

Appendix E

Communications Between the Board and the OCRWM

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 four letters written during calendar year 2000 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 2000. Inclusion of these responses does not imply the Board's concurrence.

Letter from Chairman Jared L. Cohon to Lake H. Barrett, Acting Director, OCRWM; November 10, 1999.
Subject: Board's reactions to presentations at September 1999 Board meeting.

Letter from Ivan Itkin, Director, OCRWM, to Chairman Jared L. Cohon; January 14, 2000.
Subject: The DOE's response to November 10, 1999, Board letter.

Letter from Chairman Jared L. Cohon to Wendy R. Dixon, EIS Project Manager, Yucca Mountain Site Characterization Office; February 7, 2000.
Subject: The DOE's proposed environmental impact statement for a geologic repository at Yucca Mountain, Nevada.

Letter from Chairman Jared L. Cohon to Ivan Itkin, Director, OCRWM; March 20, 2000.
Subject: Quantification of uncertainties in performance characterization.

Letter from Chairman Jared L. Cohon to Ivan Itkin, Director, OCRWM; March 20, 2000.
Subject: Board's reactions to presentations at January 2000 Board meeting.

Letter from Ivan Itkin, Director, OCRWM, to Chairman Jared L. Cohon; June 6, 2000.
Subject: The DOE's response to March 20, 2000, Board letter about January 2000 Board meeting.

Letter from Chairman Jared L. Cohon to Ivan Itkin, Director, OCRWM; June 16, 2000.
Subject: Board's reactions to presentations at May 2000 Board meeting.

Letter from Chairman Jared L. Cohon to Ivan Itkin, Director, OCRWM; September 20, 2000.
Subject: Board's reactions to presentations at August 2000 Board meeting.



UNITED STATES
NUCLEAR WASTE TECHNICAL REVIEW BOARD

2300 Clarendon Boulevard, Suite 1300
Arlington, VA 22201-3367

November 10, 1999

Mr. Lake H. Barrett
Acting Director
Office of Civilian Radioactive Waste Management
U.S. Department of Energy
1000 Independence Ave.
RW-2/5A-085
Washington, DC 20585

Dear Mr. Barrett:

As has become customary, I am writing to give you the Board's reactions to information presented by the DOE at the Board's latest meeting, which was held in Alexandria, Virginia, on September 14-15, 1999.

Board members uniformly feel that the meeting was very productive. This outcome was due, in large part, to the participation by the DOE and its contractors. The Board was pleased with the efforts of your team to develop presentations that addressed specific Board issues and concerns. The presentations were of high quality, well-integrated, and tightly focused. DOE and contractor staff responded to the Board's questions in an open and informative fashion.

The Board encourages the DOE to continue important work in three areas. First, the DOE should complete its latest revision of the repository safety strategy. This document can establish a critical foundation for explaining to both policy-makers and members of the general public how a repository at Yucca Mountain might function, for prioritizing investigations, and for developing a licensing safety case. Second, the DOE should continue pursuing experiments in the east-west cross drift aggressively. These studies can produce important data about seepage into the drifts and flow in the unsaturated zone, variables that strongly influence repository performance. Finally, the Board realizes that the DOE is making progress in evaluating new designs for the waste package and the engineered barrier system. For example, corrosion testing has produced important information about the degradation rates of Alloy 22. This work needs to be sustained into the future because it supports a central premise of the repository safety case.

The Board would like to communicate to the DOE the following specific thoughts about some of the topics that were addressed at the meeting.

Repository Safety Strategy

Previously the Board stated that an appropriate repository safety strategy consists of an assessment of projected repository performance, design margin and defense-in-depth, consideration of disruptive processes and events, insights from natural or man-made analogs, and a performance confirmation plan. The Board is pleased, therefore, that the DOE is revising its repository safety strategy along these lines in light of new information collected and changes in repository design adopted since the viability assessment was completed. In particular, the Board is encouraged by the importance attached to demonstrating defense-in-depth. Barrier importance analysis seems to be a promising vehicle for describing how much defense-in-depth is available within a repository system. The Board, however, believes that this methodology needs to be refined further before valid conclusions can be drawn about defense-in-depth.

According to the presentations at the meeting, the DOE plans to focus on seven "principal factors." These factors apparently will strongly influence what investigations will be conducted during the next two years. Moreover, these factors apparently will be the key variables for upcoming performance assessments; other, less important, influences on repository performance may be only bounded. Given the importance assigned by the DOE to these factors, it is essential that their selection be based on rigorous technical analyses that are clearly presented and supported with as much empirical data as possible. The DOE also will need to consider carefully whether bounding other, less important, variables is appropriate. Unless the DOE can support its choice of principal factors and its use of bounding analysis, making the repository safety strategy technically persuasive will be difficult.

Model Validation

As DOE's presentations and our subsequent roundtable discussion revealed, the technical defensibility of a mathematical model of complex and only partially observed physical processes can sometimes be a matter of degree. In some situations, however, particularly under conditions beyond those for which calibration data are available, the model's inadequacies may clearly and unequivocally render it invalid. The use to which the model will be put may affect the standard by which technical defensibility is judged. For example, a model like TSPA that is used to guide decision-makers carries a higher burden of defensibility than a model that is used by field investigators to gain detailed process-level understanding and to guide a discrete and limited field sampling program.

On the basis of the DOE presentations, the Board is concerned that significant issues associated with model validation may not be examined adequately by the time the final site recommendation report is currently scheduled to be sent to the President. Among the questions the Board believes that the DOE needs to address in a technically defensible way are the following.

- Have sufficient data been collected to test and to evaluate adequately alternative process-level models?

- To what extent will multiple and independent lines of evidence, including natural analogs, be marshaled to test a model's validity?
- What will be the basis for judging a model's validity over long periods of time when the model was calibrated using short-term data?
- How will external peer review be used in the validation process?
- How will the validity of the overall performance assessment be judged in relation to the validity of the individual process models?

Answering these questions is admittedly challenging. Nonetheless, the Board feels that providing policy-makers, the technical community, and the general public with well-developed responses to the questions is essential for developing a credible site recommendation report.

Treatment of Uncertainty

As you know, the Board has a long-standing interest in how the DOE analyzes and presents the inherent uncertainty that will surround its performance assessments. The Board realizes that the DOE will have to follow applicable regulations and regulatory guidance when it presents its performance assessment findings in the context of a license application. The DOE has significantly more discretion, however, in how it treats uncertainty in the site recommendation report. In particular, the Board believes that the DOE has an important obligation to present its technical analyses in a way that gives policy-makers in the executive and legislative branches as well as interested members of the general public a clear understanding of the uncertainties involved in projecting the performance of a repository at Yucca Mountain.

The Board will be devoting a significant part of its upcoming meeting in January to how uncertainty can be analyzed and presented. Among the topics that will be considered are the following.

- The different kinds of uncertainty and how they can be treated
- Displaying uncertainty in a manner that best communicates its nature and extent
- Alternative ways of incorporating and considering uncertainty in decision-making.

After the January meeting, the Board will provide you with additional views on the evaluation and description of uncertainty.

Modeling Results and Technical Investigations

The Board wants to comment on two presentations. The presentation dealing with the model of seepage flux into a repository drift concluded tentatively that seepage in drifts constructed in the middle nonlithophysal zone would not occur unless the percolation flux exceeds 1000 mm/year. This conclusion is an extremely important one, but as acknowledged in the technical analysis, it is highly dependent on assumptions about the shape of the drift and

about its long-term structural integrity. The Board will be looking closely at this model and will comment in greater detail about its appropriateness for inclusion in forthcoming performance assessments.

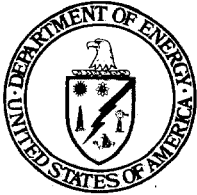
The presentation on waste package degradation indicated that valuable information is being collected on Alloy 22 at a rapid pace. However, concern still exists about the effects on corrosion of radiolytic species, including species formed in the vapor phase. Resolving that concern may necessitate additional experimental and theoretical work. In addition, in the last year or two, the project has done a significant amount of work to determine, or at least to bracket, the entire range of chemical compositions and temperatures that could exist in water films on waste package surfaces. It is important that the DOE's suite of corrosion tests continues to be performed in environments that approximate that range. Finally, the information needed to evaluate the adequacy of the new drip shield design is still fragmentary. The DOE has not established the technical foundation for the performance claims it is making for this element of the engineered subsystem.

In closing, I would like to repeat the Board's view that the DOE team's efforts made the Board's September meeting highly productive.

Sincerely,

{Signed by}

Jared L. Cohon
Chairman



Department of Energy
Washington, DC 20585

January 14, 2000

JAN 24 2000

Dr. Jared L. Cohon
Chairman
Nuclear Waste Technical Review Board
2300 Clarendon Boulevard
Arlington, Virginia 22201-3367

Dear ~~Dr. Cohon~~ *Jerry*

Thank you for your letter of November 10, 1999, providing the Board's perspective on the information presented by the Department at the September 14-15, 1999, Board meeting. We appreciate your compliments on the integration and quality of the presentations.

Your letter encourages the Department to continue important work in three areas: completing the latest revision of the repository safety strategy, testing in the cross drift related to seepage into drifts and flow in the unsaturated zone, and evaluating the new designs for the waste package and the engineered barrier system. We agree with the Board and are pursuing high priority work in these three areas. Revision 3 of our repository safety strategy was completed earlier this month. The next revision of the strategy will define the safety case for site recommendation. This revision will be traceable to the total system performance assessment and process model reports that support the site recommendation consideration report. In addition, we continue to test in the east-west cross drift and to evaluate and test new design concepts for the waste package and the engineered barrier system.

Your letter also raises two important issues related to analyzing repository performance: how to analyze and clearly present the uncertainties involved in our projections of repository performance and how to ensure the defensibility of the models we use to assess the overall performance of the repository system. We agree that both issues will be important in developing a credible basis for site recommendation and look forward to further interaction with the Board as we continue developing the appropriate methods to address them.

The Department appreciates the timely feedback from the Board as we proceed towards a decision on a site recommendation. Our responses to the Board's specific issues are provided in the enclosure. If you have any questions, please contact me at (202) 586-6842.

Sincerely,

A handwritten signature in black ink, appearing to read "Ivan Itkin".

Ivan Itkin, Director
Office of Civilian Radioactive
Waste Management

Enclosure

**Department of Energy's Responses to the
November 10, 1999, Letter from the
Nuclear Waste Technical Review Board**

Repository Safety Strategy

- *The Board ... believes that this methodology [for barrier importance analysis] needs to be refined before valid conclusions can be drawn about defense-in-depth.*

The Department believes the preliminary barriers importance analyses conducted for the enhanced system design have provided valuable insights into the way the system performs, and the roles and contributions of the various natural and engineered barriers. These analyses, which involved the neutralization of barriers and processes, were based on the models developed for the Viability Assessment, with appropriate adjustments to reflect revisions to the design. The results were considered in the process of identifying the principal factors for the postclosure safety case described in Revision 3 of the Repository Safety Strategy. The Department is aware of the limitations in these neutralization analyses and intends to refine the method before using it with the updated total system performance assessment models being developed to support site recommendation. The refined method for neutralization analyses, and possibly other methods, will be employed to examine system performance and draw conclusions about the contributions of the various barriers and the degree of defense-in-depth provided by the updated design. The refined evaluations of the performance of key barriers will be documented in the next revision of the Repository Safety Strategy and will be fully traceable to the total system performance assessment documentation for site recommendation.

- *Unless the DOE can support its choice of principal factors and its use of bounding analyses, making the repository safety strategy technically persuasive will be difficult.*

As the Department noted in the September Board meeting, the selection of principal factors is a work in progress. The proposed principal factors discussed in Revision 3 of the Repository Safety Strategy were selected using professional judgment of the principal investigators, existing sensitivity studies, and insights from preliminary barrier importance analyses. This revision of the Repository Safety Strategy provides the rationale for the selection of the seven principal factors for the postclosure safety case. The next revision of the Safety Strategy will be based on the documented results from the total system performance assessment that is being conducted to support site recommendation, including information from the supporting Analysis and Model Reports and Process Model Reports. These results will provide the technical basis to confirm or revise the set of principal factors for the postclosure safety case for site recommendation, and for the work to be done to enhance the safety case for licensing.

The Department agrees that if bounding analyses are used in the evaluation of system performance, they must be technically sound and defensible. The Department plans to develop models and conduct analyses that are as realistic as possible, given the data that are available. In some instances, use of conservative or bounding analyses may be the only credible approach. In other instances, sensitivity studies conducted for site recommendation may indicate that performance is relatively insensitive to certain models or processes. In such cases, it may be appropriate to use a conservative or bounding approach in licensing to facilitate a focus on those aspects of system performance that are the most important to the findings that need to be made. Revision 3 of the Repository Safety Strategy identifies possible candidates for such simplification. Sensitivity studies conducted for site recommendation will be used to confirm or revise this list of candidates.

