

Appendix E

Communication Between U.S. Nuclear Waste Technical Review Board and U.S. Department of Energy

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

The OCRWM typically responds to the Board's reports and letters, indicating its plans to respond to the Board's recommendations. Included here are the OCRWM's responses received by the Board during calendar year 2001. Inclusion of these responses does not imply the Board's concurrence.

- Letter from Chairman Jared L. Cohon to Lake H. Barrett, Acting Director, OCRWM; March 30, 2001.
Subject: Board reactions to presentations at January 2001 Board meeting and statement of Board priorities.
- Letter from Chairman Jared L. Cohon to Lake Barrett, Acting Director, OCRWM; June 11, 2001.
Subject: Results of the *Ad Hoc* Panel meeting on multiple lines of evidence.
- Letter from Chairman Jared L. Cohon to Jane R. Summerson, EIS Document Manager, Yucca Mountain Site Characterization Office; July 2, 2001.
Subject: Board comments on DOE supplement to the draft environmental impact statement for a geologic repository at Yucca Mountain, Nevada.
- Letter from Daniel B. Bullen, Board member, to Stephan J. Brocoum, Assistant Manager, Office of Licensing and Regulatory Compliance, Yucca Mountain Site Characterization Office; July 2, 2001.
Subject: Board reaction to presentations at the Board Joint Panel meeting on the DOE *Supplemental Science and Performance Analysis*, June 20-21, 2001.
- Letter from Chairman Jared L. Cohon to Lake Barrett, Acting Director, OCRWM; July 17, 2001.
Subject: Board reactions to presentations at May 2001 Board meeting.
- Letter from Lake H. Barrett, Acting Director, OCRWM to Chairman Jared L. Cohon; September 7, 2001.
Subject: Department of Energy Responses to the July 17, 2001 letter.
- Letter from Chairman Jared L. Cohon to Lake H. Barrett, Acting Director, OCRWM; October 16, 2001.
Subject: Board response to request for comments on the *Yucca Mountain Preliminary Site Suitability Evaluation*.

- Letter from Chairman Jared L. Cohon to Lake H. Barrett, Acting Director, OCRWM; October 17, 2001.
Subject: Board reactions to presentations at September 2001 Board meeting.
- Letter from Lake H. Barrett, Acting Director, OCRWM to Chairman Jared L. Cohon; November 20, 2001.
Subject: Department of Energy Responses to the October 17, 2001 letter.
- Letter from Chairman Jared L. Cohon to Spencer Abraham, Secretary, U.S. Department of Energy; December 11, 2001.
Subject: Board comments on the technical and scientific validity of work at the Yucca Mountain site.
- Letter from Lake H. Barrett, Acting Director, OCRWM to Chairman Jared L. Cohon; December 18, 2001.
Subject: Department of Energy Responses to the December 11, 2001 letter.



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

March 30, 2001

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

Dear Mr. Barrett:

On behalf of the Nuclear Waste Technical Review Board, I would like to convey our reactions to the presentations made by the Department of Energy's (DOE) Yucca Mountain Project personnel at the Board's January meeting in Amargosa Valley.

Overall, the Board was pleased with the quality of the presentations. A wealth of information was conveyed succinctly. Difficult concepts and models were described clearly and in a manner that was easily understood by a broad range of listeners. In particular, the Board commends Gerald Gordon, Gudmundur Bodvarsson, Al Eddebbarh, Robert Andrews, and Paul Harrington, who responded directly and candidly to specific questions posed in advance by the Board. They were all instrumental in making the meeting a success. The Board anticipates using this new format at future meetings.

As you will recall, at the beginning of the meeting, I read into the record a statement of Board priorities. I noted that the Board

... has recommended that DOE focus significant attention on four priority areas dealing with managing uncertainty and coupled processes, which, in the Board's view, are essential elements of any DOE site recommendation.

- (1) Meaningful quantification of conservatisms and uncertainties in DOE's performance assessments
- (2) Progress in understanding the underlying fundamental processes involved in predicting the rate of waste package corrosion
- (3) An evaluation and comparison of the base-case repository design with a low-temperature design

(4) Development of multiple lines of evidence to support the safety case of the proposed repository. These lines of evidence should be derived independently of performance assessment and thus not be subject to the limitations of performance assessment.

In addition to these overarching priorities, the Board has made a number of suggestions about other investigations and studies that can support, complement, and supplement these four areas. Those investigations and studies include research on the unsaturated and saturated zones as well as work to make the performance assessments more transparent and informative. As the Board continues its review of DOE's technical activities, other elements essential to the site recommendation may be identified.

