonstrate the degree of program integration needed to ensure that the transportation system will operate successfully. The DOE needs to plan for and be able to demonstrate harmonization of cask design, fleet acquisition, waste acceptance, operational practice, and other activities that must be carried out at reactor sites, during shipping, and at the repository. The Board looks forward to further discussion of program integration in future meetings.

Thank you again for the DOE's support of this meeting.

Sincerely,



B. John Garrick
Chairman

Department of Energy
Washington, DC 20585

QA: NA

January 26, 2005

B. John Garrick, Ph.D., P.E.
Chair, Executive Committee
Nuclear Waste Technical Review Board
2300 Clarendon Boulevard
Arlington, VA 22201-3367

Dear Dr. Garrick:

Thank you for the Nuclear Waste Technical Review Board's (Board) letter of July 28, 2004, providing the response to the information presented by the U.S. Department of Energy (Department) at the May 18-19, 2004, meeting of the Board. The Department appreciates the Board's continuing review of our activities as we work to develop and document the technical basis for the License Application for a repository at Yucca Mountain. Our responses to the Board's views and recommendations are summarized in the enclosure to this letter.

The Department continues to benefit from the constructive views of the Board, and we look forward to further dialog on our repository design and related issues.

Sincerely,

Margaret S.Y. Chu, Ph.D.
Director
Office of Civilian Radioactive
Waste Management

Enclosure

U.S. DEPARTMENT OF ENERGY (DOE) RESPONSES TO THE JULY 28, 2004, LETTER FROM THE NUCLEAR WASTE TECHNICAL REVIEW BOARD (BOARD)

Corrosion Issues

Calcium chloride-rich environment

Based primarily on information presented at the Board's May 2004 meeting, it appears unlikely that dusts that accumulate on waste package surfaces during the preclosure period would contain significant amounts of calcium chloride or that significant amounts of calcium chloride would evolve on waste package surfaces during the thermal pulse. Consequently, the calcium chloride-rich environment selected for corrosion tests does not appear representative of the conditions that can be expected on waste package surfaces in a Yucca Mountain repository. If calcium chloride is not present, calcium chloride-rich brines will not form by deliquescence, and crevice corrosion due to the presence of such brines in the temperature range of roughly 140°C to 160°C will not occur. Thus, the Board concludes that deliquescence-induced localized corrosion during the higher-temperature period of the thermal pulse is unlikely.

Response

We agree with the Board that calcium chloride type deliquescent brines are very unlikely to exist or be stable at Yucca Mountain. In addition, the soluble constituents in the potential dust deposits that could be present on the drip shield and waste package surfaces are rich in beneficial inhibiting ions including nitrate and to a lesser extent sulfate ions. In the presence of these anions, even in the unlikely case where calcium chloride type brines were to form and to remain stable, they would not support localized corrosion. The effect of nitrate on inhibiting localized corrosion in these type brines is quantified and documented in the updated Analysis Model Report on general and localized corrosion of waste package outer barrier. Expected benign response of Alloy 22 exposed to these types of calcium chloride rich deliquescent brines is corroborated by the technical bases discussed in the Electric Power Research Institute's presentation to the Board at the May 2004 meeting (Kessler, J. et al. 2004).

Although we agree that calcium chloride type brines are very unlikely to exist or be stable at Yucca Mountain, other chloride brines with varying amounts of corrosion inhibitors, such as nitrate and sulfate, may be present at elevated temperatures. Understanding the localized corrosion behavior of Alloy 22 given such conditions is important. Thus, the Project is continuing to evaluate the localized corrosion response of Alloy 22 over a broad range of potential salt brine compositions and over the full range of relevant temperature, relative humidity, pH values, etc. For example, the corrosion response in sodium-potassium mixed salts is being evaluated. Current measurements indicate there is a potential for some of these saturated $NaCl$-$NaNO_3$-KNO_3-H_2O type deliquescent brines to boil at maximum temperatures on the order of 200°C. To date, DOE has not found that significant corrosion damage will occur under these deliquescent salt conditions. However, the likelihood of formation and

consequences of these high-temperature brines are being analyzed further to assess the potential for localized corrosion to occur under high temperature conditions.

Characterization of waste package environment

Ideally, corrosion tests should be carried out both in environments that closely approximate the various conditions to which the waste package alloy will be exposed and in environments that reasonably bound those conditions. The extent to which the DOE has characterized accurately the likely waste package environments (i.e., temperature, relative humidity, and chemical species present) is unclear at this point. Accurate characterization of probable waste package environments and the corrosion response of the waste package alloy to those environments will continue to be a major focus of the Board's technical and scientific review.

Response

The projected range of environments that could potentially be present on the waste package surface represents a heterogeneous matrix that will vary with time as the in-drift temperature and relative humidity change. Consequently, the Project has chosen to evaluate the Alloy 22 general and localized corrosion response over a broad range of potentially relevant as well as bounding test environments.