Model Validation

- *Significant issues associated with model validation may not be examined adequately by the time the final site recommendation report is scheduled to be sent to the President.*

The Department's goal is to establish adequate confidence in the relevant models by the time the site recommendation report is completed to support a decision by the Secretary. Validation is a process used to provide confidence that a conceptual model, as represented in a corresponding mathematical model, software, or analysis, adequately represents the phenomenon, process, or system being modeled. As the Department noted in the September meeting, the goal of model validation as defined by our quality assurance program is to establish the adequacy of the scientific basis for a model and to demonstrate that this basis is sufficiently representative for its intended purpose. The level of confidence required for a specific model is tied to the importance of that model to the safety case for the decision at hand. One goal of the Repository Safety Strategy has been to identify the elements of the repository system that are most important to system performance. This allows ongoing investigations to be focused on these elements and the validation of the models used to represent the performance of these elements.

The Department is validating models by comparison of modeling results to independent lines of evidence from laboratory observations, field observations, analog studies, and alternative models. Peer review panels may be convened to review the model, the underlying assumptions, and the results. Validation is an ongoing process that will continue after site recommendation, if the site is found suitable. The Department plans for additional monitoring and data collection to test our models and enhance confidence in their validity, including testing of phenomena that are calibrated with short-term data.

Treatment of Uncertainty

- *The DOE has an important obligation to present its technical analyses in a way that gives policy-makers ... as well as interested members of the general public a clear understanding of the uncertainties involved in projecting the performance of a repository.*

The Department agrees that it is important to present technical analyses in a way that provides the policy-makers and members of the interested public a clear understanding of the uncertainties in projecting the long-term performance of the potential repository at Yucca Mountain. The Department will discuss its approach to addressing uncertainty in the total system performance assessment for site recommendation during the Full Board Meeting in January 2000. The Department is looking forward to receiving additional feedback from the Board following this meeting regarding its views on how uncertainty can be evaluated and presented.

Modeling Results and Technical Investigations

- *[The tentative] conclusion [regarding the existence of a seepage threshold] is an extremely important one but ... it is highly dependent on assumptions about shape of the drift and ... structural integrity.*

The Department agrees that the concept of a seepage threshold presented in the discussion of the seepage flux model at the September Board meeting is an important one. Recent analysis reported in the Seepage Calibration Analysis and Modeling Report (AMR) has lowered the calculated seepage threshold for the Middle Non-lithophysal unit from 1000 to 200 mm/yr. The Department also agrees that it is important to evaluate the effects of the shape of the drift on seepage, and this work has started and is reported in another AMR entitled, "Seepage Model for PA". Furthermore, the Department will soon start testing the seepage characteristics of the main repository unit, the Lower Lithophysal unit. We are looking forward to receiving feedback from the Board regarding its views on the appropriateness of the model of seepage flux and the concept of a seepage threshold for inclusion in our performance assessment for site recommendation.

- *Concern still exists about the effects on corrosion of radiolytic species, including species formed in the vapor phase.*

With adoption of the new thinner-walled waste package design, the radiation levels at the surface of the waste packages are expected to be higher than for the thicker-walled viability assessment design. To assess potential radiolysis effects, the Department has conducted calculations of radiation levels at various locations within the drift for the new design. These calculations show that the waste package surface radiation dose levels for the bounding case (21-PWR, 75,000 MWD/MTU, 5-year cooled fuel) are less than 3000 rad/hr at emplacement

and decrease to about 260 rad/hr after 50 years. The radiation levels will continue to decrease if the repository is kept open for a longer period. Since the radiation levels required to cause significant enhancement of corrosion for the nickel and titanium alloys that are planned for use in the waste package and drip shield range from 10,000 to 100,000 rad/hr, the potential impact of radiolysis on the corrosion behavior of the new design is expected to be negligible.

Current plans call for forced ventilation of emplacement drifts for at least 50 years after emplacement. With ventilation during preclosure, the relative humidity will be about 20% or lower, which is well below that required for surface films to be generated. During this time, there is little likelihood of forming a water film on the near-field components within the emplacement drifts (e.g., ground support, waste package support structures, and invert materials). Further, any species formed in the vapor phase are not likely to cause a concern if the products cannot condense on the metal surface. The calculated radiation levels on the near-field components are expected to be about 2000 rad/hr or less at emplacement and decrease to less than 200 rad/hr after 50 years. Doses at the rock bolts would be substantially lower. This suggests that the potential for radiolysis enhanced corrosion of near-field structural components or rock bolts is also negligible.

- *The DOE has not established the technical foundation for the performance claims it is making for the drip shield.*

The Department agrees with the Board's view, and has enhanced its ongoing investigations of titanium drip shield performance and the effects of the drip shield on other elements of the engineered system to strengthen the technical basis for the performance of the drip shield. The Department is conducting a broad-based, comprehensive testing program that considers known corrosion mechanisms, as well as examining engineered and natural analogs. The tests focus on the corrosion mechanisms considered to be relevant to expected repository conditions. Accordingly, the work includes testing under service conditions and aggressive conditions in order to develop models for prediction of the long-term performance of the drip shield. Specifics of the testing program were recently provided to the Board (Barrett 1999).

Reference:

Barrett, L.H. 1999. Letter from L.H. Barrett (DOE/HQ) to J.L. Cohon, November 23, 1999.



UNITED STATES
NUCLEAR WASTE TECHNICAL REVIEW BOARD
2300 Clarendon Boulevard, Suite 1300
Arlington, VA 22201-3367

February 7, 2000

Wendy R. Dixon, EIS Project Manager
Yucca Mountain Site Characterization Office
Office of Civilian Radioactive Waste Management
U.S. Department of Energy
P.O. Box 30307, Mail Stop 010
North Las Vegas, Nevada 89036-0307

Dear Ms. Dixon:

The Nuclear Waste Technical Review Board appreciates the opportunity to comment on the Department of Energy's (DOE's) proposed environmental impact statement (EIS) for a geologic repository at Yucca Mountain, Nevada. The Board submits these comments as part of its responsibility under the Nuclear Waste Policy Act, as amended, to evaluate the scientific and technical validity of the activities carried out by the Secretary of Energy and the DOE Office of Civilian Radioactive Waste Management. The Board focuses its comments on the technical quality of the analyses that support the draft EIS. The Board believes that resolution of its comments will improve the estimates of environmental impacts in the final EIS and improve the technical basis for deciding whether to pursue the proposed action described in the document.

The Board's comments on the draft EIS are attached to this letter. Some key comments are:

- The final EIS should be based on an updated repository design and should include the updated performance assessment results that the DOE plans to produce to support a possible recommendation that the site be developed as a geologic repository.
- It is clear that the nature of environmental risks posed by both alternatives, and the uncertainty about those risks, change over time. Tables S-1 and 2-7, which categorize all impacts as either short-term or long-term, should be supplemented by a discussion that explains how the environmental risks of both alternatives progress over time, including the period beyond 10,000 years.
- The specific transportation routes assumed for the analyses of transportation impacts should be identified in the EIS.
- The analyses of the impacts of transportation accidents should include estimates of the environmental impacts associated with cleaning up after any accidents that release radioactive materials to the environment.

- Population data used in the EIS should be updated from the 1990 census figures and should be extrapolated to estimate continued population growth for a reasonable time in the future.
- The EIS should acknowledge the potential for stigma effects near a Yucca Mountain repository or associated transportation routes and should explain why it is not appropriate to include estimates of those possible effects.

The estimates of long-term repository performance for the proposed action of the draft EIS are essentially the same as those used by the DOE to prepare its 1998 Viability Assessment of a Yucca Mountain repository. After reviewing the Viability Assessment, the Board stated its belief that identifying important sources of uncertainty, estimating the magnitude of those uncertainties, reducing critical uncertainties, and evaluating the effects of residual uncertainties on expected repository performance are essential for supporting a technically defensible site-suitability determination. The Board concluded that a significant amount of additional scientific and engineering work will be needed to increase confidence in a site-suitability determination. The Board recommended that the DOE evaluate alternative repository designs that have the potential to reduce uncertainties in projected repository performance, thereby reducing the scope of additional necessary scientific study. Because the draft EIS relies on essentially the same performance assessment capabilities as those used to prepare the Viability Assessment, the Board believes that these conclusions and recommendations are equally applicable to the draft EIS.

The Board believes that neither of the no-action scenarios evaluated in the draft EIS is likely to occur, but the two scenarios do appear to represent the extremes of a spectrum of possible futures. Because the no-action alternative is hypothetical, there may be little merit in attempting analyses of this alternative more sophisticated than those presented in the draft EIS.

Again, the Board appreciates the opportunity to comment on the draft EIS for a Yucca Mountain repository.

Sincerely,

{Signed by}

Jared L. Cohon
Chairman

Attachment:
Comments on draft EIS

U.S. Nuclear Waste Technical Review Board

Comments on the Draft Environmental Impact Statement for a Geologic Repository at Yucca Mountain, Nevada

1. The performance assessment models and data used to project the long-term performance of a Yucca Mountain repository are very similar to those used by the U.S. Department of Energy (DOE) to prepare its 1998 Viability Assessment of a Yucca Mountain repository. The Board has previously commented on the Viability Assessment¹ and those comments would also apply to the draft Yucca Mountain EIS. The DOE intends to refine its models and collect additional data before the final Yucca Mountain EIS is prepared. The Board recommends that the final EIS include the updated performance assessment results that the DOE plans to produce to support a possible recommendation that the site be developed as a geologic repository.
2. It is clear that the nature of environmental risks posed by both alternatives, and the uncertainty about those risks, change over time. Tables S-1 and 2-7, which categorize all impacts as either short-term or long-term, should be supplemented by a discussion that explains how the environmental risks of both alternatives progress over time, including the period beyond 10,000 years.
3. The repository design that was assumed when preparing the draft EIS already has evolved and may change further before the final EIS is prepared. The Board recommends that the final EIS be based on the most advanced design concepts available at the time the final EIS is prepared.
4. The description of the proposed action indicates that active institutional controls (e.g., monitored and enforced limitations on site access) would be applied to the Yucca Mountain site only until permanent closure of the repository has been completed. This seems contrary to the provision of the Energy Policy Act of 1992 that directs the Secretary of Energy to "continue to oversee the Yucca Mountain site to prevent any activity at the site that poses an unreasonable risk . . ." The oversight mandated by the Energy Policy Act appears to require some degree of active institutional control of the site, which would cause environmental impacts not evaluated in the draft EIS. The Board recommends that the final EIS clarify the extent to which active institutional control of the Yucca Mountain site may be required by the Energy Policy Act, and estimate the environmental impacts that would be associated with a scenario that incorporates such control.
5. Appendix J of the draft EIS describes the use of the HIGHWAY and INTERLINE computer codes to project the specific transportation routes to be used for analysis of transportation

¹ U.S. Nuclear Waste Technical Review Board, *Moving Beyond the Yucca Mountain Viability Assessment*, Washington, D.C., April, 1999.

impacts when moving radioactive wastes to a Yucca Mountain repository. However, the draft EIS does not report what those transportation routes are. The Board recommends that the final EIS identify the specific transportation routes that are used for analysis of transportation impacts. If the DOE has identified preferred transportation routes, those also should be identified in the final EIS. If preferred transportation routes have not been identified, the final EIS should discuss when and how such identification will occur.

6. The analyses of transportation accidents that result in releases of radioactive materials to the environment assume that the released materials are not cleaned up. While this assumption may provide a bounding estimate of the radiation doses that nearby residents could receive, it is unrealistic because it fails to estimate the environmental impacts of clean-up (e.g., worker radiation exposure; condemnation of roads, land, or water supplies; disposal of contaminated soil and building materials). A methodology for making such estimates was presented in *Transportation of Radionuclides in Urban Environs: Draft Environmental Assessment*, NUREG/CR-0743; SAND 79-0369, July 1980. While somewhat dated, the cost estimates and perhaps the methodology could be updated for today's use. The Board recommends that the final EIS include estimates of the environmental impacts of clean-up after transportation accidents.
7. The draft EIS uses 1990 census data for those analyses that require estimates of population sizes. Because of rapid growth in the Las Vegas Valley area, the 1990 census data are out of date. More recent population estimates and twenty-year projections of future growth are available from the Nevada State Demographer's Office at the University of Nevada, Reno. The Board recommends that the State Demographer's population projections be used when preparing impact estimates for the final EIS.
8. Comments at public meetings on the draft EIS have indicated a significant public concern about possible stigma effects (reduced land values, decreased tourism) in areas near a Yucca Mountain repository or associated transportation routes. The Board recognizes that assessing the impact of stigma effects would be difficult because such effects depend not on the actual physical effects of the proposed action, but on the negative perception of those effects by some members of the public. The extent to which stigma effects might occur is extremely speculative and therefore might be inappropriate for analysis in a Yucca Mountain EIS. The Board recommends that the final EIS acknowledge the possibility that stigma effects might occur and explain the basis for deciding whether to include an analysis of such effects in the final EIS.
9. The draft EIS uses the "Modal Study" (discussed on page 6/29 of the draft EIS) in its analyses of transportation accidents. It is our understanding that this study will be updated by the U.S. Nuclear Regulatory Commission, but not in time for inclusion in the final Yucca Mountain EIS. The Board recommends that the final EIS note any efforts to update the study and discuss the DOE's plans for reviewing the results of any update to determine whether a supplement to the final EIS may be needed.
10. The draft EIS identifies the Caliente/Chalk Mountain route (possible rail or heavy-haul route) as a *non-preferred alternative*. However, the draft EIS presents no *environmental* logic for

this designation. Instead, the draft EIS states that the designation is based on opposition from the U.S. Air Force, which is concerned about potential interference with Nellis Air Force Range testing and training activities. Since this route is about half the overall distance of the more circuitous Caliente route and therefore should be less harmful to the environment, and since this route avoids the population centers surrounding Las Vegas, it would seem to be a candidate for designation as a *preferred alternative* from an environmental perspective. The Board recommends that the final EIS provide a more thorough explanation of the basis for deciding whether to exclude the Caliente/Chalk Mountain route from consideration..