Although schedule considerations may preclude completing all work before the site recommendation decision, the Board believes it is reasonable to assume that the more those investigations have advanced, the more likely it is that the technical basis for the decision will be strengthened. In what follows, the Board comments on each area.

Meaningful Quantification of Uncertainties and Conservatism

The Board is pleased with the efforts made so far to quantify better the uncertainties and conservatism present in the performance assessments of the proposed Yucca Mountain repository. However, aside from the consideration of early failures of the waste packages, there seems to be no explicit consideration of possible differences that may evolve over time between performance of the engineered barrier systems as they have been designed and their performance as they actually may be built.

Progress in Increasing Fundamental Understanding of Corrosion Processes

The Board commends the project for developing a set of investigations that could lead to improved understanding of the fundamental processes relevant to waste package corrosion, especially the stability of the passive layer of Alloy 22. The Board is pleased that many of these investigations have started and encourages the project to begin the others as soon as possible and to expedite work in this area.

Evaluation and Comparison of Repository Designs

In its June 23, 2000, testimony before the House Subcommittee on Energy and Power, the Board observed: "Understanding the differences in estimated performance and associated uncertainties under different temperature conditions is an important component of our overall understanding of potential repository performance at the Yucca Mountain site." At its January 2001 meeting, the Board made its position more explicit when it called for an evaluation and a comparison of repository designs. We understand that work in this area has begun.

The Board is interested in obtaining an evaluation and a comparison of the base-case, high-temperature repository design with a low-temperature, ventilated design. Evaluating a possible low-temperature, ventilated design could clarify the advantages—and disadvantages—associated with keeping waste package temperatures below, say, 85° C. In particular, the Board believes that DOE should use performance assessment to evaluate a low-temperature, ventilated design concept. If necessary, performance assessment models should be modified to portray accurately the effects of temperature changes on performance. Associated levels of uncertainty in repository performance should be developed for both high- and low-temperature design concepts. The Board realizes that DOE also may want to examine other design-related considerations, including licensability, operations and logistics, flexibility, cost, etc. The more technically defensible and quantitative the evaluation and comparison, the more useful it will be for policy-makers.

Development of Multiple Lines of Evidence

The project's latest revision of its *Repository Safety Strategy* appears to be an improvement over the previous iteration. As was observed in the project's presentation, however, more work needs to be done to identify or develop multiple lines of evidence to supplement and support the safety strategy. The Board is encouraged that the project recognizes the importance of this work and is pleased that the Board and the project will be holding a public meeting on April 13, 2001, in Arlington, Virginia, to explore specifically what further steps might be taken.

Other Issues

The Board also has some specific reactions to several of the presentations (listed here generally in order of increasing specificity).

- The Board is concerned that project descriptions of short-term testing are not cast broadly enough. Testing plans mostly appear to be directed at developing better parameter estimates for performance assessment. Although better parameter estimates are necessary, the Board also would like to see testing of fundamental scientific concepts, particularly when such tests can challenge accepted models. Moreover, the project should specify better what it would do with the results of its tests.
- The project's development of a long-term, comprehensive "test and evaluation" plan is a step in the right direction. The plan, however, appears to be very general in nature. The Board believes that a much more detailed and well-integrated plan would significantly enhance the quality of the site recommendation decision. Such a plan, among other things, should detail how testing after repository closure would occur, including relevant monitoring activities.

- The project recognizes the importance of incrementally adjusting proposed repository design and operations in response to new technical information. Such a strategy makes sense, and indeed, the Board encourages the program to continue thinking along these lines. However, the implementation of such an incremental learning and adjustment process is neither easy nor straightforward. The Board looks forward to hearing more from the project about this issue in the future.
- The project needs to continue efforts to reconcile the conflicting chlorine-36 findings. Because DOE seems to believe that the conflict results from different sample-preparation methodologies, the project should develop a technically defensible strategy, implemented in a sound, peer-reviewed process, for deciding which methodology is more appropriate for the problem being investigated and for identifying which findings are more valid.
- The Board is pleased that the project will be undertaking a peer review of the performance assessment used in the site recommendation decision as well as a peer review of the project's material testing plans.
- There is still some confusion about "degraded" and "neutralized" barrier studies and about the consistent application of these terms to the different components of the repository system. The project should reexamine these studies and consider implementing an approach recommended in the Board's September 20, 2000, letter to Dr. Ivan Itkin. Under such an approach, the analysis would start off by estimating the dose, assuming that the radioactive waste is lying exposed at the earth's surface. Individual elements of the geologic and engineered systems then would be added, and resulting dose estimates would be calculated until the repository system reaches its completed form.
- Questions remain about the compositions and corrosion effects of electrolytes that may form on waste package surfaces. The Board urges the project to continue its investigations in this area and to ensure, in particular, that electrolytes chosen for future testing represent environments derived from repository pore water (as opposed to J-13 water) in its evolved state. That evolved state includes the effect of thermally driven processes caused by the decay heat from the waste and interactions with condensate, seepage, dust that may settle on waste packages during ventilation, and the engineered system materials themselves. The Board also reiterates its belief that long-term projections from performance testing in model solutions must be supported by sound mechanistic understanding, including theoretical development and experimental evaluation of theories.