The types of environments expected on the waste package surface over 10,000 years were summarized for the Board at the May 2004 meeting. In addition, the likely concentrated brine environments and their expected frequencies and uncertainties have been calculated based on modeled repository-relevant seepage waters and the modeled behavior of soluble species in dust deposits. Although the frequency of different types of brines was not addressed at the May 2004 meeting, the results were recently documented. Because ranges of geochemical and thermal-hydrologic conditions are possible, there is a range of brine environments that could potentially form on the waste package surface depending on temperature, relative humidity, and the presence of intact drip shields. For the expected case, with the drip shield function intact, expected brines are of the sodium nitrate, potassium nitrate, sodium chloride, or calcium nitrate types. Dust samples collected in the tunnels at Yucca Mountain have been analyzed and grouped to summarize the types of deliquescent brines that could form. Only a few of the dust samples analyzed indicate that a calcium nitrate type brine could form. Deliquescent brines cover a pH range from approximately 6 to 12, depending on brine type and the CO_2 partial pressure. The associated chloride concentration varies from to 1 to 8 molal and decreases with increasing relative humidity. Dissolved fluoride concentrations vary from approximately 10^{-6} molal to 0.3 molal, depending on the individual brines. The nitrate concentrations are greater at lower relative humidity (higher temperature) and decrease at lower temperature (increasing relative humidity). As a result, the nitrate to chloride molal ratio will vary from approximately 0.4 to 26, i.e., well into the beneficial range where nitrate acts as a localized corrosion inhibitor.

Currently work is underway to evaluate the following conditions:

- The amount and composition of dust on waste packages as well as the volume of brine and quantities of dissolved salts, and assess the significance of any acid-gas volatilization.
- Assess the deliquescence-related properties of ammonium salts.
- Study the effects of any chloride-containing silicate minerals or minerals containing hydroxide, which can be replaced by chloride.
- Document the argument(s) for exclusion of localized corrosion of the waste package outer barrier due to the deliquescence of dust constituents.

As mentioned earlier, past and currently ongoing corrosion tests encompass the range of these predicted environments.

Localized corrosion at below boiling temperature

First, the DOE raised the possibility that when temperatures in repository tunnels fall below boiling, localized corrosion could occur in concentrated sodium chloride solutions with low concentrations of inhibitors. The Board believes that further investigation of the possibilities for localized corrosion at below-boiling temperatures is warranted and that such an investigation should focus on (1) possible mechanisms that might create environments that would facilitate localized corrosion and (2) the likelihood that such environments could exist.

Second, the presence of ammonium ion and the implications of its presence for corrosion or other performance aspects need to be explained

Response:

Extensive Alloy 22 localized corrosion test results have been used to develop a localized corrosion predictive model that covers the below boiling temperature range as well as higher temperatures (BSC 2004a). The model quantifies the beneficial effect of soluble nitrate (calculated to be present in all concentrated seepage and deliquescent brines that might form on the waste package surface) and conservatively incorporates a threshold nitrate/chloride molal ratio of 0.5 or greater to rule out localized corrosion at temperatures up to 160°C. Although the model does not take credit for other beneficial anions such as sulfate, carbonate, and bicarbonate, experimental results indicate the presence of these anions (as well as nitrate) contributes to inhibition of localized corrosion (Dunn et al. 2004 and BSC 2004b).

At temperatures near the boiling point (about 96°C at the repository elevation), the projected waste package relative humidity will range from about 35-100 percent and will increase with decreasing temperature (BSC 2004c). With the drip shields intact, any seepage brines will be diverted; and, thus, waste package surface brine environments will result only from deliquescence of soluble salts present in surface deposits. Because the deliquescent dust constituents form brines that have nitrate to chloride molal ratios of at least 0.4 for any exposure condition, localized corrosion will likely be inhibited.

The drip shield is expected to perform its design function of seepage diversion for the next 10,000 years. Even if the drip shields were to fail, it is estimated that only a small fraction (1

percent) of the seepage brines could evaporatively concentrate into concentrated chloride brines (BSC 2004c). In general, the nitrate to chloride ion ratio in seepage brines tends to be lower than for the dust deliquescent brines. The localized corrosion model implemented in the total system performance assessment-license application initiates localized corrosion if the nitrate to chloride ion ratio is less than 0.5. The value of 0.5 was conservatively selected, and no localized corrosion has been observed in expected lower temperature Na, K, Cl, NO_3 brines and sulfate brines under open circuit potential conditions for nitrate to chloride ratios between 0.05 and 0.5 (Payer 2004). Under accelerated cyclic potentiostatic polarization conditions, inhibition of localized corrosion, i.e., $E_{corr} < E_{crit}$. was observed at chloride to nitrate ratios above 0.15 at 80°C (Payer 2004).

It is evident that a minimum nitrate concentration is needed to counteract the aggressive nature of the chloride ion at the surface of the passive film. The mechanisms for nitrate inhibition of localized corrosion are likely to involve:

1. Electro-reduction of the nitrate ion to the ammonium ion leading to a beneficial increase in local pH in the creviced regions.