UNITED STATES
NUCLEAR WASTE TECHNICAL REVIEW BOARD
2300 Clarendon Boulevard, Suite 1300
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March 20, 2000

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

Dear Dr. Itkin:

The Nuclear Waste Technical Review Board was established by Congress in 1987 to evaluate the technical and scientific validity of the activities undertaken by the Secretary of Energy to implement the Nuclear Waste Policy Act, as amended.

As the Department of Energy (DOE) approaches the critical milestone of determining the suitability of the Yucca Mountain site, the Board believes that clarity in how the DOE will characterize the performance of a potential Yucca Mountain repository is imperative. The Board believes that meaningful quantification of the uncertainties associated with performance, clearly and understandably presented, is an essential element of performance characterization. The complexity of the repository system and the length of time over which performance must be estimated make uncertainty both large and unavoidable (although perhaps reducible). Especially important in such a situation is that policy-makers and other interested parties understand the uncertainty associated with key decisions.

Over the years, the Board has endorsed the use of performance assessment (PA) as one means of estimating the long-term behavior of a repository for spent nuclear fuel and high-level radioactive waste. In this letter, the Board comments further on the DOE's current and proposed use of PA in the context of the site-suitability decision. In the Board's view, the DOE has not yet developed a consistent and transparent approach to representing the uncertainty in its estimates of long-term repository performance. Moreover, because the uncertainties in PA may be substantial, the Board believes that the DOE should supplement its performance estimates with additional lines of argument and evidence. Because these comments have a direct bearing on the DOE's recently proposed site-suitability guidelines, I am sending a copy of this letter to be included in the rule-making on 10 CFR 963.

Analysis and Display of Uncertainty in Performance Estimates

The DOE has conducted four major PA's since 1991. Although each iteration has become more sophisticated and more comprehensive, the results are still associated with a wide range of uncertainties. The uncertainties arise for many reasons, including the following:

- Incomplete information for characterizing the site and its important heterogeneities and for constructing and calibrating process models
- Lack of information on the conceptual validity of the mathematical process models
- Possible errors in extrapolating short-term information on repository subsystems to long-term projections of repository performance
- Effects on repository performance of phenomena and events that are presently not anticipated.

Some of these uncertainties, such as those associated with site heterogeneity, often have been included in past PA's; others, such as those associated with model uncertainty, often have been left out. Of course, the uncertainties associated with unanticipated phenomena cannot be included.

For the PA being prepared for its site recommendation, the DOE is using a methodology in which uncertainties are addressed differently for different input assumptions and parameters. According to presentations made to the Board at its January 2000 meeting, some of these assumptions and parameters will be single-valued conservative estimates, and others will be represented probabilistically. The Board understands the value of using conservative estimates, but it strongly urges the DOE to work with statisticians and other experts to develop coherent and consistent probability statements about projected repository performance based on those conservative estimates.

The Board is concerned that the PA approach now envisioned by the DOE could deprive policy-makers of critical information on possible trade-offs between projected performance and the uncertainty in those projections. For example, one policy-maker might be willing to accept development of a repository that would release half of the permitted dose, with only a 1 in 1,000 chance of exceeding that permitted dose. However, that same policy-maker might decline to develop a repository that is expected to release only a tenth of the permitted dose, but has a 1 in 4 chance of exceeding that permitted dose. Another policy-maker's preferences might be the opposite. Because the uncertainties about repository system performance may be substantial, estimates of uncertainty about doses are at least as important as estimates of performance.

Importance of Multiple Lines of Argument and Evidence

As explained in the Board's April 1997 letter commenting on an earlier DOE proposal to revise the site-suitability guidelines, the Board endorsed the use of PA in support of a site-suitability determination. But the Board stated that the DOE should supplement PA with other meaningful approaches, such as a demonstration of defense-in-depth—including multiple and independent barriers—and compliance with a margin of safety. Similarly, in its 1999 report on the DOE's *Viability Assessment*, the Board concluded that PA could be used as the "core analytical tool" for making the safety case for a repository. However, the Board also noted the limits of PA and expressed doubt that relying "solely on [PA] to demonstrate repository safety will ever be possible." Therefore, the Board recommended that additional lines of evidence, such as natural analogs, be used to overcome these limitations.

The DOE has acknowledged the limits of PA in its *Repository Safety Strategy*. The DOE has indicated that it would demonstrate waste isolation by a number of approaches, including

PA, safety margins and defense-in-depth, performance confirmation, consideration of disruptive processes and events, and insights from natural and man-made analogs. These approaches add confidence to the evaluation of the repository system. They help address concerns about uncertainties that are not explicitly incorporated in PA. Given past experiences at Yucca Mountain and the long operating life of the repository, those concerns may be well-founded. Nonetheless, the DOE's draft site-suitability guidelines propose using only PA to determine the suitability of the Yucca Mountain site, leaving unclear how these additional approaches will in fact be used in the context of site suitability.

Conclusions

The Board continues to endorse the use of PA, along with other supporting lines of evidence and reasoning, for making a site-suitability determination. At the same time, the Board believes that addressing PA's uncertainties and the sources of these uncertainties as clearly as possible is essential for technical credibility and sound decision-making. Therefore, the Board recommends that the DOE include in its representation of performance uncertainty a description of critical assumptions, an explanation of why particular parameter ranges were chosen, a discussion of possible data limitations, an explanation of the basis and justification for using expert judgments (whether or not they are elicited formally), and an assessment of confidence in the conceptual models used. In addition, the Board recommends that the uncertainties associated with the performance estimates be identified and quantified well enough so that their implications for the performance estimates can be understood. This analysis also would help the DOE demonstrate the safety-margin component of the postclosure safety case described in the latest revision of *Repository Safety Strategy*.

The Board believes that PA should not be used as the sole source of guidance about the features, events, and processes that might affect long-term repository system performance. Multiple lines of argument and evidence—combined with a clear and complete description of uncertainty—will present a much more technically defensible demonstration of repository safety than will any individual component of the safety case. The Board urges the DOE to keep this perspective in mind as the program moves forward.

Sincerely,

{Signed by}

Jared L. Cohon
Chairman

cc:
W. Boyle



UNITED STATES
NUCLEAR WASTE TECHNICAL REVIEW BOARD
2300 Clarendon Boulevard, Suite 1300
Arlington, VA 22201-3367

March 20, 2000

Dr. Ivan Itkin
Director
Office of Civilian Radioactive Waste Management
U.S. Department of Energy
1000 Independence Avenue, SW, RW-2/5A-085
Washington, DC 20585

Dear Dr. Itkin:

On behalf of the Nuclear Waste Technical Review Board, please let me thank you and your staff and contractors for participating in the Board's January 2000 meeting, which all members felt was productive and stimulating. We were particularly pleased that you were able to attend and participate in the meeting.

In your remarks to the Board, we noted your intention to maintain the DOE's current schedule for evaluating the suitability of the Yucca Mountain site. According to that schedule, the Secretary of Energy will decide in less than 18 months whether to recommend the site to the President. The DOE's scientific program has amassed a considerable body of knowledge to date, and additional efforts in the scientific program during the next year and a half will augment that body of knowledge. Despite the large amount of work, however, significant technical uncertainties will still be present at the time of the Secretary's decision. A central theme of the January meeting was the challenge of describing uncertainties in ways that will be meaningful in the decision-making process. This letter gives the Board's views on four aspects of uncertainty relating to: repository safety strategy, repository design, scientific studies, and communication.

Repository Safety Strategy. The repository safety strategy presented to the Board recognizes the importance of describing uncertainties as part of the postclosure safety case. The strategy proposes five ways of addressing uncertainty:

1. Quantification of repository performance in a performance assessment (PA).
2. Mitigation of uncertainties through safety margin and defense-in-depth.
3. Consideration of potentially disruptive processes and events.
4. Insights from studying natural analogues.
5. Long-term reduction of uncertainties through a continuing program of testing and performance confirmation until permanent closure.

In a separate letter on the DOE's Part 963 rulemaking (dated March 20, 2000), we note that the Board continues to endorse the use of PA, along with other supporting lines of evidence and reasoning, for making a site-suitability determination. At the same time, the Board believes

that addressing PA's uncertainties and the sources of these uncertainties as clearly as possible is essential for technical credibility and sound decision-making. Therefore, the Board recommends that the DOE include in its representation of performance uncertainty a description of critical assumptions, an explanation of why particular parameter ranges were chosen, a discussion of possible data limitations, an explanation of the basis and justification for using expert judgments (whether or not they are elicited formally), and an assessment of confidence in the conceptual models used. In addition, the Board recommends that the uncertainties associated with the performance estimates be identified and quantified well enough so that their implications for the performance estimates can be understood. This analysis also would help the DOE demonstrate the safety-margin component of the postclosure safety case described in the latest revision of *Repository Safety Strategy*.

The Board believes that PA should not be used as the sole source of guidance about the features, events, and processes that might affect long-term repository system performance. Multiple lines of argument and evidence—combined with a clear and complete description of uncertainty—will present a much more technically defensible demonstration of repository safety than will any individual component of the safety case. The Board urges the DOE to keep this perspective in mind as the program moves forward.

In developing the repository safety strategy, sensitivity analyses were among the considerations used by the DOE to identify the seven "principal factors" that most strongly affect the postclosure safety case. As indicated above, performance assessment is only one element of the safety case. We urge the DOE to ensure consideration of all elements of the safety case, including defense-in-depth, in defining principal factors.

The principal factors apparently will be the focus of much of the DOE's scientific studies in the future. The Board's understanding is that current performance assessment models may not adequately describe the interactions of heat, water flow, chemical reactions, and mechanical disturbances within the rocks near heated emplacement drifts. If this is the case, then sensitivity analyses could fail to identify coupled processes as principal factors. The Board recommends that the DOE reexamine its evaluation of the importance of coupled processes in its identification of principal factors.

The Board urges the DOE to pursue studies of natural analogues. The Board is concerned that there continues to be little evident progress in this area. Presentations at the January Board meeting described modest plans for studying analogues, but there seems to be no serious commitment to funding such studies. In addition to those analogues discussed at the meeting (e.g., Peña Blanca, Rainier Mesa), the Board urges the DOE to consider studies of josephinite, a naturally occurring alloy of nickel and iron that may provide insights into the long-term corrosion resistance of waste packages in a Yucca Mountain repository.

To maintain its site recommendation and licensing schedules, the program may choose to rely more heavily on performance confirmation rather than on site characterization for the information needed to determine whether the Yucca Mountain site can safely isolate wastes. If this is the case, the Board believes that the DOE should develop and communicate a carefully

thought-out plan for its performance confirmation and site monitoring program as an integral part of its site recommendation.

Repository Design. One way to address uncertainties is to reduce them through modifications of repository design, although uncertainties can never be entirely eliminated. In a recent letter,¹ the Board stated that it “. . . does not believe that a strong-enough technical basis exists at this time to support adequately any above-boiling repository design.” (In that letter, “above-boiling” referred to the temperatures of the drift walls after closure.) The Board suggested that many of the above-boiling designs studied by the management and operating (M&O) contractor could be modified to achieve below-boiling conditions by aging the spent fuel or by increasing the rate or the duration of ventilation before repository closure.

In its response to the Board’s letter,² the DOE committed to examining uncertainties associated with coupled thermally driven processes, to refine models that are the basis for evaluating thermal conditions, and to evaluate design options for increasing the efficiency of heat removal prior to repository closure. We look forward to reviewing the results of these very important efforts and discussing them with you as soon as they become available.

We noted above the possibility that existing models may not have captured adequately the effects of coupled processes when identifying principal factors. Similarly, the evaluation of repository design alternatives (including above-boiling and below-boiling design options) using performance assessment models may cause above-boiling designs to appear to have greater certainty about performance than they really have. Adoption of a below-boiling design could substantially reduce most concerns about coupled processes.

Scientific Studies. Another way to address uncertainties is to attempt to reduce them through additional scientific and engineering studies. Presentations on scientific studies at the January Board meeting indicated that significant new information continues to be generated and plans for important future work are being developed. Expert judgment and careful interpretation of data will be needed to accurately characterize and quantify the uncertainties associated with data and their use in predicting repository performance.

The Board heard at the meeting that moisture conditions within the bulkheaded part of the cross-drift appear to be approaching equilibrium conditions and active dripping does not appear evident. We look forward to additional observations from within that part of the cross-drift, including evaluation of the apparent condensation of moisture in some locations. Regarding seepage modeling efforts, there is a need either to incorporate U.S. Geological Survey calcite deposition data and concepts into seepage models or to explain why it would be inappropriate to do so.

