Department of Energy
Washington, DC 20585

QA: NA

May 5, 2006

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

Dear Dr. Garrick:

Thank you for your December 19, 2005, and March 6, 2006, letters providing the Nuclear Waste Technical Review Board's (Board) comments on the information presented by the U.S. Department of Energy at the Board's meetings on November 8-9, 2005, and February 1, 2006, respectively. Our responses to each of the Board's letters are enclosed.

We appreciate the opportunities to inform the Board of the progress of the Civilian Radioactive Waste Management Program. The Department continues to benefit from the constructive views of the Board, and we look forward to further dialog on the repository and related issues.

Sincerely,

Paul M. Golan
Principal Deputy Director
Office of Civilian Radioactive
Waste Management

2 Enclosures

ENCLOSURE 1

U.S. DEPARTMENT OF ENERGY RESPONSES TO THE DECEMBER 19, 2005, LETTER FROM THE NUCLEAR WASTE TECHNICAL REVIEW BOARD

Program Overview

The Board emphasized the need for close coordination and cooperation with the utilities to ensure compatibility of the transportation, aging, and disposal (TAD) canister design(s) with the fuel loading facilities at reactor sites. The Department agrees and activities are ongoing to develop a performance specification for the TAD canister which involve interactions between the Department and the nuclear industry. The Department will consider preclosure operations, handling, transportation, aging, and postclosure performance in development of the specification.

The Department agrees that the thermal management strategy must be clearly defined to provide the technical basis for waste acceptance, transportation, waste handling, and waste emplacement. Postclosure near-field and in-drift conditions affecting performance of the engineered and natural barriers are being addressed in the postclosure elements of the thermal management strategy. This includes the thermal decay characteristics of the waste and temperature limits at key locations such as the waste package wall and drift wall. The Department will consider the Board's recommendation for external review of the TAD canister system development.

Science Update

The Department agrees that post-test characterization, especially of longer term *in-situ* tests, can provide valuable and insightful information leading to refinement of process models and reduction of uncertainty. Regarding the Drift Scale Test and the moisture-monitoring activity behind the bulkhead in the Enhanced Characterization of the Repository Block (ECRB), technical work plans are being developed for post-test characterization activities. For the Drift Scale Test, near-term activities include re-entry, retrieval of sample materials, collection of additional samples, and photography. Longer term activities will include coring, rock-bolt pull tests, and investigation of spalling at the drift crown. The objectives for these activities include better understanding of thermal-hydrologic-chemical-mechanical effects on repository performance. Evaluation of the ECRB bulkhead moisture data is planned for fiscal year 2007 to better understand the impact of seepage and condensation processes that occur in the near-field and host-rock.

The Department appreciates the Board's continued support of ongoing scientific investigations by the Office of Science and Technology and International (OSTI). These investigations are focused on evaluating the representation of conservatism in natural barrier system contributions to waste isolation and repository performance. For example, scientific studies at the Peña Blanca natural analog site have yielded valuable data on seepage in unsaturated tuff.

The Department agrees that host-rock thermal conductivity is a key rock property affecting the prediction of thermal-hydrologic conditions in the repository. From sensitivity analyses performed using the Multiscale model [*Multiscale Thermohydrologic Model (ANL-EBS-MD-000049, REV 03)*, Section 8.1], host-rock thermal conductivity and percolation flux are identified as the two principal natural-system parameters affecting peak temperatures and boiling duration. Other model parameters, such as waste package proximity to the edge of the repository layout, are also important.

The *in situ* measurements of thermal conductivity were acquired for the purpose of validating the geostatistical model used to calculate the bulk thermal conductivity of repository units. The model has been developed based on site-specific data including geophysical well logs, physical property measurements on rock cores from surface boreholes, and laboratory thermal conductivity measurements. Because a sequential Gaussian simulation is used, the model provides an appropriate representation of the spatial variability and uncertainty of the underlying data, especially the key input parameters (i.e., matrix thermal conductivity and lithophysal porosity). Both parameters contribute to the spatial variability and uncertainty in the model results, though the dominant influence is from matrix thermal conductivity. Whereas *in situ* tests are useful in evaluating the effects of discontinuities such as lithophysal cavities, laboratory tests are used to measure matrix thermal conductivity, the dominant contributor to spatial variability and uncertainty.