In conclusion, the Board appreciates the project's responsiveness to its concerns, especially considering the importance of rapidly approaching project milestones. The Board looks forward in the next few months to commenting on specific project plans for additional technical studies and to interacting productively with project personnel.

Sincerely,

{Signed by}

Jared L. Cohon
Chairman



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NUCLEAR WASTE TECHNICAL REVIEW BOARD
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June 11, 2001

Mr. Lake Barrett
Acting Director, Office of Civilian Radioactive Waste Management
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1000 Independence Avenue, SW
Washington, DC 20585

Dear Mr. Barrett:

The U.S. Nuclear Waste Technical Review Board (Board) thanks you for your opening comments and for supporting the participation of personnel from the Department of Energy (DOE) and its contractor team at the April 13, 2001, meeting on developing multiple lines of evidence. The Board is pleased to provide you with its impressions of that meeting.

As you know, the Board's view is that developing multiple lines of evidence is an essential element of any site recommendation decision by the DOE. Board members and representatives of the DOE who participated in the meeting agreed that some multiple lines of evidence could increase the level of confidence in the projections of repository behavior derived from the DOE's integrated performance assessment of Yucca Mountain. However, the Board believes that other lines of evidence could reduce confidence in the conclusions of performance assessment. Therefore, the DOE should indicate which performance assessment conclusions are supported by multiple lines of evidence, which are contradicted by multiple lines of evidence, and which are not supplemented at all by multiple lines of evidence.

There seemed to be agreement on potential approaches that the DOE might take to develop multiple lines of evidence, such as natural and anthropogenic analogues, simplified calculations, direct observation and measurement, first principles, and laboratory and field testing of predictions. (Of course, the last two approaches should be an integral part of any rigorous model development program as well.) The choice of approaches used will need to be determined on a case-by-case basis; none of the approaches appears to be inherently superior to any other.

The more these lines of evidence can be derived independently of performance assessment, the more they can serve as a "check" on the conclusions of performance assessment. Multiple lines of evidence that provide insights into phenomena whose uncertainty significantly affects estimates of repository performance are especially useful. Furthermore, the Board was encouraged to hear from DOE representatives that a case for multiple barriers and defense-in-depth might be advanced using lines of evidence other than performance assessment.

In the final analysis, however, the meeting demonstrated to the Board that talking about multiple lines of evidence in the abstract is less useful than examining specific examples that reinforce (or call into question) a particular scientific conclusion. The technical basis of the site recommendation decision for the proposed Yucca Mountain repository would be strengthened by

the extensive use of such examples. William Dudley's thoughtful analysis of multiple lines of evidence corroborating the estimate of mean present-day infiltration is a good model for what the Board has in mind.

The DOE also mentioned other possible approaches for developing multiple lines of evidence, such as confirmatory monitoring, additional field-testing after licensing approval, and peer review. Although each of these latter approaches can improve the technical rigor of performance assessment models and assumptions, the Board would view these approaches as carrying less weight for site recommendation than physically based lines of evidence assembled before the site recommendation.

The Board appreciates the DOE's participation in this meeting and looks forward to additional interactions as the DOE develops multiple lines of evidence to broaden the basis of its repository safety case.

Sincerely,

{Signed by}

Jared L. Cohon
Chairman



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July 2, 2001

Jane R. Summerson, EIS Document Manager
Yucca Mountain Site Characterization Office
Office of Civilian Radioactive Waste Management
U.S. Department of Energy
P.O. Box 30307, M/S 010
North Las Vegas, NV 89036-0307

Dear Dr. Summerson:

The Nuclear Waste Technical Review Board appreciates the opportunity to comment on the Department of Energy's (DOE) recently published supplement to its draft 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 believes that the technical basis for projecting the long-term performance of the base-case (high-temperature) repository design has weaknesses. They include the apparently large uncertainties in projections of repository performance caused by the relatively high temperatures produced by the base-case design. The Board has urged the DOE to evaluate a low-temperature design so that its performance (and uncertainties in performance) can be compared with that of the high-temperature design. The DOE decided to address this area of Board concern by taking a single general repository design (referred to as the "Science and Engineering Report [S&ER] flexible design") and comparing its performance and associated uncertainties when it is operated at a high temperature and at a representative lower temperature. This choice was influenced, in part, by the fact that the same process models and performance assessments could be used to evaluate both the higher- and the lower-temperature design concepts. Information in the *Supplemental Science and Performance Assessment* report should provide some indication of the validity of this analytical approach. The final EIS should justify use of the S&ER design operated in a low-temperature mode as a surrogate for a true low-temperature design for purposes of projecting environmental effects, especially long-term releases of radionuclides to the environment.