2. Electro-reduction of the nitrate ion to atomic nitrogen, followed by adsorption of nitrogen on the depassivated metal in the crevice or at the base of an incipient pit. In this case, nitrogen may act as an anodic site blocker. Once adsorbed, nitrogen might then undergo further reduction to the ammonium ion.

The ongoing ammonium studies are addressing the importance of ammonium salts as they may affect the volatilization of nitrate, and solution conditions that result from the behavior of ammonia. Our current understanding based on handbook data and published literature is that ammonium nitrate and ammonium chloride, two common constitutents of atmospheric dust, will volatilize completely on the waste package surface either during preclosure ventilation or within a few years afterward. Ammonium sulfate and bisulfate salts are less deliquescent and relatively nonvolatile.

The currently available data on the ammonium content in dust comes from reanalysis of tunnel dust samples, and from the National Airfall Deposition Program monitoring data (collection station at Red Rock). These data indicate that ammonium and nitrate have generally comparable molalities, so there is the potential for volatilization of nitrate (e.g., as HNO3 or N2O). Understanding the extent to which nitrate in the dust analyses is incorporated in nonvolatile compounds (NaNO3 and KNO3) depends on the partitioning of ammonium among the various common atmospheric compounds. We are investigating the literature for atmospheric chemistry to establish this partitioning and its uncertainty.

Volatilization of ammonia from deliquescent brine could lower brine pH, but there is ample buffering capacity associated with the silicate mineral constituents of the dust, to maintain brine pH in the neutral range.

Third, the State of Nevada suggested that nitrates could be aggressive corrodents in some circumstances. The Board believes that it would be worthwhile to review existing corrosion data

to determine whether they bound nitrate-containing environments that reasonably could be anticipated at Yucca Mountain.

Response:

The State of Nevada studies used an unrealistic experimental design involving the collection and condensation of acidic gas volatiles (e.g., HNO_3 and HCl) from evaporation of groundwaters (Pulvirenti, et al. 2004). It is more likely that in the open repository system these volatiles will disperse to the drift wall and become neutralized by reaction with the surrounding rock. In this way, acid-gas volatility will limit, rather than increase, the development of low pH (acidic conditions) on the waste package surface. Exposure environments such as the one created *in vitro* by Pulvirenti et al. (2004) are not realistic or expected repository environments.

As mentioned earlier, DOE has focused on evaluating corrosion behavior over a broad range of potentially relevant and accelerated test environments. Based on the results of the Physical and Chemical Environment model (BSC 2004c), the calculated maximum chloride concentration in the range of relevant seepage and deliquescent concentrated brines is about 13 molal, and the calculated maximum nitrate concentration is about 28 molal. In comparison, existing cyclic polarization data for creviced specimens include a broad range of chloride and nitrate concentrations up to 36 molal chloride plus 18 molal nitrate tested at 160°C. This essentially bounds the expected maximum nitrate levels for the full range of seepage and deliquescent dust brines. There appears to be no deleterious effect of nitrate concentration on the general corrosion rate. For example, test results for Alloy 22 covering a range of nitrate levels up to and above the calculated maximum nitrate level of 13 molal were reported at the May 2004 Board Meeting (Payer 2004). Also, specimens exposed in 2.7 molal NaCl + 15.1 molal KNO_3 for 158 days at temperatures up to 160°C exhibited very low corrosion rates of <0.2 μm/year. In addition, a limited amount of cyclic polarization data have been collected in concentrated nitrate solutions at high temperatures (e.g., 22.5 m $Ca(NO_3)_2$ + 0.225 m $MgCl_2$ at 145°C and 15 m $Ca(NO_3)_2$ + 1.5 m $CaCl_2$ at 125°C). No hysteresis was observed and no evidence of localized corrosion was found indicating that nitrate ions are beneficial to localized corrosion resistance even at high concentrations and at higher exposure temperatures.

Integration

DOE contractors have been performing corrosion tests at high-temperatures in high-chloride brines for several years, presumably because it was thought that the test conditions might occur at Yucca Mountain or might reasonably bound actual conditions. However, as became clear as a result of presentations at the May 2004 meeting, geochemical considerations preclude high-temperature, high-chloride brine conditions at Yucca Mountain, rendering the corrosion tests of limited relevance. This situation underscores the need for thorough integration and close cooperation among diverse technical disciplines, particularly when "coupled" processes are involved. For example, excellent integration among geochemists and corrosion scientists/engineers was evident at the meeting and helped bring clarity to an extremely important corrosion issue. Continuing integration will be necessary for resolving other issues associated with the DOE's current repository design.