¹ July 9, 1999, letter from Jared L. Cohon, Chairman, Nuclear Waste Technical Review Board, to Lake H. Barrett, Acting Director, Office of Civilian Radioactive Waste Management, U.S. Department of Energy.

² September 10, 1999, letter from Lake H. Barrett, Acting Director, Office of Civilian Radioactive Waste Management, U.S. Department of Energy, to Jared L. Cohon, Chairman, Nuclear Waste Technical Review Board.

We were impressed with the careful planning and attention to detail for the fluid inclusion studies. We look forward to completion of that work and hope that it will help resolve remaining questions about the hydrothermal history of the Yucca Mountain site. The Board also looks forward to reviewing plans and schedules for other new tests to be carried out in support of site characterization and, potentially, repository licensing. We noted that coordination of Yucca Mountain participants with the Nye County Early Warning Drilling Program appears to be productive. However, we were disappointed in continuing delays in the chlorine-36 validation studies. At this, and previous, Board meetings, presentations on this important topic were canceled due to insufficient progress. We look forward to hearing about the results of these studies at our next meeting.

Communication. Accurately portraying the nature of uncertainties about the performance of a complex system like a Yucca Mountain repository is a formidable challenge. As you are aware, the DOE will need to communicate effectively to a wide variety of audiences as the project moves forward. The DOE's initiative to develop a simplified performance-assessment capability is a commendable effort to make the "black box" of performance assessment more transparent to nonspecialists. While it remains to be seen how successful this will be, we urge the DOE to make this tool available to the public well in advance of the release of the site recommendation consideration report. We also urge the DOE to seek other innovative ways of improving communication with all stakeholders.

Again, the Board thanks you for your efforts in supporting the Board's January meeting. We that hope you find these comments timely and helpful.

Sincerely,

{Signed by}

Jared L. Cohon
Chairman



Department of Energy

Washington, DC 20585

June 6, 2000

JUN 12 2000

Dr. Jared Cohon
Chairman
Nuclear Waste Technical Review Board
2300 Clarendon Boulevard
Arlington, Virginia 22201-3367

Dear Dr. Cohon:

Thank you for your letter of March 20, 2000, providing the Board's perspective on the information presented by the Department of Energy at the January 25-26, 2000, Board meeting in Las Vegas, Nevada. The Department appreciates your comment that the meeting was productive and stimulating. We, too, found the exchange to be valuable.

In your letter you stressed that technical uncertainties about repository performance will still be present at the time of an anticipated site recommendation decision and noted the challenge of communicating those uncertainties in a meaningful way for the purposes of decision-making. The Department recognizes that the treatment of uncertainty has always been an important factor in the decision-making process on a repository recommendation. The Department's goal is to ensure that the technical basis for any site recommendation fully describes the performance assessment results and the associated uncertainties in data and models. The technical basis will also indicate the scope of uncertainty related to the estimates of repository performance. This information will be evaluated by the Department to provide a sound scientific basis for decision-making.

The Board stated that repository operation at below-boiling temperatures would reduce uncertainties in assessing performance, in particular those associated with the complexity of thermally coupled processes. The Board has also suggested that these reduced uncertainties would increase the confidence in any site suitability determination by the Department by improving confidence in the scientific basis for the determination.

In response to the Board's recommendations, the Department is developing a flexible repository design concept that can balance technical and programmatic considerations. The Program's ongoing evaluation is focused on combinations of operational parameters that would allow a future choice from a wide range of possible thermal behaviors, including below-boiling temperatures.

The Department appreciates feedback on the meeting from the Board as we proceed toward a decision on a possible site recommendation. The Department's responses to the Board's specific issues are provided in the enclosure. If you have any questions, please contact me at (202) 586-6850.

Sincerely,

A handwritten signature in black ink, appearing to read "Ivan Itkin". The signature is written in a cursive style with a prominent flourish at the end.

Ivan Itkin, Director
Office of Civilian Radioactive
Waste Management

Enclosure

**Department of Energy's Responses to the
March 20, 2000, Letter from the
Nuclear Waste Technical Review Board**

Repository Safety Strategy

... the Board recommends that the DOE include in its representation of performance uncertainty a description of critical assumptions, an explanation of why particular parameter ranges were chosen, a discussion of possible data limitations, an explanation of the basis and justification for using expert judgments (whether or not they are elicited formally), and an assessment of confidence in the conceptual models used. In addition, the Board recommends that the uncertainties associated with the performance estimates be identified and quantified well enough so that their implications for the performance estimates can be understood. (page 2)

The Department recognizes that it must clearly identify uncertainties, explain the sources of these uncertainties, and characterize the potential implications of these uncertainties for system performance. This work is necessary to support the technical credibility of the total system performance assessment (TSPA). The Department intends to build on its experience in preparing the TSPA report for the Viability Assessment (VA) and the supporting Technical Basis Document as it completes the TSPA document for any site recommendation (TSPA-SR) and its technical basis.

Ongoing work in developing the Analysis and Model Reports (AMRs) and Process Model Reports (PMRs) that support the TSPA-SR is documenting the basis for and treatment of uncertainty at multiple levels: from the basic data, through the conceptual models, to the abstractions that are the building blocks for the TSPA. The TSPA-SR document will provide a synopsis of those uncertainties associated with each component model. The TSPA-SR will also include detailed discussions on the treatment of uncertainty, uncertainty versus variability, and the use of alternative conceptual models. It will include presentation and analysis techniques for dealing with uncertainty. The Department's evaluation of the implications of the uncertainties on estimates of repository performance will be a major component of the TSPA-SR. The results of these evaluations will be discussed explicitly for the nominal scenario and for the disruptive scenarios.

The Board believes that PA should not be used as the sole source of guidance about the features, events, and processes that might affect long-term repository system performance. Multiple lines of argument and evidence—combined with a clear and complete description of uncertainty—will present a much more technically defensible demonstration of repository safety than will any individual component of the safety case. The Board urges the DOE to keep this perspective in mind as the program moves forward.....We urge the DOE to ensure consideration of all elements of the safety case, including defense-in-depth, in defining principal factors. (page 2)

The Department agrees that multiple lines of evidence and reasoning will be important to support any site recommendation. We are identifying and evaluating multiple and independent barriers to waste isolation to provide information on defense-in-depth. Insights from natural and man-made analogues are being analyzed and included in the TSPA. The underlying documentation of the TSPA calculation will include the margin by which the expected performance of the repository meets the applicable radiation protection standards.

The Department shares the Board's view that elements of the safety case beyond performance assessment should be considered in defining the principal factors. One foundation for development of a technically credible TSPA-SR is identification of the full set of features, events, and processes (FEPs) that must be considered in evaluating long-term repository performance. These FEPs are being identified through a screening process that begins with a comprehensive list of potentially relevant FEPs. The bases for identifying the initial list of FEPs for consideration and for selecting those FEPs that are actually considered in evaluating performance have been documented. Support for inclusion or exclusion of any FEP involves consideration of probability and consequences. Potentially disruptive processes and events are included to the extent that they meet the screening criteria, and natural analogue information is considered in the screening process. For each of the process models supporting TSPA-SR, an AMR is being developed to document the screening of FEPs and the bases for identifying the set of FEPs that will be considered in developing the representation of system behavior. Sensitivity studies will be used to narrow the focus to those factors (and related FEPs) that have the greatest influence on performance. Barrier importance analyses will be used to help identify factors that would provide defense-in-depth, if particular barriers did not perform as expected. The results of these various analyses will be presented in the TSPA-SR document. The Department is committed to considering all elements of the postclosure safety case in defining the principal factors to carry forward to a site recommendation decision.

The Board recommends that the DOE reexamine its evaluation of the importance of coupled processes in its identification of principal factors. (page 2)

The Department agrees with the Board's position. Because of the iterative nature of TSPA and development of the postclosure safety case, the Repository Safety Strategy (RSS) is periodically updated. Revision 3 of the RSS was based on the information then available. That information included the TSPA models used for the VA with modifications to reflect subsequent design enhancements, such as the use of backfill. The evaluations performed for Revision 3 resulted in the preliminary identification of seven principal factors. Workshops are currently underway to support the development of Revision 4 of the RSS. These workshops are being conducted in parallel with development of the technical basis for TSPA-SR and are considering the available TSPA results. These workshops are designed to provide a forum for consideration of the technical information being developed for a site recommendation decision and to continue development of the principal factors of the postclosure safety case. The importance of thermally coupled processes in the identification of principal factors is

being reexamined during the course of these workshops. Revision 4 of the RSS will include the results from performance analyses, sensitivity studies, and barrier importance analyses in establishing principal factors, which may be modified from those in Revision 3.

The Board urges the DOE to pursue studies of natural analogues. The Board is concerned that there continues to be little evident progress in this area.....there seems to be no serious commitment to funding such studies.the Board urges the DOE to consider studies of josephinite, a naturally occurring alloy of nickel and iron that may provide insights into the long-term corrosion resistance of waste packages in a Yucca Mountain repository. (page 2)

The Department agrees that natural analogues have the potential to increase understanding of certain processes that are principal factors in the postclosure safety case. Natural analogues can thus play an important role in supporting any recommendation and as a means of reducing uncertainty. For these reasons, funding for analogue studies has been continued in Fiscal Year 2000 despite budget constraints. These studies include continuation of work at Peña Blanca, modeling unsaturated zone flow and radionuclide transport in fractured rocks at the Idaho National Engineering and Environmental Laboratory, modeling of processes at selected active geothermal sites, a field and modeling study of Paiute Ridge intrusive bodies, and, potentially, process modeling with Krasnoyarsk (K-26) data. It is anticipated that in future years, consideration will be given to funding confirmatory studies of additional natural analogues that address Yucca Mountain processes and models.

The Department agrees that studies of metallic natural analogues may prove useful. Although josephinite is not Alloy 22, the material selected for the waste package outer barrier, josephinite and selected meteorites are metallic analogues that could provide useful information on long-term performance. Studies of these materials will continue with an emphasis on understanding the development and stability of the passive film. To date, only preliminary microstructural analysis of samples of josephinite has been performed.

To maintain its site recommendation and licensing schedules, the program may choose to rely more heavily on performance confirmation rather than on site characterization for the information needed to determine whether the Yucca Mountain site can safely isolate wastes. If this is the case, the Board believes that the DOE should develop and communicate a carefully thought-out plan for its performance confirmation and site monitoring program as an integral part of its site recommendation. (pages 2-3)

The Department has always viewed performance confirmation as essential to the assurance of acceptable repository performance in support of an eventual decision on whether and when to close the repository. The role of performance confirmation in the Yucca Mountain Project has not changed in light of the Project's current site recommendation and licensing schedules.

The Department expects that preliminary analysis of repository performance conducted for site recommendation, together with the safety margin and defense-in-depth provided by the multiple natural and engineered barriers in the current repository design, will provide a sufficient technical basis to judge whether the Yucca Mountain site is suitable and should be recommended for development as a repository.

As the Board, the Department, the Environmental Protection Agency, and the Nuclear Regulatory Commission (NRC) all have recognized, uncertainty about long-term repository performance cannot be totally eliminated. As one means of enhancing confidence in the understanding of repository behavior in support of the NRC decision to permit repository closure, the NRC requires that a performance confirmation program be put in place, starting during site characterization and continuing until repository closure. Such a program requires continued involvement in evaluating new information obtained during licensing, construction, operation, and monitoring of the potential repository to determine whether the essential assumptions and bases for the postclosure compliance evaluation are confirmed. The length of the post-emplacment performance confirmation period will exceed by several times the length of the site characterization period, and the actual performance of repository systems will be monitored. Therefore, the Department expects performance confirmation to lead to a significant increase in understanding and confidence before any decision to close the repository is made.

Repository Design

... the DOE committed to examining uncertainties associated with coupled thermally driven processes, to refine models that are the basis for evaluating thermal conditions, and to evaluate design options for increasing the efficiency of heat removal prior to repository closure. (page 3)

The Department has recently initiated an effort to better quantify the uncertainties in the current thermal-hydrologic model; we will keep the Board apprised of this effort. The current design has adequate flexibility to be operated in above-boiling or below-boiling modes, and we recognize the need to further address the uncertainties associated with a choice of operating mode. Even with an above-boiling operating mode, for which boiling would be restricted to less than half of the thickness of the pillar between emplacement drifts and water could drain within the pillars, uncertainties associated with thermally driven processes would be considerably reduced compared with the design concept in the VA.

Some additional design features for increasing the efficiency of heat removal have undergone preliminary consideration; however, to date, they have not been determined to be cost-effective. The current expectation is that approximately 70 percent of generated heat will be removed through the ventilation system. Other additional design features, which have not been explored during the preliminary work done to date, may be able to remove more of the remaining heat and will be evaluated.

Scientific Studies

Regarding seepage modeling efforts, there is a need either to incorporate U.S. Geological Survey calcite deposition data and concepts into seepage models or to explain why it would be inappropriate to do so. (page 3)

The calcite deposition data collected by the U.S. Geological Survey provides important information on seepage into lithophysal cavities. The seepage models developed by the Project will incorporate, as appropriate, these data sets, as well as the niche seepage data. The results from these models will provide additional insight about seepage into emplacement drifts over long time periods.