The supplement to the draft EIS shows, in Table 3-14, that the peak annual dose and the time of the peak are exactly the same for the higher- and lower-temperature operating modes. Because corrosion rates, coupled processes, and the size of the repository footprint are likely to be temperature-dependent, the Board is concerned that this result may reflect model limitations. In its September 2000 letter to the DOE,^{*} the Board identified a number of limitations in the

* Letter from Jared L. Cohon, Board chairman, to Dr. Ivan Itkin, dated September 20, 2000.

DOE's performance assessment models that could hinder an accurate prediction of the effects of temperature on repository performance. The Board recommends that the DOE revise its performance assessment models to capture the effects of temperature more accurately, allowing an improved assessment of the merits of higher-temperature versus lower-temperature repository designs.

Section 3.2.3 discusses the predicted long-term performance of a Yucca Mountain repository. According to this section, predicted radiation doses during the first 10,000 years are zero "... because waste packages would remain intact for more than 10,000 years." Unclear from this section is whether the analysis considered the potential for defective waste packages to be produced that could fail in less than 10,000 years, potentially causing radiation doses earlier than predicted in the supplemental draft EIS. The final EIS should discuss the potential for early (first 10,000 years) waste package failures.

For the S&ER design, the waste packages may contain more potentially toxic metals, such as chromium and nickel, because stainless steel has replaced carbon steel as a component of the packages. The final EIS should provide new estimates of the concentrations of these elements that humans could be exposed to through groundwater near Yucca Mountain and should evaluate the potential cumulative public health and environmental hazards that could occur if groundwater also contains radionuclides released from a Yucca Mountain repository.

The Board realizes that the potential environmental impacts of transportation were addressed in the draft EIS and that those impacts are not the subject of this supplemental draft EIS. The Board previously offered its views on transportation impacts when it commented on the draft EIS and expects the DOE to respond to those comments when it prepares the final EIS.

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

Sincerely,

{Signed By}

Jared L. Cohon
Chairman



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July 2, 2001

Dr. Stephan J. Brocoum
Assistant Manager, Office of Licensing and Regulatory Compliance
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Dear Dr. Brocoum:

On behalf of the Nuclear Waste Technical Review Board, I thank you and your staff for their very hard work in preparing for and presenting material at the joint June 20-21, 2001, meeting in Las Vegas of the Board's Panel on Performance Assessment and Panel on the Repository. The meeting was completely devoted to the Department of Energy's *Supplemental Science and Performance Analyses (SSPA)*. Clearly, a great deal of work has been carried out, and the DOE appears to have been very responsive in addressing the Board's four priority areas.

The meeting was very interesting, and the presentations stimulated many questions. We appreciate DOE management's willingness to present and discuss the *SSPA* before it becomes final. The Board is looking forward to receiving the final version of the *SSPA* so that we may gain a better understanding of the new information, models, and assumptions presented. Any comments that the Board may have on the *SSPA* will be made subsequent to our evaluation of the material in the final version of the report.

Again, please convey our appreciation to all the presenters.

Sincerely,

{Signed by}

Daniel B. Bullen
Chair, Panel on the Repository
Chair, Panel on Performance
Assessment

cc.
Lake H. Barrett
J. Russell Dyer



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July 17, 2001

Mr. Lake Barrett
Acting Director
Office of Civilian Radioactive Waste Management
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1000 Independence Avenue, SW
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Dear Mr. Barrett:

On behalf of the Nuclear Waste Technical Review Board, thank you for attending and supporting the Board's meeting in Arlington, Virginia, on May 8 and 9, 2001. This letter conveys the Board's reactions to the presentations made by the Department of Energy (DOE) and its Yucca Mountain Project contractor team at that meeting.

Meaningful Quantification of Uncertainties and Conservatisms

The Board is encouraged by the work being undertaken by the Project to quantify uncertainties and conservatisms in its performance assessments (PA). The work appears to be responsive to the concerns that the Board has voiced in the past. The Board will have more detailed comments on this issue when it completes its review of the *Supplemental Science and Performance Analyses (SSPA)* report.