The *in situ* test results are not part of the basis for spatial variability and uncertainty in the model results. The reason is that *in situ* tests by their nature (and cost) cannot be performed over nearly as broad a range of spatial distribution and stratigraphic facies as can be performed using geophysical well logs and core samples. Thus, additional *in situ* tests would not be a practical way to improve the model treatment of spatial variability and uncertainty.

The *in situ* thermal conductivity test results are point measurements that corroborate the geostatistical model. All test results are within the range of values derived from the model. One of the test results is slightly above 1.5 standard deviations of the model-derived mean and the others are within 1 standard deviation. Additional confidence in the model is gained by the validation of methods and models used to estimate matrix thermal conductivity, lithophysal porosity, matrix porosity, and bulk density. The latter two are used to estimate the former two, which are used to obtain bulk thermal conductivity. The Department believes that an acceptable level of model validation has been achieved; and, while potentially useful, further *in situ* thermal conductivity tests are not necessary for this purpose.

The Department shares the Board's view that fundamental understanding of the source term including oxidation, dissolution, and transport is important for predicting repository performance. Current models of these processes provide an adequate level of this understanding for regulatory total-system dose assessment, but the Department plans to continue OSTI investigations in this area for possible future use.

The OSTI Source-Term Thrust Area is dedicated to scientific studies relevant to spent nuclear fuel (SNF) and nuclear waste glass and the critical processes within the waste package and drifts that affect potential radionuclide release from the waste forms and from the engineered barrier

system. This program is focused on developing a basic understanding of the fundamental mechanisms of radionuclide release and a quantification of the release as repository conditions evolve over time. The Thrust Area is an integrated set of about 15 research projects involving multiple national laboratories and universities, as well as international collaboration. These projects focus on (1) dissolution mechanisms and rates for SNF, (2) formation and properties of secondary uranyl phases, (3) waste-form and waste-package interactions, and (4) modeling studies to synthesize the understanding of the chemical and physical processes. Integration of the research in this area will be ongoing throughout its progress to determine how the information developed could be used for the Yucca Mountain Project.

There are two ongoing activities related to analyses of Cl-36. The first activity documents the work on the Cl-36 validation activities performed by Lawrence Livermore National Laboratory, U.S. Geological Survey, and Los Alamos National Laboratory that have previously been presented to the Board. A draft report is in review.

The second activity is an independent study of Cl-36 conducted under a Cooperative Agreement between the Department and the University and Community College System of Nevada (UCCSN). The UCCSN scientists collected samples from the Exploratory Studies Facility in 2005, investigated experimental techniques, and started testing rock samples in 2006.

Drip Shield Design

The Department agrees that it is important to evaluate factors that will influence the final drip shield design well in advance of repository closure. The Department plans to fabricate prototype drip shields to evaluate operational envelopes and design and installation tolerances in the performance confirmation drifts.

Localized Corrosion of the Waste Package

The Department has noted the Board's continued concern regarding screening out from the Total System Performance Assessment (TSPA) localized corrosion initiated by deliquescent brines formed at high temperatures (160°C – 220°C) from airborne dust deposited on the waste package surfaces. We reiterate that the initiation of localized corrosion of Alloy 22 by brine from deliquescent salts has been excluded on the basis of low consequence.

Although the possibility of multisalt deliquescent brine formation at elevated temperatures in the repository does exist, studies show the brines would not be stable due to acid degassing (see *Screening of Features, Events and Processes in Drip Shield and Waste Package Degradation [ANL-EBS-PA-000002 REV 02]* and *Analysis of Dust Deliquescence for FEP Screening [ANL-EBS-MD-000074 REV 01]*). As acid degassing occurs, typically rapidly at first, the pH increases to near-neutral or alkaline values. Further degassing can result in dryout, producing an assemblage of less-deliquescent salts that yield a higher pH solution (decreasing the likelihood of localized corrosion initiation) when redeliquescence occurs. In addition, the presence of carbonate anions, as well as nitrate anions, inhibit the initiation of localized corrosion on Alloy-22. The limited volume of brine and retention of brine by capillarity in the dust assemblage would also inhibit localized corrosion initiation on dust-covered surfaces. Furthermore, analysis shows that even if localized corrosion initiates, the corrosion products

formed would consume some of the aqueous brine phase, thus limiting local corrosion propagation. It is on the bases of the overall analysis, as documented in the referenced reports, that localized corrosion due to dust deliquescence has been excluded from the TSPA.