Communication

The DOE's initiative to develop a simplified performance-assessment capability is a commendable effort to make the "black box" of performance assessment more transparent to nonspecialists.....we urge the DOE to make this tool available to the public well in advance of the release of the site recommendation consideration report. (page 4)

The Department intends to make a version of the simplified TSPA available to the public via the Internet and in a CD-ROM version that can be run on a personal computer. Timing of this initiative is constrained by availability of resources. We anticipate making the simplified TSPA available about the time the site recommendation consideration report is released, allowing the public to use it during the public comment and hearing process on a possible site recommendation.



UNITED STATES
NUCLEAR WASTE TECHNICAL REVIEW BOARD
2300 Clarendon Boulevard, Suite 1300
Arlington, VA 22201-3367

June 16, 2000

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

Dear Dr. Itkin:

On behalf of the Board, I would like to extend our appreciation for the presentations made by your staff and contractors at the Board's meeting held last month in Pahrump, Nevada. We were especially pleased that you were able to attend and participate in the gathering.

Although the meeting covered a wide range of topics, the presentations raised among Board members an interrelated set of impressions and observations. In particular, the Board notes that the Department of Energy (DOE) is still in the process of addressing key uncertainties and that new uncertainties continue to arise. The existence of these uncertainties, coupled with some of your own comments, suggests that the DOE is beginning to explore ways of systematically tying important milestones to the acquisition of critical information. For such an approach to be credible and effective, preserving flexibility and ensuring that the bases for decision-making are transparent will be important.

Addressing Old and New Uncertainties. We appreciated Jean Younker's presentation on thermally driven uncertainties. The presentation demonstrated that DOE scientists have a good grasp of the types of uncertainties that currently are present. The next step, important for the fast-approaching site recommendation by the Secretary of Energy, is to analyze and explain quantitatively the size and significance of those uncertainties for performance and how they vary with repository temperature. For example, the variations with temperature of uncertainties in generalized and localized aqueous corrosion rates of waste-package and drip-shield materials must be determined over the temperature range from ambient to at least the boiling point of water that contains highly concentrated dissolved salts. Similarly, quantifying uncertainties in variables and processes that pertain to fluid flow and transport in the repository rock over the temperature range from ambient to the maximum predicted temperature in the rock is very important.

Other uncertainties that had not been discussed previously with the Board also became evident during the meeting. One involves potential interactions between repository materials. An employee of the management and operating contractor (M&O), commenting from the floor, indicated that closely placed steel sets (ring beams) would be used throughout the emplacement drifts for rock support. We are concerned about the adequacy of the corrosion database on the interaction of steel and its corrosion products with Alloy 22. We realize that steel sets rather

than concrete drift liners were chosen for rock support because concrete might have deleterious effects on waste package performance. However, we have not seen the analysis indicating that steel would be less deleterious than concrete. Additional corrosion studies may be needed to determine whether current waste package designs are compatible with the environmental conditions that might result from the use of steel for rock support.

The Board also appreciated the information in the presentations by Bill Boyle of the DOE and Marc Caffee of Lawrence Livermore National Laboratory (LLNL). We were pleased as well by the candor of the subsequent discussions among the two presenters, June Fabryka-Martin of Los Alamos National Laboratory (LANL), and Board members. The Board realizes that much of the data discussed were obtained very recently and that the analysis of the data is just beginning. LLNL and LANL investigators appear to disagree about the presence of bomb-pulse chlorine-36 in a faulted and fractured area of the Exploratory Studies Facility and about the background ratio of the chlorine-36 to chlorine in that area. Because the presence of bomb-pulse chlorine-36 at specified locations within the ESF has been interpreted as evidence of fast paths for the infiltration of water to the repository level and the background ratio of chlorine-36 to chlorine has been used to estimate the age of the water in the rock, validating the chlorine-36 measurements is important. Perhaps of even greater importance is how this dispute could affect the credibility of the scientific program. Although differences in interpretation are quite normal and expected in science in general and in geology in particular, the standing of the program is not enhanced if these differences appear, as is presently the case, to be due to differences in sampling and processing techniques. In the Board's view, resolving the apparent disagreement should be a very high priority.

Predictions of performance that will be developed to support the Secretary's site recommendation will depend on the assumptions that the waste packages and drip shields can be manufactured with high reliability and will function as intended. Showing that these assumptions are true may take many years of research, development, and demonstration. Although complex designs may be justified under some circumstances, they often are the source of increased uncertainty. For example, the designs of the final closure end of the waste package and the connections between drip shields have become very complex over the last year or so. As a result, current performance assessment models do not capture well how water might elude the drip shields and cause stress corrosion cracking. Thus, the Board urges DOE to explore the possibility of simplifying the current designs for the repository, the waste package, and the drip shield.

Another significant area of uncertainty is the saturated zone flow-and-transport model. It may be possible to improve this model using geochemical information being collected by Nye County. In fact, Don Shettel's presentation included a substantial amount of geochemical data. The Board is looking forward to the interpretation of those data in the larger context of the geochemical and hydrological investigations of the regional groundwater system.

Of course, there are many other sources of uncertainty that will affect estimates of repository performance. As the Board has communicated to you before, meaningful quantification of the uncertainties associated with performance, clearly and understandably presented, is an essential element of performance characterization.

Interpreting New Data Acquired Over Time. In your prepared remarks to the Board and in the discussion that followed, you made reference to the reality that the Yucca Mountain project is unique in its long duration, its high degree of complexity, and the persistence of significant technical and institutional uncertainties. You alluded to the possibility of using a modular approach to design and proceeding in stages to develop a repository at Yucca Mountain. Although you did not specifically use the term, the process you seemed to outline appears to be an "evolutionary" one as opposed to one that tries to foresee and address in advance all potential contingencies.

The Board can appreciate why the DOE may think that this kind of evolutionary process may offer important advantages, especially given many of the singular characteristics of the Yucca Mountain project. The Board observes, however, that for such an approach to be technically credible and effective, the DOE would likely want to consider several prerequisites. For example, broad agreement would have to be reached on how to quantify and rank uncertainties that significantly affect performance, a program would have to be created to gather data designed to address key uncertainties, clearly stated benchmarks and criteria would have to be developed to evaluate uncertainty reduction, and a clear protocol for technical decision-making, including a bona fide exit strategy from the site if a fatal flaw were found, would have to be established.

Ric Craun's presentation suggested that the current repository design contains sufficient flexibility to allow for changes in repository design as new data are acquired. The chart he presented, which related ventilation time, "staging" time, and distance between waste packages to repository temperature, was very helpful. We agree that there is a great deal of operational latitude in the current design. In particular, the chart clearly shows that broad flexibility exists to implement the design as either a below-boiling or an above-boiling repository. The Board notes, however, that even more flexibility might be available if certain factors now held constant (e.g., spacing between drifts, age of fuel when received at the repository, ventilation efficiency) were allowed to vary.

On several occasions, the Board has commented to the DOE on the importance of carrying out technical analyses and making critical decisions in a manner that is highly transparent to the broad range of interested and affected parties involved in developing a potential repository at Yucca Mountain. The remarks made at the Board meeting by the representatives from the municipality of Oskarshamn, Sweden, suggest that the complicated development process can be carried out in a transparent fashion. Although it is unclear which, if any, lessons from Sweden might be applied in this country, it is clear that transparency has been and will continue to be an important requirement for this program.

Sincerely,

{Signed by}

Jared L. Cohon
Chairman



UNITED STATES
NUCLEAR WASTE TECHNICAL REVIEW BOARD
2300 Clarendon Boulevard, Suite 1300
Arlington, VA 22201-3367

September 20, 2000

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

Dear Dr. Itkin:

On behalf of the Nuclear Waste Technical Review Board, I extend our appreciation for the presentations made by your staff and contractors at the Board's meeting last month in Carson City, Nevada. We were especially pleased that you were again able to attend the meeting and address the Board. The main focus of the meeting was total system performance assessment for site recommendation (TSPA/SR), and we appreciate your staff's willingness to present and discuss the preliminary results of the calculations that are the bases for estimates of repository performance in models being developed for the TSPA/SR. The presenters were very responsive to the Board's requests for information and helped make this one of the most informative meetings the Board has held over the last few years. We would like to single out Claudia Newbury of your staff for her contributions to this meeting and other DOE-Board interactions.

The comments enclosed with this letter provide the DOE with the Board's views on the status of the program at a time when changes can be made that will strengthen the technical and scientific bases for a DOE decision, scheduled for July 2001, on whether to recommend the Yucca Mountain site. The Board notes that most of the key issues discussed in the letter (extrapolation of corrosion rates, modeling coupled processes, analyzing alternative repository designs, developing multiple lines of evidence, quantifying uncertainty) have been raised by the Board in previous letters and reports to the DOE. The Board also notes that in several areas the DOE has made significant progress since the 1998 viability assessment—e.g., substantial improvements have been made in performance assessment capability, integration has increased significantly, new and better models have been developed, and new and important data are being collected.

There remain many areas where improvements are needed, however. The Board is not convinced that the range of experiments and analyses carried out by the DOE is broad enough to describe, or even bound, all relevant coupled processes in the near-field environment affecting the engineered barrier system. Furthermore, because the understanding of fundamental corrosion processes is limited, extrapolation of corrosion rates determined from short-term (several years)

experiments to predict waste package performance over tens of thousands of years is a subject of concern. Extrapolations based on assumptions about the fundamental long-term mechanisms that affect the passive layer critical to the corrosion resistance of Alloy 22 may be suspect. Although the Nye County Early Warning Drilling Program has yielded improved hydrogeological information, substantial uncertainties persist. Furthermore, it is not clear to the Board how the program plans to incorporate or reflect new data and analyses that are obtained in the next year or so in its site recommendation.

In its March, 20, 2000, letter to you, the Board discussed the importance of proper treatment and estimation of uncertainties. Several suggestions were made to assist the DOE in this task. We are encouraged by the efforts made thus far and presented at the meeting, but we also offer the caution that additional efforts are needed before a case can be made that uncertainties are estimated in a technically credible manner. The Board believes that the quantification, analysis, integration, and communication of uncertainty need to be addressed in a more rigorous manner than shown in the presentations at the Board meeting. Any projection of repository performance will be incomplete unless the DOE also provides a description and a meaningful quantification of the level of uncertainty associated with its predictions.

The Board has strongly endorsed the DOE's efforts in developing multiple lines of evidence to construct a "safety case" for the proposed repository. However, the Board believes that the evolving *Repository Safety Strategy (RSS)* does not yet substantially increase confidence that a repository at Yucca Mountain will perform as anticipated, because a majority of the components of the *RSS* are all dependent on performance assessment. In the Board's view, multiple lines of evidence that are not subject to the same limitations of performance assessment are needed to increase confidence in performance projections.

Recently, the Board answered questions from Representative Joe Barton following the Board's June 23, 2000, testimony before Mr. Barton's Subcommittee on Energy and Power. In its answers, which also are enclosed, the Board noted that, on the basis of information it has reviewed to date, the Board believes that the technical basis for current long-term projections of repository performance has critical weaknesses. These projections and their associated weaknesses reflect in part the DOE's "base case" (above-boiling) repository design. Although the site may merit a positive recommendation, the DOE has not yet demonstrated—for the base-case design—a firm technical basis for such a conclusion. As the Board pointed out in its July 1999 letter to Lake Barrett, who was at that time Acting Director of the program, some of the current large uncertainties about waste package and repository performance are directly or indirectly related to the high (i.e., above-boiling) repository temperatures associated with the current base-case design. Other uncertainties are related to a lack of fundamental understanding about physical processes that will occur over thousands of years; realistic predictions are therefore very difficult to make.

The Board reiterates its observation that there have been substantial improvements in performance assessment since the viability assessment. We particularly appreciate the DOE's willingness to discuss its preliminary calculations in an open and thoughtful manner. Addressing

the concerns we have discussed in this letter will help to make the TSPA/SR and the proposed *Repository Safety Strategy* more useful and understandable to the scientific community and to the decision-makers involved in deciding whether to recommend development of a repository at Yucca Mountain.

Sincerely,

{Signed by}

Jared L. Cohon
Chairman

Attachments:

**“Comments of Nuclear Waste Technical Review Board
on Meeting of August 1 and 2, 2000, in Carson City, Nevada”**

**“Nuclear Waste Technical Review Board Responses to
Questions for the Record from Mr. Barton, August 31, 2000”**

Comments of Nuclear Waste Technical Review Board on Meeting of August 1 and 2, 2000, in Carson City, Nevada

Total System Performance Assessment

The Board notes with satisfaction the substantial improvements made in performance assessment capabilities since the last iteration in 1998 for the viability assessment (TSPA/VA). Integration has increased substantially, and new and better models have been developed, including the site-scale saturated zone flow-and-transport model and the model relating the presence or absence of water on the surface of the waste package to relative humidity at high temperatures. New and important field data are being collected, for example, in the Exploratory Studies Facility (ESF), the east-west cross drift, the Nye County Early Warning Drilling Program, and the Busted Butte facility. Laboratory data also are being collected, for example, in the long-term-corrosion testing facility at Lawrence Livermore National Laboratory (LLNL).