Dealing adequately with uncertainty inherent in a large and complex system is challenging and requires many difficult analytical judgments. The Board has two concerns in this regard. First, the Project may be dismissing some sources of uncertainty prematurely simply because they seem to have very minor effects on the performance of a particular barrier or component. One purpose of carrying out a PA is to gain insights into the behavior of the system as a whole that cannot necessarily be gleaned from looking at the subsystems alone. Some subsystems may have nonlinear interactions. Second, even if uncertainty in a single component or barrier does not have a large effect on final dose calculations, it may, together with other "minor" uncertainties, have a nonnegligible cumulative effect. As the questions from the Board at the meeting suggest, the criteria for including some variables and not others in the next round of PA are not clear.

Progress in Understanding the Underlying Fundamental Processes of Corrosion

The Board continues to believe in the importance of developing an understanding of underlying physical phenomena of corrosion processes. Although obtaining better model parameters has obvious appeal in the short run, the Board continues to have concerns about the validity of the underlying models. We are encouraged that the Nuclear Regulatory Commission's Center for Nuclear Waste Regulatory Analyses is trying to develop insights into conceptual models of corrosion processes.

The Board is pleased that the Project will obtain an independent peer review in this area and urges the Project to make the review process as open and accessible as possible to interested and affected parties. The review will complement the international workshop on long-term extrapolation of passive behavior of metals that the Board will sponsor in July.

Evaluation and Comparison of Base-Case and Low-Temperature Repository Designs

In its response to a written question from Representative Joe Barton last August, the Board concluded that the technical basis for projecting the long-term performance of the Project's base-case (high-temperature) repository design has "critical weaknesses." These weaknesses include the apparently large uncertainties associated with projections of repository performance that are due to the relatively high temperatures produced by the base-case design. The Board therefore urged the Project to evaluate a low-temperature design and to compare its performance with the high-temperature design as a means of gaining further insights into system performance and reducing key uncertainties.

The Project decided to address this area of Board concern by taking a single general repository design and comparing its performance and associated uncertainties when it is operated in a high-temperature mode and in a selected low-temperature mode. This choice was influenced, in part, by the fact that the same process models and PA's could be used to evaluate both modes.

It is premature to determine whether the Project's approach, presented at the May meeting and elaborated in a letter to the Board dated May 30, 2001, will address adequately the questions the Board raised. We look forward to examining closely the content of the *SSPA* to ascertain whether the Project actually has gained the needed further insight. In particular, the Board is looking for clarity of objectives, transparency in design evaluation and comparison (including the Project's choice of designs), adequacy of representations and analysis between natural and engineered systems, and technical defensibility of the underlying models included in PA.

Development of Multiple Lines of Evidence to Support the Proposed Repository Safety Case

The presentation on multiple lines of evidence was candid and gave the Board specific and useful information. The Board is encouraged that the Project now intends to develop

multiple lines of evidence more aggressively than it has in the past. The Board urges the Project to integrate those lines fully into its analyses and documents. As the Board stated in its June 11, 2001, letter on multiple lines of evidence, "...the DOE should indicate which [PA] conclusions are supported by multiple lines of evidence, which are contradicted by multiple lines of evidence, and which are not supplemented at all by multiple lines of evidence."

More specifically, analogues that provide insights into the areas that PA suggests have substantial uncertainty and effect on performance should be given priority. Thus, the Board encourages the Project to explore analogues, such as those at Peña Blanca, Paiute Ridge, and Yellowstone National Park. An examination of natural analogues to man-made metals, including, but not limited to, josephinite, also may be promising.

Observations About Other Technical Investigations

The Board believes that the Project continues to make important progress in gathering data and developing models that can be useful in supporting PA. The infiltration studies in the cross-drift and the development of more-sophisticated climate models are examples. Nevertheless, the Board reiterates its earlier comments about the importance of expeditiously resolving ambiguities in interpreting the source of moisture in the bulk-headed drift and in determining if bomb-pulse chlorine-36 has migrated to the repository horizon.

Furthermore, the Board is concerned that investigations needed to connect the near-field natural environment with the engineered repository system, such as studies of deliquescence of brines on the waste package and drip shield, colloid transport, and thermal conductivity of the lower lithophysal rock unit, still have not been completed.

Finally, the presentations at the meeting revealed what appeared to be an instance of poor communication among Project scientists, designers, and modelers. The repository layout described in the *Science and Engineering Report* extends over a new area that includes a part of the large hydraulic gradient, but the repository layout evaluated in the PA for site recommendation does not include this area. This inconsistency may have significant potential consequences. The Board urges the Project's management to understand why this occurred and to resolve whatever problems are discovered so that inconsistencies like this are prevented in the future.

The Board again thanks you and your colleagues for participating in its May meeting.