In further support of the dust deliquescence analysis, the Department is in the process of investigating stifling at higher temperatures (i.e., under dust deliquescence exposure conditions), including the effects of limited availability of reactants. The tests will use methods intended to address the relationship between the amount of dust containing deliquescent salts on the waste package surface and the extent of damage that may occur.

The recent high-temperature corrosion data and their applicability can be discussed at the upcoming corrosion workshop.

Total System Model

The Department is pleased that the Board believes that the Total System Model (TSM) has significant potential for simulating and understanding the performance of the waste management system. The Department is prepared to support additional interactions with the Board to further understanding of the capabilities and limitations of the TSM in conducting probabilistic assessments, optimizing the waste management system, and analyzing "what if" operational scenarios.

The results of TSM analyses were used to inform the Department regarding the decision to evaluate a primarily canister-based system using TADs for commercial SNF. Insights from the TSM analyses included, but were not limited to, factors such as dose, thermal management, and waste handling.

Additional TSM analyses are currently underway to support the development of a recommended design solution as part of the Departmental process for formally evaluating and approving the change in technical baseline from a primarily bare fuel handling approach to a primarily canister-based approach. Documentation of these additional TSM analyses is scheduled for completion this summer.

The Department recognizes that information obtained from the utilities is important to the quality of the TSM analyses and success of the primarily canister-based approach. In January 2005, the Department completed a voluntary survey of all reactor operators to gather updated site-specific data, e.g., their respective capabilities to load and transport SNF needed for planning transfer of SNF from each reactor site to the waste management system. Approximately 75 percent of the site operators responded.

The Department has also provided information on the new approach to the cask vendors and nuclear utilities and is evaluating technical issues related to development and licensing of TADs raised by cask vendor and utility representatives. The Department is committed to continuing the close coordination with cask vendor and utility representatives, not only in the development of the performance-based specification for TADs, but also in the subsequent design of the TADs.

Conservatism in the Total System Performance Assessment for the License Application

The Department's approach to the TSPA reflects international experience, Nuclear Regulatory Commission (NRC) staff perspectives, and unique challenges of modeling transport in partially saturated fractured rock. The Department believes that the performance assessment supporting the postclosure compliance analyses is reasonable for this application and has been developed cautiously. However, we recognize the Board's perspective that some aspects of the model might be considered unrealistic. Because the approach that the Department is using for postclosure performance assessment has evolved over many years through interaction with NRC staff, and is reflected in the Yucca Mountain Review Plan, it is an integral part of our approach to the license application. The Department is currently undertaking development of a best-estimate total system performance assessment. This best-estimate analysis would be used (1) as a management and communication tool, (2) to build confidence in the estimate of repository performance in the compliance-based analysis, and (3) to quantify and help understand the degree of overall conservatism in the TSPA. We believe this will help to address directly the Board's concerns.

ENCLOSURE 2

U.S. DEPARTMENT OF ENERGY RESPONSES TO THE MARCH 6, 2006, LETTER FROM THE NUCLEAR WASTE TECHNICAL REVIEW BOARD

New Organization

The Department recognizes your interest in the restructuring of the Office of Civilian Radioactive Waste Management (OCRWM) organization. OCRWM is being reorganized to create a more project-focused approach in the accomplishment of its critical mission. The organizational changes are designed to improve and streamline the structure and processes to more effectively manage the Program through the design, licensing, construction, and operations phases. It should be noted that while the managers of functional responsibilities report to the Director, significant responsibilities will be delegated to the managers. It is the Director's role to hold each manager accountable; accountability is critical for any organization, any program, or any system to be successful.

Realistic Analysis of Repository Performance

The Department is currently undertaking development of a best-estimate Total System Performance Assessment (TSPA) that will allow it to investigate conservatism in the component models and build confidence in the postclosure compliance analyses. It is, however, important to recognize that the process models the Department has developed are consistent with information available at the time the models were completed. Some of these models are based on scientific understanding developed over two decades. In the face of large uncertainty or alternate conceptual models, the Department and its contractors will continue to use a "cautious, but reasonable" approach for postclosure compliance analyses to assure that the predicted risk (i.e., the dose to the reasonably maximally exposed individual) is not underrepresented and is not inappropriately diluted.