Response

We agree that integration among diverse technical disciplines is an important element of assuring that there are no unintended gaps or inconsistencies between the models, data, and parameters developed and implemented by analysts in these different disciplines. The example cited by the Board of the calcium chloride, high-temperature corrosion test conditions not being representative of potential geochemical conditions at Yucca Mountain is a good example of the need for assuring such integration takes place. However, we disagree that these tests were of little relevance. Defining the corrosion potential and critical potential of Alloy 22 over a range of possible environmental conditions, including but not limited to high-chloride conditions and high-temperature conditions, was (and continues to be) an important element of the corrosion testing program. Although we agree that calcium chloride type brines are very unlikely to exist or be stable at Yucca Mountain, other chloride brines with varying amounts of corrosion inhibitors, such as nitrate and sulfate, may be present at elevated temperatures. Given such conditions, understanding the localized corrosion behavior of Alloy 22 is important. The tests cited by the Board give additional lines of evidence to support the confidence in the model when extrapolated to such conditions. Because a range of geochemical and thermal-hydrologic conditions are possible on the waste package surface, DOE intends to test Alloy 22 over this range and to extend the range to bound the possible behavior of the Alloy in extreme environments. This notwithstanding, the need for continued integration among diverse scientific and engineering disciplines remains an ongoing area of focus for the Department, particularly in the area of coupled processes.

Hydrology and Thermohydrology Issues

After reviewing the information presented at the May 2004 meeting, the Board continues to question the pervasiveness of vaporization and capillary barriers because of persistent uncertainties related to the expected repository tunnel environments. Examples of uncertainties include (1) the conceptual basis for the drift-scale thermohydrologic seepage analysis, including the axial convective transport of water vapor, air, and thermal energy in drifts; (2) the source of liquid water observed in the bulkheaded part of the cross drift; (3) the effects of drift degradation on the waste package environment; and (4) potentially unrealistic combinations of parameters used in the performance-assessment calculations of seepage.

The Board understands that significant scientific challenges are associated with analyzing the complex hydrology at Yucca Mountain, especially when the repository is subject to a large thermal perturbation. However, the Board believes that addressing uncertainties such as those noted above could create a more solid technical basis for determining whether the DOE's high confidence in the effectiveness of capillary and vaporization barriers is warranted.

Response

The pervasiveness of a capillary barrier has been tested and verified in both the middle nonlithophysal and lower lithophysal repository units. The testing ranges from several-meter scale in the niches to tens-of meters scale in Alcove 1 and Alcove 8-Niche 3. That a seepage threshold (orders of magnitude larger than predicted infiltration) exists has been shown by the

field tests and their analysis, although the performance calculation employs a more conservative approach in selecting the seepage relevant parameters. All of the field tests are incorporated into relevant seepage models.

As for the effectiveness of a vaporization barrier, modeling addressing explicitly model uncertainties and parameters uncertainties, including effects of drift degradation, has been performed. However, at the present time, field data that directly address the issue of seepage under thermal conditions and hence the pervasiveness of the vaporization barrier do not exist. If appropriate and consistent with the Department's safety case, experimental investigations along these lines may be considered in the future to add confidence in the effectiveness of a vaporization barrier.

Seismic Update

We were very pleased to learn from the update at the May 2004 meeting that the DOE has initiated a program aimed at deriving more realistic estimates of seismic hazard at the Yucca Mountain site. In its June 27, 2003, letter to you, the Board indicated its concern about what may be physically unrealizable estimates of very low-probability (annual probabilities of exceedance of 10^{-6} or less) seismic ground motion being calculated for Yucca Mountain by the DOE and its contractors. The new program appears to be a thoughtful first step. It is based on using the extent of fracturing observed in the tunnels at Yucca Mountain to limit the ground motions that could have taken place at the site during the last 10 million years. As discussed in our June 2003 letter, deriving limits to low-probability ground motions will be challenging. We therefore urge the DOE to implement an external peer review of these efforts.

Response

The Department is pursuing both mid- to long-term and short-term activities to establish limits on low-probability earthquake ground motions. An external peer review of these efforts would be premature as they have just begun. However, the Department is actively soliciting input from the cognizant technical community in formulating its plans.

The longer term activities are being conducted under the Science and Technology (S&T) program, which has as a goal the achievement of a fundamental advancement in the approach to probabilistic seismic hazard analysis. The timeframe for this effort is 5-10 years. This advancement is envisioned to involve numerical modeling of ground motion from specific faults and nonlinear propagation of seismic waves from the source to the locations of engineered facilities. Limits on low-probability ground motions will be incorporated through empirical and theoretical limits on seismic source parameters and nonlinear material properties along the propagation path. The S&T program has established a review panel with the charter of recommending research activities to further the program's objectives. The panel is focusing, first, on research to establish limits on extreme ground motions. The panel conducted a workshop on this subject on August 23-25, 2004, in Menlo Park, California, and is preparing its recommendations at this time.

The Office of Repository Development also is pursuing activities to develop a technical basis for limiting low-probability ground motions, but in a timeframe (12-18 months) that will allow the results to be used to support the licensing hearings and the final design of the repository. This shorter term effort likely will focus on (1) the observation that the rocks at Yucca Mountain, which are over 10 million years old, do not appear to have been fractured by extreme earthquake ground shaking and (2) numerical modeling of the propagation of seismic waves through the mountain, accounting for the finite strength of the rock. To obtain input from the cognizant technical community on the specific activities to be conducted, the Office of Repository Development conducted a workshop in Las Vegas, Nevada, on September 28-29, 2004.