Sincerely,

{Signed by}

Jared L. Cohon
Chairman



Department of Energy
Washington, DC 20585

September 7, 2001

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

Dear Dr. Cohon:

We appreciate the Nuclear Waste Technical Review Board's letter of July 17, 2001 providing comments on the information we presented at the Full Board Meeting on May 8 and 9, 2001. Our responses to the specific comments raised in your letter with regard to the Board's priority issues and observations on other aspects of our technical program are enclosed.

We continue to value the Board's feedback and look forward to the Board's detailed comments on the Supplemental Science and Performance Analyses Report. If you have any questions, please contact me at (202) 586-6842.

Sincerely,

Lake H. Barrett, Acting Director
Office of Civilian Radioactive
Waste Management

Enclosure:
Department of Energy Responses to the
July 17, 2001 letter from Jared L. Cohon



DOE Responses to Comments and Concerns Raised in the July 17, 2001 letter from the Nuclear Waste Technical Review Board

Meaningful Quantification of Uncertainties and Conservatism-Inclusion/Exclusion of variables in performance assessment

The U. S. Department of Energy (DOE) agrees that the decision to include some variables, and not others, in the Total System Performance Assessment (TSPA) is important. Many of the subsystem level results described in Volume 1 of the Supplemental Science and Performance Analyses (SSPA) Report were abstracted and carried forward into the supplemental performance assessment model. Some new results were only evaluated through sensitivity analyses and were not included in the SSPA supplemental performance assessment model. Other results were only considered at the component model level. There are several reasons for not including a new parameter or model in the supplemental performance assessment model. These reasons include:

- low probability of occurrence
- no significant effect at the component model level
- no significant effect at the system level
- results are sufficiently uncertain so that inclusion would be non-conservative
- model is still conceptual

For example, the effects of coupled thermal-hydrologic-chemical (THC) processes on fracture porosity in the unsaturated zone were included in the subsystem model and described in the SSPA Report, Volume 1. However, the effects were not carried forward and evaluated in the supplemental performance assessment model, because the THC effects on fracture porosity were less than one percent for the higher-temperature operating mode and would be smaller for the lower-temperature operating mode. These changes are within the degree of uncertainty for this parameter and are thought to be insignificant. In addition, the effects of THC are relatively short-lived and local. Changes in the flow field at the mountain scale are influenced more by the boundary conditions, such as infiltration, rather than THC processes.

The DOE acknowledges that cumulative effects of uncertainties may have a non-negligible effect on performance. We will continue to re-evaluate the validity of the screening decisions as new data and refined models become available. We will also strengthen project reports to clearly articulate the rationale for including or excluding variables, related to features, events and processes, from evaluations of system-level performance.

Progress in Understanding the Underlying Fundamental Processes of Corrosion

The DOE agrees that it is important to develop an understanding of the underlying physical phenomena of corrosion processes. The DOE has implemented a detailed experimental program and development of a more advanced theoretical corrosion model to reduce uncertainties in the long-term performance of waste package and drip shield materials. Specific areas of study

include general corrosion, localized corrosion, waste package environmental conditions, and stability of passive films.

Long-term passive film stability is particularly important to long-term performance of the waste package. Additional theoretical and experimental work is ongoing to address specific processes that may affect the passive layer, including defect and debris accumulation in the passive layer and quasitranspassive dissolution.

The experimental program will provide data leading to a better understanding of the fundamental corrosion processes in passive materials such as Alloy 22 and confirm our ability to extrapolate short-term data to predict long term behaviors, which is important to postclosure performance. In addition, Alloy 22 samples that reflect heat lot variability are included in the test program to determine the effects of chemical compositional variations on alloy performance.

As noted by the Board, the DOE has also initiated a Peer Review of the technical basis for waste package performance. The Peer Review Panel (Panel) is reviewing the current technical basis for predictions of waste package and drip shield performance, and the long-term testing and modeling program. Several panelists attended and were able to benefit from discussions at the Board's recent International Workshop on long-term extrapolation of passive behavior of waste package materials. The Panel recently (July 24, 2001) held a public meeting at which experts from both the State of Nevada and the Nuclear Regulatory Commission's contractor, the Center for Nuclear Waste Regulatory Analyses, made detailed presentations to the Panel and attending public. The Panel will provide recommendations for augmenting planned tasks and underlying models in areas that will reduce uncertainties in predicting material performance. They will provide an interim report on their comments, conclusions, and recommendations in September 2001.