In the following paragraphs, we provide detailed comments on TSPA and its specific components. Carrying out a performance assessment for the proposed exceedingly long-lived repository at Yucca Mountain, including taking into account highly complex interactions between the natural and engineered systems, is an extremely difficult undertaking. As might be expected for such a challenging project, our comments tend to highlight areas where improvement is needed. They should not be interpreted as diminishing the significant progress made in the last few years.

TSPA: General Comments

Efforts were made in the TSPA/VA and in the most recent performance assessment to increase transparency, but additional work is needed. For example, the most recent performance assessment and the latest version of *Repository Safety Strategy* contain sensitivity studies that show the effect of "neutralized" and "degraded" barriers. The differences between neutralized and degraded barriers should be stated clearly and justified. In addition, a clear explanation is needed to justify why some neutralization analyses assume the complete removal of a barrier while others, such as waste package neutralization, assume only partial removal of a barrier. Differences between the "nominal" and the "igneous activity" scenarios also need to be clarified, and the rationale for separating these scenarios should be clearly stated and justified. "Nominal" may be a poor name for what usually has been referred to as the "base case." In addition, presenting only the probability-weighted igneous scenario is confusing. It would be much clearer if the conditional results of the igneous scenario were presented and discussed both with and without probability weighting.

The Board is concerned about the lack of formal peer review for the TSPA/SR. The peer review panel convened for the TSPA/VA provided very useful comments and insights on that analysis. Several of their suggestions were implemented in the TSPA/VA and in the current version of the TSPA/SR. Areas where peer review would be particularly useful for site recommendation are statistics and uncertainty estimation. Evaluation of the statistical techniques used to estimate parameter ranges and the overall treatment of uncertainty could increase the

credibility of the conclusions drawn. At the meeting, the Board was told that a peer review (by an international body) would be completed for license application. Unfortunately, important national decisions, whose technical components will rest in large part on the TSPA/SR, must be made for site recommendation.

TSPA: Comments on Specific Components

Program integration has improved, but problems still exist. Several models were presented that address coupled processes, including the mountain-scale thermal-hydrological (TH) model, the thermal-hydrological-chemical (THC) model, and the thermal-hydrological multiscale model. Determining how these coupled-process models interact with each other and with other TSPA models is difficult. For example, the input to the isothermal seepage model is somewhat arbitrarily taken to be the fluxes predicted by the TH multiscale model 5 meters above the drifts. Because a large amount of thermally mobilized water is predicted to be present at this location at the time of peak waste package and drift-wall temperatures, seepage into the drifts is predicted. This is contrary to the conceptual model that to a large degree provides major justification for an above-boiling repository design showing that heat would move water away from the emplacement drifts when drift-wall and waste package temperatures are high. The credibility of these analyses would be improved by a coherent narrative description of the interrelationships of the various process models and their abstraction for TSPA.

The THC model predicts that coupled THC processes will have no significant effect on flow in the unsaturated zone. The TSPA/VA peer review panel, on the other hand, observed that a precipitate cap could be formed by thermally induced mineral deposits above the repository. Formation of such a cap would be important in determining how the repository environment would change with time and how that would affect the distribution and quantity of water flowing through the repository. At the Board meeting, Yucca Mountain scientists stated that the assumption of minimal THC effects on flow may be optimistic—that is, nonconservative. The validity of the assumption that there are no THC effects on flow in the unsaturated zone should be demonstrated in a scientifically sound and defensible manner.

The DOE stated that radionuclide transport in the unsaturated zone is not affected significantly by large changes in fracture aperture. The Board is puzzled by this statement, given the known sensitivity of permeability to fracture aperture and the known sensitivity of radionuclide transport to permeability. The DOE should examine the justification for this assumption more closely. In addition, some assumed rock properties are supported by little or no data. Examples are the dearth of information at the appropriate measurement scale on intrinsic permeability, variability of permeability (including anisotropy), and input parameters needed for the models of active fractures and saturated zone diffusion.

According to DOE sensitivity studies, an important assumption affecting repository performance is the value assigned to the coefficient for diffusion of radionuclides through the invert to the rock immediately below the waste package. The DOE should evaluate whether the currently assigned diffusion coefficient may be too high (conservative). If so, justification for a different diffusion coefficient not only would improve predicted repository performance but also would allow a more robust estimation of barrier performance.

The environment affecting the engineered barrier system (EBS) is critical to determining the interactions between the natural and engineered components of the repository. Of particular importance to the corrosion of the drip shield and the waste packages is the chemistry of water and gases in the drifts. The Board is not convinced that the range of experiments and analyses carried out by the DOE is broad enough to describe, or even bound, all relevant coupled processes in the near-field environment affecting the EBS. For example, the work done at LLNL in the last few years to determine the changes in composition and boiling point of synthetic J-13 water as it becomes more concentrated via evaporation represents a major advancement in knowledge. However, the Board is unaware of any work—theoretical or experimental—for determining whether there are plausible fractionation mechanisms that could result in brines that are disproportionately enriched in trace elements or that show significant composition differences other than those anticipated to result from simple evaporation. Given the importance of the EBS environment, the DOE should examine and evaluate all pertinent and important chemical interactions.

Because sensitivity and neutralization studies indicate that the waste package may be the most important barrier for containing and isolating radioactive waste, the data, models, and assumptions pertaining to the waste package deserve special scrutiny. There have been significant improvements in waste package data and models since the TSPA/VA. For example, a major advancement is the model relating the presence or absence of water on the outer surface of the waste package to relative humidity at temperatures above the boiling point. Similarly, LLNL's long-term-corrosion testing facility (LTCTF) has improved the data set from which corrosion rates are estimated.

Still, there are important gaps in understanding waste package performance. For instance, the current TSPA model for generalized corrosion of Alloy 22 is based almost entirely on corrosion data from the LTCTF. These data were developed using Alloy 22 samples in comparatively dilute J-13-derived brines at temperatures no higher than 90°C. However, recent experimental and theoretical work carried out principally at LLNL shows that concentrated brines could be present on waste packages at temperatures up to 120°C. The DOE must establish that the water that will contact waste packages is similar to (or bounded by) J-13-derived water and ensure that the basis for predicting generalized corrosion rates at 90°-120°C is adequate.

The work for determining the temperatures and compositions at which water (with dissolved components) could exist on waste package surfaces has been under way for only a few years. Although progress has been made, the work should continue and broaden. For example, work comparing J-13 water and pore water from the repository horizon raises the issue of whether they are sufficiently similar so that J-13-derived water can be used as a reasonable surrogate for water that will contact waste packages. This issue needs to be resolved.

Extrapolation of corrosion rates determined from short-term (several years) experiments to predict waste package performance over tens of thousand of years is a subject of great concern to the Board. Long-term extrapolations may be suspect if they are made with little or no understanding of the fundamental mechanisms that either preserve or dissolve the passive layer critical to the corrosion resistance of Alloy 22. Such understanding should be accompanied by examples of long-term (archeological-geological) protection by passive layers in aggressive environments. Currently "unknown" processes that could affect the long-term viability of the passive layer include the following:

- passive layer defect accumulation—that is, the passive layer encounters microscopic defects as it sweeps into metal
- passive layer debris accumulation—that is, the long-term effects of corrosion products on the passive layer
- (quasi)transpassive dissolution—that is, if the open-circuit potential creeps up over time, transpassive regimes may be approached, promoted by the high molybdenum content of Alloy 22.

Several groups, including those at VTT (Finland), the Center for Nuclear Waste Regulatory Analyses, and The Pennsylvania State University, are investigating mechanisms that could affect the long-term behavior of passive layers. The DOE should familiarize itself with this work to improve the credibility of the extrapolation of long-term performance from short-term data.

The waste form consists of the radioactive waste itself, cladding, and any encapsulating or stabilizing matrix. Models of waste form degradation take into account several important considerations, including the radionuclide inventory, degradation of spent nuclear fuel and high-level defense waste, cladding, radionuclide solubilities, and formation of colloids. Waste form degradation determines the availability of radionuclides for transport out of the EBS and into the natural system after a waste package is breached. As in other areas, there have been substantial improvements since the TSPA/VA. Such improvements include better models for the perforation and unzipping of Zircaloy cladding, radionuclide solubilities, and in-package chemistry. In-package chemistry (for example, pH, carbonate content, ionic strength, and fluoride concentration) is particularly important because it will have a large effect on waste form degradation. Low pH in the first thousand years after waste package breach would result in a relatively high solubility for neptunium, which is the prime contributor to long-term dose.

The model that simulates colloid-facilitated transport of radionuclides seems reasonable but lacks sufficient data. Colloids are microscopic particles and other solids that can, and do, move rapidly through groundwater systems. Colloids can be man-made, resulting from corrosion of the waste package or the waste form itself, or they can be naturally occurring. Examples of natural colloids include organic humic substances, microbes, and inorganic materials, such as clays, iron and manganese oxides, and some silicates. Colloids are important in unsaturated and saturated zone transport because several important radionuclides, including plutonium and americium, can attach (sorb) themselves onto these microscopic solids. Recent studies, such as those at the Nevada Test Site, have shown that colloids are present in larger amounts than previously assumed. Data presented thus far are not adequate to form a technical basis for simulating colloidal transport. Recent performance assessments apparently assumed that colloid concentrations leaving the waste form are determined by the availability and stability of iron oxide. However, other studies have shown that sorbed plutonium is associated with manganese oxide and smectite (a form of clay) rather than iron oxide. Basing colloidal-transport coefficients on site-specific studies that consider the appropriate colloidal forms is needed for a technically defensible prediction of radionuclide transport.

Flow and transport in the saturated zone determine the timing and rate at which radionuclides reaching the water table beneath Yucca Mountain travel to the accessible environment, currently defined as 20 km from the repository. This is an area where there have

been particularly important changes since the TSPA/VA. For example, in TSPA/VA, the DOE relied on an extremely simple flow-tube model to characterize flow and transport in the saturated zone. The current approach makes use of a three-dimensional site-scale flow-and-transport model for most radionuclides. Other changes include simulation of matrix diffusion and sorption in the alluvium.

The Nye County Early Warning Drilling Program has yielded improved hydrogeological information; continuation of that program will produce very valuable data in the future. Unfortunately, substantial hydrogeological uncertainties persist at present. Rock and fault permeabilities (including anisotropy) remain to be measured at the appropriate scale for numerical model predictions. The vertical distance between zones of fracture concentration that conduct fluid flow is a critical parameter for fracture-matrix diffusion calculations. This parameter has been quantified only in the 3 C-Well boreholes, located outside of the likely flow paths from the repository footprint to the proposed compliance points downgradient. The extent of the alluvial zone, a potentially important contributor to repository performance because of its ability to retard radionuclides, still has not been defined adequately by field investigations. The areal extent and magnitude of the upward gradient from the deep regional carbonate aquifer remain defined by only a single data point. The use of the same dispersivity values for all rock formations is better suited to homogeneous rocks than to the rocks near Yucca Mountain. The Board anticipates that the Nye County program can help to fill in many of these data gaps.

Biosphere models in the TSPA determine how the plant and animal communities take up radionuclides that reach the accessible environment. A major change has occurred at the interface between the saturated zone and the biosphere. In the TSPA/VA, radionuclide concentrations in water were determined by calculating the concentration in water wells penetrating specific locations in the saturated zone. The current approach simply assumes that all the radionuclides crossing a boundary 20 km from the repository are diluted by the amount of water used by a hypothetical agricultural community. This approach lessens the need to determine specific flow paths unless they change the time it takes for transported radionuclides to reach the 20-km boundary. The Board notes, however, that this approach may be inconsistent with the "representative volume" concept used by the U.S. Environmental Protection Agency (EPA) in its proposed standards for a Yucca Mountain repository, 10 CFR Part 197. Consistent with the EPA's proposal, the current approach assumes that future populations will be similar to present populations. This eliminates the need to predict changes in the communities surrounding Yucca Mountain thousand of years into the future, predictions that are impossible to make reliably.

One of the most interesting results from the current performance assessment is the conclusion that igneous activity is the only contributor to estimated dose during the 10,000-year regulatory period. This is due to increased efforts in modeling the consequences of igneous activity and to the assumption that, absent igneous activity, waste packages will not be breached during the first 10,000 years. Modeling the consequences of igneous activity includes two igneous release scenarios: (1) eruption through the repository and (2) disruption of the waste packages in the emplacement drifts, allowing greatly increased exposure of waste to water seeping into the drifts. These scenarios involve many assumptions about the nature of igneous activity, the extent of waste package disruption, the transport of radionuclides through the atmosphere, and dose-conversion factors for atmospherically transported radionuclides. Future technical interactions between the DOE and the Nuclear Regulatory Commission on igneous

activity will, in large part, be devoted to examining the assumptions made by the DOE in its consequence models. The Board will be examining the basis for the assumptions.