Transportation Planning

Information presented at the May 2004 meeting indicates that real progress is being made in planning a transportation system for a Yucca Mountain repository. The timelines that the DOE presented at the meeting identify several important milestones that your Office of National Transportation plans to develop further into detailed project plans with cost, schedule, and technical baselines. The Board's Panel on the Waste Management System has tentatively scheduled a meeting for October 13-14, 2004, in Salt Lake City, Utah. We look forward to a more detailed review of progress in transportation planning at that time. We also would like to discuss aircraft hazard and public perceptions of transportation risk at the panel meeting.

Response:

DOE appreciates the Board's recognition of the progress being made in planning a transportation system for the Yucca Mountain repository. In the meeting of the Panel on Waste Management System held last month in Salt Lake City, DOE gave an update on more recent activities in the transportation area. DOE is committed to working with the States and local entities, and the Tribes in a cooperative manner to address transportation issues relative to the Yucca Mountain repository, such as routing and emergency response training similar to the Foreign Research Reactor and Waste Isolation Pilot Plant programs.

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Department of Energy
Washington, DC 20585

QA: NA

February 1, 2005

Dr. B. John Garrick
Chairman
U.S. Nuclear Waste Technical Review Board
2300 Clarendon Boulevard, Suite 1300
Arlington, VA 22201-3367

Dear Dr. Garrick:

Thank your for your letter of December 1, 2004, providing the Nuclear Waste Technical Review Board's (Board) comments on the information presented by the U.S. Department of Energy's (Department) Office of Civilian Radioactive Waste Management (OCRWM) at the October 13 and 14, 2004, meeting of the Board's Waste Management System panel. We appreciated the opportunity to inform the Board about the progress in the transportation portion of the OCRWM Program as discussed by members of my staff from the Office of National Transportation. Our responses to the Board's views and comments are summarized in the enclosure to this letter.

The Department continues to benefit from the constructive views of the Board. We look forward to further dialogue on technical issues pertinent to transportation and the repository program at future Board meetings.

Sincerely,

Margaret S.Y. Chu, Ph.D.
Director
Office of Civilian Radioactive
Waste Management

Enclosure

ENCLOSURE

U.S. DEPARTMENT OF ENERGY (DOE) RESPONSES TO THE DECEMBER 1, 2004, LETTER FROM THE NUCLEAR WASTE TECHNICAL REVIEW BOARD (BOARD)

TRANSPORTATION PLANNING

COMMENT

There is no overarching implementation organization in the Office of Civilian Radioactive Waste Management (OCRWM) that can develop a safe, secure, and efficient transportation system.

RESPONSE

The Office of National Transportation (ONT) is responsible for developing, building, operating, and managing a national transportation system to ship spent nuclear fuel (SNF) and high-level radioactive waste (HLW) in a safe, secure, and efficient manner to a repository and, as such, is the overarching implementation organization within OCRWM. ONT manages two projects, National Transportation and Nevada Transportation. The Nevada Transportation Project is responsible for developing the transportation infrastructure in Nevada, primarily a railroad for connecting the repository to existing mainline track in the State. The National Transportation Project is organized into four subprojects: (1) Cask Acquisitions, (2) Rolling Stock Acquisitions, (3) Operations, and (4) Institutional. ONT has the responsibility for integrating these projects with the Office of Repository Development, with the Waste Acceptance Office, and with a broad range of stakeholders to ensure the transportation system is safe, secure, and efficient. In addition to ONT's integration responsibilities, OCRWM also has an Office of Systems Analysis and Strategy Development which is responsible for organizational integration as part of its strategic planning charter.

COMMENT

Specific logistical plans need to be developed that identify what entity is responsible for each system component and the key interactions required of each involved entity.

RESPONSE

We agree. ONT is building the foundation for transportation operations. Project plans are being developed that show responsibilities for the various transportation project elements and the interfaces required for each activity. A conduct of operations plan and specific campaign plans will be developed after key decisions are made regarding policy and technical issues such as the use of dedicated trains, and cask and rail car acquisition. While these plans are not complete at this point in the program, ONT is aggressively

putting the foundation in place to develop detailed plans for shipping, taking into account systems analyses and logistical modeling results. A logistics model is being developed at Sandia National Laboratories specifically for the OCRWM transportation program. Development of detailed shipment logistics are also tied to funding and to progress for the repository as a whole. The OCRWM Program Plan (an internal management document) spells out roles and responsibilities for each element of the organization.

COMMENT

DOE needs to focus its attention on the transportation options within Nevada for both rail and truck. In particular, contingency plans need to be developed for higher levels of truck use in case a rail spur is not built or delayed beyond the initiation of the shipping campaign.