Evaluation and Comparison of Base-Case and Low-Temperature Repository Designs

The DOE has evaluated and compared the performance of a potential repository over a range of temperatures. For this evaluation, two specific examples (one higher- and one lower-temperature operating mode) were analyzed. These examples represent only two of many combinations of the design and operating parameters that can be used to achieve a range of thermal objectives. The primary purposes of this evaluation and comparison were to provide insights into the effects of thermal parameters on overall repository performance, including uncertainties, and to develop confidence in repository performance over a range of thermal conditions. The results of this comparison and evaluation are documented in the SSPA Report. The results were summarized at the Board's June 20 and 21, 2001 joint meeting of its Repository and Performance Assessment Panels. The SSPA report evaluated and compared subsystem as well as total system level repository performance during the post-closure period. The DOE is looking forward to the Board's comments on the Project's approach to the comparison and evaluation of performance over a range of temperatures.

We believe that the needs of the Nation may best be met by preserving the ability to select from a broad thermal range a design for repository licensing and initial operations. Preserving this

ability, however, may require testing and analytical efforts to support production of licensing documentation for the lower end of the thermal range. This documentation would supplement the analysis for the upper end of the thermal range and the technical and programmatic information developed would be used to further support the lower end of the thermal range in a potential license application. Accordingly, the Department has issued technical direction to Bechtel-SAIC Company, our Management and Operating Contractor, to begin evaluating this work in accordance with our project control processes so that the overall cost and schedule impacts of this effort can be fully understood. The Program's 2002 budget, which at this point is very uncertain, will strongly influence our ability to implement this work. We will evaluate these cost and schedule impacts in light of these broader program constraints and make appropriate management decisions regarding implementation of the technical work. We will keep the Board informed of our progress and decisions on this important topic.

Development of Multiple Lines of Evidence to Support the Proposed Repository Safety Case

The expanded consideration of multiple lines of evidence during the development of the recent Supplemental Science and Performance Analyses Report has improved the DOE's understanding of processes important to repository performance, independent of the results of the quantitative TSPA. As a consequence, the DOE intends to continue the expanded evaluation of multiple lines of evidence to provide additional confidence in the results of TSPA. Current plans include additional studies of various analogs, including work at Peña Blanca, Paiute Ridge, Yellowstone National Park, and examination of evaluation of analogs to man-made metals, such as Josephinite. We will consider both supporting and opposing lines of evidence to provide a balanced discussion of the available lines of evidence.

Ambiguities in interpreting the source of moisture in the bulk-headed drift and in determining if bomb-pulse chlorine-36 has migrated to the repository horizon.

The DOE has given high priority to studies investigating the source of moisture in the bulk-headed section of the cross drift and determining if bomb-pulse chlorine-36 has migrated to the repository horizon. Those studies are still underway. We will be providing the Board an update on the current progress in resolving these issues in the September 2001 Full Board meeting.

Investigations to connect the near-field natural environment with the engineered repository system

The DOE is aware of the Board's concern that studies to connect the near-field natural environment with the engineered barrier system are still under way. The Board's examples include studies of deliquescence of brines on the waste package and drip shield, colloid transport, and thermal conductivity of the lower lithophysal rock unit of the Topopah Spring. The DOE believes that there are sufficient data to bound the natural environment in the near field for evaluations of the effects of the near-field environment on the engineered barrier system.

Additional testing and analysis are ongoing to improve the defensibility of these bounds and possibly move toward more realistic bounds.

These studies include investigations of the potential occurrence of hygroscopic salts that could lead to concentrated brines such as sodium nitrate, sodium chloride, sodium sulfate, sodium carbonate, calcium sulfate, and possibly calcium or magnesium chloride. Corrosion test conditions include many of these constituents and provide a reasonable representation of water characteristics relative to the effects on corrosion. Along these lines, samples of dust are being collected in the Exploratory Studies Facility from horizontal or near-horizontal surfaces. These samples are being analyzed to determine the total organic components, major and minor ionic species, and particle analyses using petrographic and scanning-electron microscopes. To strengthen the colloid transport database, the DOE is continuing work at Busted Butte, the Alluvial Testing Complex, and in the laboratory. In addition, a study is ongoing to collect data on the thermal properties of the Topopah Spring Tuff lower lithophysal unit.

The repository layout described in the *Science and Engineering Report* extends over a new area that includes a part of the large hydraulic gradient, but the repository layout evaluated in the PA for site recommendation does not include this area. This inconsistency may have significant potential consequences.

The DOE's performance assessments are iterative. As new data become available and as the underlying processes are better understood, the models and inputs are refined. These models are then abstracted and analyzed in an updated TSPA model. Because this is an iterative process, the inputs, and therefore the simulation results, are a snapshot of the information available at the time the simulations are run. The Total System Performance Assessment-Site Recommendation (TSPA-SR) implemented the results of analyses in the Process Model Reports and supporting Analysis and Modeling Reports that were based on the modified Enhanced Design Alternative II. Since that time, the layout of potential repository development areas for site recommendation has continued to evolve. Therefore, the effects of the water table rise on the large hydraulic gradient beneath the northernmost emplacement drifts were not explicitly included in the TSPA-SR.