TSPA: Treatment of Uncertainty

In its March 20, 2000, letter to you, the Board discussed the importance of proper treatment and estimation of uncertainties. Several suggestions were made to assist the DOE in this task. We are encouraged by the efforts made thus far and presented at the meeting, but we also offer the caution that additional efforts are needed before a case can be made that uncertainties were estimated in a technically credible manner. The Board believes that the quantification, analysis, integration, and communication of uncertainty need to be addressed in a more rigorous manner than shown in the presentations at the Board meeting. Any projection of repository performance will be incomplete unless the DOE also provides a description and a meaningful quantification of the level of uncertainty associated with its predictions.

The Board believes that meaningful quantification of the uncertainties associated with performance, clearly and understandably presented, is essential to provide policy-makers who are deciding on a site recommendation with critical information on trade-offs between projected performance and uncertainty in those projections. The Board realizes that projecting long-term performance of a potential repository at Yucca Mountain, or anywhere else for that matter, is inherently associated with uncertainty. Eliminating all the uncertainties will never be possible (although they can be reduced). In fact, the Board has noted that a decision on whether to recommend the site can be made at any time, depending in part on how much uncertainty policy-makers are prepared to accept. The timing of the site recommendation, of course, is clearly beyond the Board's charge.

At the Board meeting, we noted several issues that need further attention. For example, the ranges of chosen parameters need further justification. The use of performance assessment to set these ranges by determining what "really counts" may be of limited value because of the dependence of this method on the specific models used. Sound evidence is needed to justify the parameter range chosen. The number of "realizations" to be used for uncertainty analyses appears to have been determined somewhat arbitrarily. A more rigorous determination of the optimal number of realizations would make the uncertainty analyses more defensible. We heard at our meeting the preliminary results of sensitivity studies aimed at defining the effect of changes in assumptions about models and input parameters. In some cases, it was difficult to determine whether results were insensitive to some parameters because of the underlying physics and chemistry in the process models or because of simplifying assumptions used in the abstractions. We realize that many of these studies were so new that the presenters did not have sufficient time to evaluate them. Analysts and project scientists need to make the effort to do so and, as appropriate, modify them accordingly. Otherwise, they will be of limited use to reviewers.

Analysis and integration of uncertainties are other topics of Board interest. The Board is puzzled by the sharp decrease in uncertainty, as defined by the bandwidth of the Monte Carlo simulations after 100,000 years. Uncertainty typically increases over time, but in the performance assessment analyses, this measure of uncertainty decreases. If, as some maintain, the decrease is due to the assumed failure of most of the waste packages by that time, an effort should be made to demonstrate convincingly that this is so. As indicated previously, a clear analysis of the contribution of uncertainty to the overall results is needed.

Another issue requiring further thought is the adoption of a mix of conservative, realistic, and optimistic assumptions in models and parameters: for example, the "conservative" estimates of diffusion through the invert and the "optimistic" estimate of the extent of THC coupling. Determining the overall level of conservatism for a mix of conservative, realistic, and optimistic assumptions will be very difficult. If the DOE wants to argue that the TSPA is conservative, an effort must be made to provide a defensible estimate of the overall level of conservatism.

Finally, even if a technically credible performance assessment is carried out, poor communication can hurt the perception of credibility. An example of this is the potential confusion generated by the differences between the nominal scenario and the igneous scenario, as discussed above. In contrast to the nominal scenario, the igneous scenario is heavily influenced by the very low probability of the occurrence of igneous activity affecting the proposed repository. This probability is about one chance in 100,000,000 per year. Much of this confusion can be prevented if the differences between the two scenarios and the rationale behind probability weighting are clearly explained along with a presentation and discussion of igneous activity scenarios without probability weighting.

Ongoing Scientific Studies

Results of ongoing scientific investigations at Yucca Mountain were presented at the August Board meeting. Much significance was attached to certain observations in the lower lithophysal rock in the cross drift. These observations appear to show greater capillary suction and fracture permeability and therefore lower seepage in the lower lithophysal unit than in the middle nonlithophysal unit in the ESF. According to present plans, the lower lithophysal units will house more than 70 percent of the waste packages. Based on other observations, a new mechanism explaining the mineral deposits found in lithophysal cavities also was proposed. Both these observations and the related hypotheses are important in determining the ability of water to seep into the drift. They need to be evaluated carefully.

Access to the lower lithophysal unit is providing very useful information to the project. We understand that some tests, including the thermal test in the cross drift, are being deferred. The Board urges the DOE to continue and complete ongoing studies, such as the crossover-drift test, and start deferred tests in a timely manner. To finalize a repository design and conduct a convincing performance assessment, the DOE needs to know as much as reasonably possible about the actual rocks within which the waste will be placed.

Finally, at the May 1, 2000, meeting in Pahrump, Nevada, an independent study was presented that apparently contradicted results from the original study of chlorine-36 in the ESF and the cross drift. The differences may be due in large part to differences in sample processing. No new results were presented at the August meeting. We understand that an effort is under way to address the processing differences, and we look forward to resolution of the issue.

Repository Safety Strategy

At its August meeting, the Board heard a presentation on the latest version of *Repository Safety Strategy (RSS)*. Although demonstrating, in the conventional sense, how a repository will behave thousands of years into the future may not be possible, steps can be taken to increase confidence in estimates of future performance. The Board has strongly endorsed the DOE's

efforts in developing multiple lines of evidence to construct a “safety case” for the proposed repository. The DOE develops such a case in the *RSS*, now being revised. The DOE’s safety case rests on six elements, or “pillars”: performance-assessment calculations, safety margins, defense-in-depth, explicit consideration of potentially disruptive events, insights from natural analogs, and performance confirmation.

In the Board’s view, the pillars of the *RSS* do not yet satisfy the goal of providing multiple lines of evidence and do not substantially increase confidence that a repository at Yucca Mountain will perform as anticipated. Four of the pillars—performance-assessment calculations, safety margins, defense-in-depth, and analyses of disruptive events—as currently presented are not independent of each other. They are all dependent on performance assessment. Thus, if one lacks confidence in the DOE’s performance assessment, one is not likely to have much confidence in any of the four pillars. The last two pillars of the repository safety case—natural analogs and performance confirmation—are independent of performance-assessment calculations. However, the DOE’s evaluation of natural analogs so far has been minimal, and performance confirmation is simply a plan of activities that will be subject to future budget and time constraints.

The Board has endorsed the DOE’s use of performance assessment-calculations, but it has noted the limits of those calculations and has expressed doubt that relying solely on them to demonstrate repository safety will ever be possible. Multiple lines of evidence that are not subject to the same limitations of performance assessment can increase confidence in performance projections. The DOE’s safety case has not yet accomplished those important ends.

Finally, as part of its approach to demonstrating defense-in-depth, the DOE conducted neutralization analyses. The analyses show the effect on the calculated dose of neutralizing or removing different barriers. We point out above the need to clarify this effort. We also note that a useful supplement to this approach would be to see the incremental effect on dose of adding individual barriers. In other words, the analysis would start off by estimating the dose, assuming that the radioactive waste was lying exposed at the surface. Individual elements of the geologic and engineered system then would be added, and resulting dose estimates would be calculated until the repository system reached its proposed form. Such an analysis could give interested parties a clearer picture of how much each individual element adds to repository performance.

Appendix F

Other Board Communications

Letter from Chairman Jared L. Cohon to Jim Wells; Director; Energy, Resources, and Science Issues; United States General Accounting Office; July 21, 2000.

Subject: Repository Design.

Letter from Rep. Joe Barton, Chairman, Subcommittee on Energy and Power, Committee on Commerce, United States House of Representatives, to Debra S. Knopman, Board member; July 20, 2000.

Subject: Appearance before Subcommittee on Energy and Power on June 23, 2000. Questions for NWTRB enclosed as attachment.

Letter from Chairman Jared L. Cohon to Rep. Joe Barton, Chairman, Subcommittee on Energy and Power, Committee on Commerce, United States House of Representatives; August 31, 2000.

Subject: Response to questions for NWTRB attached to July, 2000, letter from Rep. Barton to Debra S. Knopman.



UNITED STATES
NUCLEAR WASTE TECHNICAL REVIEW BOARD

2300 Clarendon Boulevard, Suite 1300
Arlington, VA 22201-3367

July 21, 2000

Mr. Jim Wells
Director
Energy, Resources, and Science Issues
United States General Accounting Office
Washington, D.C. 20548-0001

Dear Mr. Wells:

In your recent report for Senator Pete Domenici, *Radiation Standards: Scientific Basis Inconclusive, and EPA and NRC Disagreement Continues*, you referred to the views of the Nuclear Waste Technical Review Board (Board) about the design for the proposed Yucca Mountain high-level waste repository. I believe that your report is misleading in two respects. First, by stating that the Board "favors" a below-boiling repository design, your report creates a mistaken perception that the Board has recommended a particular design to the Department of Energy (DOE). Second, your report creates a mistaken perception of the cost of alternative repository designs.

Consistent with its mandate from Congress, the Board has followed closely the evolution of the DOE's repository design. The Board has stated that the choice of design could reduce the uncertainties in projecting repository performance for thousands of years. It also has stated that there is not yet a strong technical basis for selecting an above-boiling repository design. Thus, the Board has recommended that the DOE evaluate (among other things) the magnitude of uncertainty associated with alternative designs having different thermal characteristics. However, contrary to the impression created by your report, the Board has never recommended that the DOE select either an above-boiling or a below-boiling design. In fact, in its June 2000 testimony before the House Commerce Subcommittee on Energy and Power, the Board explicitly stated that "more thorough analysis is needed before any judgment is made about the optimal thermal conditions for repository operation."

Your report also stated that a below-boiling design "could add about \$2 billion to the costs" of developing a repository at Yucca Mountain. At the Board's meeting in May 2000, the DOE presented some preliminary results and cost estimates related to its evaluation of alternative thermal designs. That analysis suggests that the incremental discounted cost of implementing a below-boiling (as opposed to an above-boiling) design might be as low as \$600 million. If, for example, different assumptions are adopted about the distance between repository tunnels, the incremental cost might be reduced even further. This type of evaluation, stimulated by a Board recommendation, will likely help the DOE to understand better the technical and economic trade-offs associated with alternative repository designs. Such an understanding is essential for a sound decision, regardless of what regulatory standard is ultimately established.

Regrettably, the Board was not given the opportunity to comment on a draft during your report's preparation. We strongly encourage your office to contact the Board to ensure that possibly misleading impressions of Board positions are not created.

Sincerely,

{Signed by}

Jared L. Cohon
Chairman

cc:
The Honorable Pete V. Domenici
Dr. Ivan Itkin

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U.S. House of Representatives
Committee on Commerce
Room 2125, Rayburn House Office Building
Washington, DC 20515-6115

July 20, 2000

JUL 26 2000

Dr. Debra S. Knopman
Board Member
U.S. Nuclear Waste Technical Review Board
2300 Clarendon Boulevard
Suite 1300
Arlington, VA 22201

Dear Dr. Knopman:

I am writing to thank you for appearing before the Subcommittee on Energy and Power on June 23, 2000, to present testimony on the status of the Department of Energy (DOE) program to develop a permanent geologic repository at Yucca Mountain, Nevada for spent nuclear fuel and high-level radioactive waste. Your testimony allowed the Subcommittee Members to gain a better understanding of this extremely important issue.

Pursuant to the Chair's order of June 23, 2000, the record of the Subcommittee's hearing remains open to permit Members to submit questions to witnesses in writing. Attached you will find questions submitted by Members of the Subcommittee. I would appreciate it if you could respond to these questions in writing no later than the close of business on August 18, 2000 in order to facilitate the printing of the hearing record.

Thank you again for your time and effort in preparing and delivering testimony before the Subcommittee.

Sincerely,



Joe Barton
Chairman

Subcommittee on Energy and Power

Attachment

QUESTIONS FOR THE RECORD FROM MR. BARTON FOR NWTRB

- 1. Is the Technical Review Board concerned that funding constraints are causing DOE to postpone or skip critical technical analyses necessary to support the site recommendation and licensing decisions? If so, please identify the specific areas that are not being addressed adequately by DOE.**
- 2. Is it correct that the Technical Review Board is concerned that DOE is not paying enough attention to the uncertainties inherent in the repository's long-term performance, especially with respect to the "hot" repository design?**
- 3. How would the Board suggest that DOE should take these uncertainties into account -- is this a matter of DOE actually changing its repository design, or merely a matter of presenting this uncertainty information to the decision-makers?**
- 4. When does the decision on hot versus cool repository design have to be made? Can DOE leave this decision open into the licensing phase?**
- 5. A recent GAO report on radiation standards suggested that the cooler repository design favored by the Board could add \$ 2 billion to the cost of the repository. What is the basis for that statement by GAO, and is that estimate correct?**
- 6. Please identify any other outstanding technical issues with the repository design that, in the Board's view, are not being addressed adequately by DOE. Explain these concerns fully, and make recommendations on actions that DOE and the Congress should take to resolve these issues.**



UNITED STATES
NUCLEAR WASTE TECHNICAL REVIEW BOARD
2300 Clarendon Boulevard, Suite 1300
Arlington, VA 22201-3367

August 31, 2000

Honorable Joe Barton
Chairman
Subcommittee on Energy and Power
Committee on Commerce
U.S. House of Representatives
Room 2125, Rayburn House Office Building
Washington, DC 20515-6115

Dear Mr. Barton:

Enclosed are responses to the questions posed in your letter of July 20, 2000, to Dr. Debra Knopman following her appearance before the Subcommittee on Energy and Power on June 23, 2000. The Board provides independent advice on the technical issues associated with the management of the country's commercial spent nuclear fuel and defense high-level radioactive waste. The Board offers its technical views to help inform the larger consideration of issues that faces the Department of Energy and the Congress in their evaluation of the suitability of the Yucca Mountain candidate repository site.