RESPONSE

The Department notes the recommendation to develop contingency plans in the event of delays. We are investigating various contingencies at this time; however, our transportation planning already envisions a mix of transport modes as part of the system due to physical and operational constraints at reactor sites. Logistical planning will constantly be adjusted to reflect the status of the program, decisions by States to designate alternative highway routes, and the status of shipping sites. Operational decisions will not be finalized until several years before the first shipment.

COMMENT

Communication between DOE and the stakeholders could be improved to ensure the public understands technical aspects of the program, particularly in the context of risk perception.

RESPONSE

We do have a robust and proactive institutional program that is working with stakeholders to develop the transportation system, both for the Nevada rail corridor and for national transportation activities. We appreciate and agree about the need for the public to understand this program and have fully funded the institutional project to support the public information and public involvement aspects of the transportation program. Our approach has been first to work with various groups we believe are the correct ones to provide unbiased information to their constituents. An example of working with key stakeholders is the coordination in place with four State regional organizations: the Midwestern Regional and Northeastern Regional Offices of the Council of State Governments, the Southern States Energy Board and the Western Interstate Energy Board. These organizations and their State committee members are working with ONT to develop the plans for Section 180(c) policy implementation, public information and outreach plans, and coordination with local officials, routing determinations, and other similar transportation issues.

SECURITY AND EMERGENCY RESPONSE PLANNING

COMMENT

Risk assessment results should be merged into an integrated, all-hazards risk management approach that fully considers both safety and security threats.

RESPONSE

DOE appreciates the Board's concern that safety and security should be complimentary activities and will take into consideration the all-hazards risk management approach as it develops the transportation system. Traditional risk analysis techniques cannot be applied directly to terrorist acts since the probability of an attack cannot be ascertained; therefore, we are using a systematic approach that considers the consequences of a variety of threat scenarios and assesses threat mitigation options. In much the same way, we are taking actions to mitigate the consequences of accidents by using Nuclear Regulatory Commission (NRC) certified casks and the highest quality rail cars and by supporting emergency preparedness training. In addition, we are coordinating with the DOE's Office of Security and Safety Performance, the Departments of Homeland Security and Transportation, and industry to establish the appropriate transportation system to ensure both security and safety for OCRWM shipments.

COMMENT

DOE needs to define what constitutes a minimum acceptable level of emergency response along each segment of each transport route and needs to develop a method for verifying that such capability exists.

RESPONSE

Basic emergency preparedness is in place in States and local communities to respond to all hazardous materials transportation accidents, including those that have a much higher risk of immediate death or injury than do SNF or HLW. OCRWM will address the incremental level of preparedness associated with the risk of our shipments by providing the funding and technical support envisioned by Congress for State and Tribal governments. This support includes funding for planning and training activities under Section 180(c) of the Nuclear Waste Policy Act (NWPA) and technical assistance for training and exercises associated with emergency preparedness and transportation operational readiness.

DOE has articulated in prior 180(c) policy documents that the minimum level of response is that of awareness-level understanding for the shipments made under the NWPA. To achieve awareness-level capability, the State and Tribal governments along the routes will be provided funding and technical assistance such as train-the-trainer and exercise support with participation by DOE. Validation of preparedness capabilities would occur through planned readiness reviews and exercise programs, modeled after the Foreign

Research Reactor shipping program experience cited by the Board. In addition, we believe that it is important for the Board to recognize the role the local governments have in ascertaining whether a responder is prepared for the kinds of risks posed by hazardous shipments through their districts. The employer certifies the readiness of its employees. In addition, State and Tribal governments are responsible for maintaining emergency preparedness plans and coordinating training with local officials so that an integrated response system is in place.

COMMENT

Also important is understanding of the general expectations of security provisions, safe havens, notifications, escorts, and emergency personnel, including first responders.

RESPONSE

DOE has promulgated guidance for all shipping programs through the *Radioactive Materials Transportation Practices Manual*, DOE Order 460.2 M. OCRWM supported the development of the Manual, which outlines the Department's guidance on procedures to be followed by any DOE shipper. The Department's actions with regard to notifications, safe havens (which are for emergencies as much as for security), escorts, and emergency preparedness are articulated in the Manual. In addition, stakeholders reviewed the Manual during its development. OCRWM expects to update the practices applicable to its shipments starting in 2006 and will use a process similar to that used to develop the Manual to obtain input from our key stakeholders using the Transportation External Coordination (TEC) Working Group and the State regional groups for review of any additions or changes.

OCRWM will develop Transportation Campaign Plans to describe the roles and responsibilities for conducting specific shipments and will outline the steps and coordination needed for those shipments. The Transportation Plans will be developed prior to actual shipments and will involve State and Tribal officials, other appropriate Federal agencies, and the carriers in the planning process.

TRANSPORTATION RISK ASSESSMENT

COMMENT

DOE's approach to transportation risk assessment has been largely one of applying deterministic models (i.e., RADTRAN).