The Department has experience in evaluating repository performance over the period of peak dose, having done such analyses for the viability assessment, the site recommendation, and the final environmental impact statement. Recent postclosure performance assessment activities and modeling have focused primarily on a 10,000-year compliance period. The Department plans to conduct postclosure performance assessment analyses over the period of peak dose in accordance with final regulations, once they are promulgated.

Radionuclide Transport

The Department considers there to be ample information regarding the processes affecting the rate of transport under a range of environmental conditions that are expected in the waste package and the invert. As noted in the presentations, this transport is a function of the mode of degradation of the waste package and the expected environmental conditions, both of which are uncertain. Treatment of this uncertainty has been appropriately included in the models affecting source term releases as presented to the Board. The Department agrees, however, that there is benefit in continuing research in this area to enhance the understanding and evaluate the

representativeness of the current results under a reasonable range of repository-relevant conditions. These conditions could be affected by the introduction of the transportable, ageable, and disposable canister concept.

The forms of ^{237}Np and ^{242}Pu expected to exit the Engineered Barrier System (EBS) were discussed in the February meeting. The form of ^{237}Np is a dissolved radionuclide transported by either diffusive or advective processes through the EBS and into the host rock. The form of transported ^{242}Pu is both dissolved and colloidal. As presented in the meeting, the significance of these different forms depends on the particular scenario class and the antecedent degradation conditions of other elements of the EBS (notably the waste package and drip shield) and the waste form type (i.e., high-level waste glass or commercial spent nuclear fuel). The Department welcomes additional discussion on this subject in the future to ensure the Board's questions and concerns are adequately addressed.

Sensitivity of Dose Results to Different Models

The presentation by Dr. Michael T. Ryan was focused on dose models, in particular biokinetic and dosimetric models. For a given intake of radionuclides, these models determine the expected dose. These models generally reflect well accepted dose transfer coefficients published by such bodies as the International Commission on Radiological Protection (ICRP) and the National Council on Radiation Protection and Measurements (NCRP). While these organizations recognize the large uncertainty of such models, they are widely used and accepted by regulatory bodies and agencies that implement the ICRP and NCRP recommendations; i.e., the U.S. Nuclear Regulatory Commission and the U.S. Environmental Protection Agency (EPA). The difference in inhalation and ingestion dose is in part affected by the biokinetic and dosimetric models mentioned above and other assumptions related to the biosphere. The Department is, as noted previously, currently undertaking development of a best-estimate TSPA that will allow it to assess conservatism in component models such as dosimetric analyses, and we look forward to interactions with the Board on how best to address this issue.

Natural Correlations of Parameters

The Department considers the range of possible advective transport times to be consistent with the range of observations presently available and reasonably represents the current state of knowledge of unsaturated and saturated zone transport. For example, these observations include potentially disparate findings of carbon-14 ages in perched water zones in the unsaturated zone of greater than 10,000 years and possible "bomb-pulse" (less than about 50 years) chlorine-36 observations in samples taken from the Exploratory Studies Facility. This range is reasonably and appropriately captured in the unsaturated zone transport model presented to the Board.

The inferred decoupling of seepage and percolation identified in the Board's comments reflects the assumptions made in the analysis presented in the February 1, 2006, meeting. In the case of the seepage sensitivity analysis, the assumptions associated with whether the drifts were collapsed or not were significantly different. This results in a significant difference in the likelihood and amount of seepage expected. The percolation sensitivity analysis was applied only to the case where the drifts were assumed to have collapsed. In this case, over the range of different percolation values investigated, the resulting differences in seepage amount did not significantly affect the rate of release of dissolved radionuclides because of the range of

solubility values used in the analysis. This result and observation is discussed in the report that the Department submitted along with the comments to EPA on the proposed rule. Again, the Department welcomes additional discussion with the Board to explain better its perspectives on the correlations.

Compliance Period

The Department is focused on the technical adequacy of the data, parameters, analyses, and models regardless of the time period for the compliance analysis. The Department is also focused on understanding the impact of uncertainty on the results of the relevant analyses and models that support the compliance evaluation and continues to apply the "cautious, but reasonable" philosophy recommended by the National Academy of Sciences and the regulatory guidance contained in the applicable regulations. In addition, as noted above, we are currently undertaking a best-estimate TSPA to build confidence in the estimate of repository performance in the compliance-based analysis and to quantify the degree of overall conservatism in the TSPA.