The Board is keenly aware that many of the issues that must be considered in making decisions in this policy area are technical ones, but others are not. Regarding site suitability, we believe that Congress and the Secretary will find it useful to have our views on the adequacy of current information to technically support a possible site recommendation. As noted in our responses, a site recommendation can be made at any time, depending in part on how much uncertainty policy-makers are prepared to accept.

Please let me or the Board's staff know if we can provide you or your staff with any additional information on the enclosed responses.

Sincerely,

{Signed by}

Jared L. Cohon
Chairman

Enclosure

**NUCLEAR WASTE TECHNICAL REVIEW BOARD RESPONSES TO
QUESTIONS FOR THE RECORD FROM MR. BARTON
AUGUST 31, 2000**

1. Is the Technical Review Board concerned that funding constraints are causing DOE to postpone or skip critical technical analyses necessary to support the site recommendation and licensing decisions? If so, please identify the specific areas that are not being addressed adequately by DOE.

The Board's congressional mandate is statutorily limited to reviewing the technical and scientific validity of Department of Energy (DOE) activities. Therefore, the Board has not examined the details of DOE's budget for Yucca Mountain research or its funding allocations for program operation, management, procurement, and contracting. Consequently, the Board cannot judge the extent to which the Yucca Mountain site characterization and repository design activities have been or will be constrained by budget limitations. What is clear, however, is that the Board's present understanding of a potential repository located at Yucca Mountain is affected by many policy-related factors, including congressional appropriations, DOE's research and program priorities, and statutory and administrative deadlines, as well as the significant challenge of undertaking a first-of-a-kind activity.

Because less than a year remains before the scheduled site-recommendation decision in July 2001, the amount of additional scientific and technical work that can be completed by that date is very limited. Thus, the information available in July 2001 for a site recommendation will in all likelihood not be appreciably affected by whatever budget Congress passes for FY 2001. However, funding constraints in DOE's budget for FY 2001 and beyond could limit ongoing and new work that might support a DOE license application for repository construction.

The Board reviews the scientific and technical program as it is and makes its technical judgments accordingly. On the basis of information it has reviewed to date, the Board believes that the technical basis for DOE's current long-term projections of repository performance has critical weaknesses. These projections and their associated weaknesses reflect in part the DOE's "base-case" (above-boiling) repository design. Although the site may, in fact, merit a positive site recommendation, DOE has not yet demonstrated—for the base-case design—a firm technical basis for that conclusion.

Some of the current large uncertainties about waste package and repository performance are directly or indirectly related to the high (i.e., above-boiling) repository temperatures associated with DOE's current base-case design. High temperatures increase the level, extent, and significance of the combined, or "coupled," effects of thermal, hydrologic, mechanical, and chemical processes. Furthermore, the waste packages may be more vulnerable to corrosion at higher temperatures if water is present. The Board believes that it will be very difficult for the DOE to improve substantially its current understanding of these high-temperature effects during the next year or two. However, it may be possible over the next several months to reduce some uncertainties, for example, by developing a defensible technical basis for a lower-temperature repository design.

In addition to the effects of high temperatures, some uncertainties are related to a lack of fundamental understanding about physical processes that will extend over thousands of years; realistic predictions are therefore very difficult to make. For example, the performance of the waste packages over thousands of years has been extrapolated from a few years of corrosion data and too limited an understanding of fundamental corrosion processes. Finally, the characterization of the hydrogeology below the repository horizon, although supported by some data, continues to rest largely on inadequately supported hypotheses. As a result, for example, the flow and transport of radionuclides in the unsaturated and saturated zones from the repository to the accessible environment are poorly understood.

The Board believes that significantly improving the fundamental understanding of these natural features and engineered barriers during the next year or two will be very difficult. However, the Board believes that work in these areas is important and should continue. Because of the complexity of the Yucca Mountain site and the challenges involved in extrapolating data over long time periods, gaining such an understanding of these basic processes will take time. Continued adequate funding of these long-term studies will be important.

2. Is it correct that the Technical Review Board is concerned that DOE is not paying enough attention to the uncertainties inherent in the repository's long-term performance, especially with respect to the "hot" repository design?

The persistence of substantial uncertainties has led the Board over the last few years to recommend strongly that DOE develop a more technically defensible basis for making design, site-recommendation, and licensing decisions. In particular, the Board has recommended initiation of fundamental studies on long-term corrosion, evaluation of alternative repository designs, improved characterization of rock formations in the vicinity of Yucca Mountain, examination of radionuclide retardation in the unsaturated and saturated zones below the repository horizon, evaluation of colloidal transport, and investigation of the effect of structures and heterogeneities on water movement above and below the water table. DOE has responded to many of the Board's suggestions, but it has not yet completed all of those studies. Although the Board is encouraged by the level of attention DOE is now giving to the quantification and characterization of uncertainty in estimating repository system performance, the Board also continues to have concerns in this area.

The Board realizes that projecting long-term performance of a potential repository at Yucca Mountain, or anywhere else for that matter, is inherently associated with uncertainty. Eliminating all the uncertainties will never be possible (although they can be reduced). In fact, the Board has noted that a site recommendation can be made at any time, depending in part on how much uncertainty policy-makers are prepared to accept. The timing of the site recommendation, of course, is clearly beyond the Board's charge.

As noted in the answer to question #1, on the basis of information reviewed to date, the Board believes that the technical basis for DOE's current long-term projections of repository performance has critical weaknesses. These projections and their associated weaknesses reflect in part the DOE's base-case (above-boiling) repository design. The Board explicitly raised this concern about above-boiling repository designs in a July 9, 1999, letter to DOE's Office of Civilian Radioactive Waste Management. Although the site may, in fact, merit a positive site

recommendation, DOE has not yet demonstrated—for the base-case design—a firm technical basis for that conclusion.

Adopting a lower-temperature repository design for commercial spent fuel might mitigate some of the weaknesses associated with projections of long-term repository performance, such as problems associated with coupled processes. A lower-temperature repository design could make projections of performance less dependent on areas where scientific understanding is incomplete. Therefore, DOE should augment its current design evaluations with a rigorous and persuasive evaluation of the performance of, and trade-offs associated with, alternative repository designs, including assessing the effects of the following factors on performance and uncertainty: age of waste at emplacement, spacing between waste packages, ventilation rates and efficiencies, and time before repository closure. It is possible, but not certain, that a cooler, drier, and simpler design than the current base-case design would lower the technical hurdles that DOE now faces in projecting long-term waste package and repository performance.

DOE, however, has not yet carried out a sufficiently thorough evaluation of low-temperature repository designs. By carrying out such an evaluation, DOE would develop a much better understanding of how the thermal characteristics of different designs may affect critical uncertainties (e.g., those associated with coupled processes, the stability of the passive layer of Alloy 22, and the waste package environment). But the magnitude of other uncertainties, such as those associated with the saturated zone under the repository, are very likely to be independent of the facility's design.

3. How would the Board suggest that DOE should take these uncertainties into account— is this a matter of DOE actually changing its repository design, or merely a matter of presenting this uncertainty information to the decision-makers?

DOE intends to base its site-recommendation decision primarily on the results of a total system performance assessment (TSPA), a complex computer model that estimates repository performance many thousands of years into the future. The technical soundness of DOE's site-recommendation decision will therefore depend to a large extent on the technical validity of its TSPA. Put another way, policy-makers' confidence in performance assessment reflects in many ways the level of uncertainty associated with estimates of performance: the greater the uncertainty, the lower the confidence in repository performance may be.

There are several internationally recognized strategies for managing or reducing uncertainties. One strategy involves using "conservative" assumptions and parameters throughout the performance assessment. Thus, if the assessment is in error, the long-term performance of the repository is underestimated, not overestimated. A second strategy involves using multiple lines of evidence independent of performance assessment in developing a "repository safety case." A third strategy involves making repository design choices that minimize uncertainties.

DOE has made progress in implementing each of these three strategies, but it can—and should—do more. For example, it is difficult to know whether the assumptions and parameters used in DOE's performance assessments are truly conservative or how the combination of conservative, optimistic, and realistic estimates affects overall dose calculations and the uncertainties associated with those calculations. As noted in the response to question #6, DOE has not yet

completed the evaluation of independent lines of evidence—an evaluation that is needed to increase confidence in the conclusions of its safety case derived from performance assessment. Finally, as noted in the answer to question #2, DOE has not yet performed a rigorous and persuasive analysis of how uncertainty in repository performance varies with repository design.

Regardless of what strategies are used to manage or reduce uncertainty, the Board believes that DOE's projections of repository performance will be incomplete unless DOE also provides a description and a meaningful quantification of the level of uncertainty associated with its predictions. DOE then will be in a better position to make important decisions, including choosing waste package and repository designs having acceptable predictions of performance, and decision-makers will be able to make technically informed choices related to the DOE's work at Yucca Mountain.

4. When does the decision on hot versus cool repository design have to be made? Can DOE leave this decision open into the licensing phase?

For DOE to make a positive site recommendation, the Board believes that DOE would need to make a technically defensible argument that at least one repository design concept, including firm operational assumptions, will perform satisfactorily for thousands of years. Such an argument would presumably consider the associated levels of uncertainty in repository performance. Therefore, the Board assumes that DOE would describe for the site recommendation at least one design concept and a set of operational assumptions with sufficient specificity so that sound and complete assessments of performance can be developed.

The Nuclear Regulatory Commission, of course, will determine whether the particular detailed design or designs used in DOE's license application will, in fact, provide reasonable assurance of satisfactory performance to warrant constructing a facility.

5. A recent GAO report on radiation standards suggested that the cooler repository design favored by the Board could add \$2 billion to the cost of the repository. What is the basis for that statement by GAO, and is that estimate correct?

The statements in the GAO report are misleading in two respects. First, although the Board noted in July 1999 that the technical basis supporting any above-boiling repository design was, in its opinion, not strong enough, the Board is not in a position to *recommend* a specific design alternative. In fact, in its June 23, 2000, testimony before the Subcommittee, the Board explicitly stated, "... more thorough analysis is needed before any judgment is made about the optimal thermal conditions for repository operation."

Second, at the Board's meeting in May 2000, DOE presented some preliminary results and cost estimates related to alternative thermal designs. That analysis suggested that the incremental discounted cost of implementing a below-boiling (as opposed to an above-boiling) design may be as low as \$600 million. If, for example, different assumptions were adopted about the distance between repository tunnels, the incremental cost might be reduced even more. This type of result, stimulated by a Board recommendation, is likely to help DOE understand better the technical and economic trade-offs associated with alternative repository designs. Such an

understanding is essential for making a sound decision, regardless of what regulatory standard is ultimately established.

6. Please identify any other outstanding technical issues with the repository design that, in the Board's view, are not being addressed adequately by DOE. Explain these concerns fully, and make recommendations on actions that DOE and the Congress should take to resolve these issues.

Unfortunately, DOE's models are not well enough developed or supported by sufficient data to differentiate between the performance of below-boiling and above-boiling repository designs over the next several thousand years. To develop the tools necessary for evaluating these differences, DOE would have to increase substantially its understanding of the coupled thermal, hydrologic, mechanical, and geochemical processes taking place within the repository; the mechanisms and paths by which radionuclides could be transported from the repository tunnels into the unsaturated and saturated zones below; and the data and fundamental knowledge used to project the long-term corrosion susceptibility of waste packages.

Although the Board has endorsed the use of TSPA, in an April 1999 report the Board noted the limits of TSPA calculations and expressed doubt that relying "solely on [performance assessment] to demonstrate repository safety" will ever be possible. Therefore, the Board recommended in this report that DOE develop multiple lines of evidence that can supplement performance assessment.

DOE is working on a repository safety case that is designed to increase confidence that a repository at Yucca Mountain is likely to perform as predicted. The strategy currently rests on six "pillars": performance-assessment calculations, safety margins, analysis of disruptive events, defense-in-depth, natural analogs, and performance confirmation during and after waste emplacement. On the surface, these pillars may appear to satisfy the Board's recommendation that DOE develop multiple lines of evidence that can supplement performance assessment. A closer look suggests otherwise.

To begin with, four of the pillars—performance-assessment calculations, safety margins, defense-in-depth, and analysis of disruptive events—as currently presented are not independent of each other. They are all dependent on performance assessment. Thus, if one lacks confidence in DOE's performance assessment, one is not likely to have much confidence in any of the four pillars. The last two pillars of the repository safety case—natural analogs and performance confirmation—are independent of performance-assessment calculations. However, DOE's evaluation of natural analogs so far has been minimal, and performance confirmation is simply a plan of activities that will be subject to future budget and time constraints.