RESPONSE

RADTRAN 5, including the Latin Hypercube Sampling (LHS), was thoroughly tested and validated before 1999. RADTRAN is a probabilistic model rather than a deterministic one. The ability to distribute input as a complementary cumulative distribution function has been available to all RADTRAN users since 1998. Results

using this option have been published, notably in NUREG/CR-6672. The LHS option has not been available outside Sandia since January 2004; this is a temporary situation resulting from the shutdown of TRANSNET and the porting of RADTRAN, in 2003, from the Sandia server to a downloadable executable form. The LHS option is still available internally at Sandia, and we will continue to perform LHS analyses on request until LHS becomes available as a download (probably by early 2006). Even when RADTRAN uses single values of input parameters, probability is incorporated into the output, which reflects the risk triplet. This is particularly evident in the accident analysis: RADTRAN multiplies the conditional probability of each accident scenario by the appropriate dose, sums the products, and then multiplies by the estimated accident frequency. The result is reported as a "dose risk." Since the probability of incident-free transportation is negligibly different from unity, results are reported as doses rather than "dose risks."

COMMENT

The Board would like to be kept informed on the status of the NRC Package Performance Study.

RESPONSE

DOE will be pleased to share information it has relative to the Package Performance Study with the Board; however, conduct of the Package Performance Study is within the purview of the NRC. We have and will continue to support NRC's study activities. DOE cannot speak for the status of NRC activities and recommends that the Board contact the NRC directly relative to any issue pertinent to this request.

ROUTE SELECTION

COMMENT

DOE needs to ensure that the technical issues involved in route selection are identified and that sound methods for addressing issues are developed and applied.

RESPONSE

We agree with the Board that sound methods to address routing issues be developed and applied to the program. In this regard, DOE is using a decision model tool that Sandia National Laboratories has developed as part of the routing criteria development work underway with State regional groups and the TEC Working Group. In addition, ONT provided training on RADTRAN, TRAGIS, and the decision model for State officials in January. These analytical tools are being provided to State and Tribal decision makers and staff for their use as we work together to develop regional suites of routes for the OCRWM shipments. The next TEC meeting will have several smaller workshops to allow participants to become more familiar with the routing decision model.

COMMENT

Tribal groups may not be adequately represented in the deliberations establishing routing criteria and recommending preferred routes.

RESPONSE

DOE is sensitive to the needs of Tribal governments and it is our intention to work with Native American Tribal governments on a government-to-government basis to identify their preference for consultation and coordination. We expect to initiate visits to Tribes potentially impacted by future shipments to Yucca Mountain to discuss issues regarding emergency preparedness, information exchange, and coordination with their technical staff or leadership.

In addition, the TEC Working Group Tribal Issues Topic Group is an important resource for developing approaches to interacting with Tribes and discussing issues such as routing, emergency planning and funding, and security. Established in 1998, the Topic Group addresses government-to-government consultation between DOE and Tribes affected by its transportation activities, and has active tribal participation, which we expect to expand.

PROGRAM INTEGRATION

COMMENT

The DOE presentations did not demonstrate the degree of program integration needed to ensure the transportation system will operate successfully. DOE needs to plan for and be able to demonstrate harmonization of cask design, fleet acquisition, waste acceptance and operational practice, and other activities that must be carried out at reactor sites, during shipping, and at the repository. The Board looks forward to further discussion of program integration in future meetings.

RESPONSE

We will be happy to present the status of program integration activities at the next Board meeting. We look forward to further discussion. We believe that the systems are fully integrated because of ongoing work with the repository on cask acquisition, rail interface, and cask handling requirements for repository site operations. Cask integration meetings are held regularly to integrate the repository's operating needs with the design of transportation casks. Integration of aging cask designs with transportation cask designs is another area of integration between transportation and the repository design effort. ONT is also working with OCRWM's waste acceptance organization on transportation interfaces with the utilities. These interfaces address facility capabilities that affect cask and rolling stock specifications and operating plans.

Department of Energy
Washington, DC 20585

QA:NA

March 31, 2005

B. John Garrick, Ph.D.
Chairman
Nuclear Waste Technical Review Board
2300 Clarendon Boulevard
Arlington, VA 22201-3367

Dear Dr. Garrick:

I have appreciated the interactions we have had to date on the Yucca Mountain project. I want to be responsive to the Board's requests and continue to address your concerns. In that light, I have been "clearing the deck" of old correspondence. I realized we had still not replied to some of the issues contained in your November 30, 2004 letter. As you know, we previously responded to your transportation issues.

The enclosure addresses particular areas of your November 30, 2004, letter which I think are important for us to provide additional information.

Again, my apology for not responding sooner. I look forward to our future discussions.

Sincerely,

Theodore J. Garrish
Deputy Director
Office of Civilian Radioactive
Waste Management

Enclosure

Enclosure

Systems Integration and Stress Corrosion Cracking of the Titanium Drip Shield

The Department agrees with the Board's assessment of the importance of systematic integration and assessment of waste management activities to optimize the system as a whole and, in particular, the relationships between science and engineering. We were pleased to be able to discuss our two-tiered approach to systems integration and analysis at the Board's Winter Meeting. The upper-tier approach, known as the total system model (TSM), was initiated in early fiscal year (FY) 2004 while the lower-tier approach, known as throughput modeling, was started around the middle of FY 2004.

The TSM is a high-level model created to help estimate the logistic and cost impacts of various operational scenarios in acceptance, transportation, handling and emplacing of radioactive wastes. The TSM tracks waste shipments from the waste generating and storage sites through emplacement within the repository at Yucca Mountain, Nevada. Waste forms currently modeled in the TSM are commercial spent nuclear fuel (SNF), the Department's SNF, and defense high-level waste. The TSM also provides logistic information regarding the Civilian Radioactive Waste Management System, including information relative to the waste stream movement and the system resources (casks and their carriers) required to accomplish that movement. The lower-tier work is a suite of detailed models and studies, known generically as throughput models, and is focused on the throughput capability of each of the individual waste handling facilities at Yucca Mountain, Nevada.

The integration of the upper-tier TSM with the lower-tier throughput models helps represent the existing state of design. In the future, as these models are refined and enhanced, the TSM will support the waste management and related strategies; and the throughput models will support facility development and optimization.

Changes in engineering design or operations that have a potential to affect postclosure performance are and will be evaluated before they are formally incorporated in the baselined design. Postclosure impacts of potential changes in design and operations will be partially evaluated through preliminary sensitivity analyses by using the Total System Performance Assessment before moving forward with final design specifications. Such sensitivity analyses have been performed in the past and will be conducted using the LA design and models as appropriate. The Yucca Mountain Project (Project) activities, such as performance assessment and repository design, are carried out in accordance with a rigorous change control process to ensure integration.

At the Board's Winter Meeting, we briefly discussed Stress Corrosion Cracking (SCC) of titanium drip shields and consequences of the SCC. These topics are more fully addressed in the Project document, "Stress Corrosion Cracking of the Drip Shield, the Waste Package Outer Barrier, and the Stainless Steel Structural Material" (ANL-EBS-MD-000005, Revision 02). The model assumes that the drip shields will be subject to rockfall-induced residual stresses and will undergo SCC, independent of the environment, if the residual stresses exceed specified thresholds (50 percent of the yield stress). The report addresses the basis for the plugging of the cracks by mineral deposits and the role of capillary forces in

preventing liquid from penetrating the cracks. It concludes that the likelihood of conditions conducive to SCC of the drip shield occurring in the Yucca Mountain repository is thus extremely small.

As you noted, issues related to SCC need to be addressed within the context of other corrosion tests carried out in environments that closely approximate the conditions to which Alloy 22 and titanium will be exposed and in environments that reasonably bound those conditions. In its response to the Board's letter of July 28, 2004, OCRWM discussed corrosion testing environments and likely waste package environments in the repository. The projected range of environments that could be present on the waste package and drip shield surfaces represents a heterogeneous matrix that will vary with time as the in-drift temperature and relative humidity change.

The likely concentrated brine environments and their expected frequencies and uncertainties have been calculated based on modeled repository-relevant seepage waters and the modeled behavior of soluble species in dust deposits. Although the frequency of different types of brines was not addressed at the May 2004 meeting, the results were recently documented. Because ranges of geochemical and thermal-hydrologic conditions are possible, there is a range of brine environments that could form on the waste package surface, depending on temperature, relative humidity, and the presence of intact drip shields. For the expected case, with the drip shield function intact, expected brines are of the sodium nitrate, potassium nitrate, sodium chloride, or calcium nitrate types. Dust samples collected in the tunnels at Yucca Mountain have been analyzed and grouped to summarize the types of deliquescent brines that could form. Only a few of the dust samples analyzed indicate that a calcium nitrate type brine could form. Deliquescent brines cover a pH range from approximately 6 to 12, depending on brine type and the CO_2 partial pressure. The associated chloride concentration varies from 1 to 8 molal and decreases with increasing relative humidity. Dissolved fluoride concentrations vary from approximately 10^{-6} molal to 0.3 molal, depending on the individual brines. The nitrate concentrations are greater at lower relative humidity (higher temperature) and decrease at lower temperature (increasing relative humidity). As a result, the nitrate to chloride molar ratio will vary from approximately 0.4 to 26; i.e., into the beneficial range where nitrate acts as a localized corrosion inhibitor.

Currently, work is underway to evaluate the following:

- The amount and composition of dust on waste packages as well as the volume of brine and quantities of dissolved salts, and assess the significance of any acid-gas volatilization.
- Assess the deliquescence-related properties of ammonium salts.
- Study the effects of chloride-containing silicate minerals or minerals containing hydroxide, which can be replaced by chloride.
- Document the screening argument(s) for exclusion of localized corrosion of the waste package outer barrier due to the deliquescence of dust constituents.

As mentioned earlier, past and currently ongoing corrosion tests encompass the range of these predicted environments.