The SSPA (Volume 1, Section 3.3.4) does, however, include information on the performance implications of the expanded repository footprint to the north. The extensive zeolitization of the Calico Hills Formation in this area diverts water flow above the water table. Consequently, the values of total percolation flux at the water table are generally among the lowest in the area of the northernmost emplacement drifts. In addition, the fraction of the total number of radionuclide particles released from the repository and reaching the water table is generally lowest in this area for the medium infiltration case and the glacial transition climate case. This information suggests that any errors introduced by the simplified model of a uniform climate induced water table rise in the TSPA are likely to be small.

As noted in the Science and Engineering Report, the layout of potential repository development areas illustrates parts of the upper and lower blocks that could be used for emplacement of waste. If the site is designated, then as the design evolves to support a license application the performance implications of the northernmost drifts will be evaluated in TSPA analyses.



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

October 16, 2001

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

Dear Mr. Barrett:

Thank you for your August 28, 2001, letter to each member of the Nuclear Waste Technical Review Board (Board) asking for comments on *Yucca Mountain Preliminary Site Suitability Evaluation (PSSE)*. I am responding on behalf of the Board.

The information in the *PSSE* will be assessed by the full Board as part of its continuous evaluation of the validity of technical and scientific activities related to the Department of Energy's (DOE) radioactive waste management program. Because the *PSSE* addresses issues that are at the core of the Board's congressional mandate, the Board feels strongly that it is inappropriate for its members to respond as individuals.

As you know, the Board will hold a business meeting in late November to begin preparing its comments on the DOE's technical bases for a decision on whether to recommend the Yucca Mountain site for repository development. On the basis of these and subsequent discussions, the Board expects to comment on the *PSSE* and other relevant DOE documents in the coming months. The Board's comments will be sent in letters and reports to the program, the Secretary, and Congress.

Thank you again for your letter.

Sincerely,

{signed by}

Jared L. Cohon
Chairman

cc. Robert G. Card



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

October 17, 2001

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

Dear Mr. Barrett:

Thank you for attending and supporting the Nuclear Waste Technical Review Board's (Board) meeting in Las Vegas on September 10-12, 2001. That the meeting went forward in such a professional manner despite the difficult circumstances caused by the events of September 11 is a tribute to your staff and contractors. The Board appreciates your efforts.

It is clear from presentations at the Board's September meeting and from our preliminary review of *Science and Engineering Report, Preliminary Site Suitability Evaluation (PSSE)*, and *Supplemental Science and Performance Analysis (SSPA)* that progress has been made. The amount of work described at the Board's September meeting and the range of analyses conducted by the program in a relatively short time are commendable. We understand that work is continuing in several areas, including uncertainty analyses and corrosion studies.

As you know, the Board will hold a business meeting in late November to begin preparing its comments on the Department of Energy's (DOE) technical bases for a decision on whether to recommend the Yucca Mountain site for repository development. However, the Board's evaluation of the status of the DOE's program, including progress on the Board's four priority areas, will be made more difficult because of gaps in data and analyses. A few key examples of such gaps follow:

Incomplete comparison of high- and low-temperature repository designs. The Board has stated several times that it believes there are significant problems associated with the technical basis for the DOE's base-case repository design, which is a high-temperature design. Because it appears that a lower-temperature design could reduce the significance of some of the uncertainties related to coupled processes and corrosion of the waste packages, the Board recommended that the DOE undertake a comparison of higher- and lower-temperature designs. The DOE's May 30, 2001, letter to the Board indicated that an integrated evaluation and comparison of designs would be completed before a decision on site recommendation is made. This comparison does not appear to have been completed.

Although the *PSSE* suggests that the DOE believes that its repository design can be operated over a range of temperatures, the DOE's plans, if any, to increase its understanding of low-temperature operations are unclear. For example, in general, the analyses in the *PSSE* show little difference in performance and levels of uncertainty between high- and low-temperature operations. This could mean that repository performance and levels of uncertainty are not affected by the repository's thermal regime or that the DOE's performance assessment models are not sufficiently sensitive to show differences between high- and low-temperature regimes.

Questions about the contributions of natural and engineered barriers. In previous "one-off" analyses presented by the DOE, barriers have been "neutralized," (i.e., *individually removed*) to evaluate the performance of the repository system. The Board noted in letters to the DOE dated September 20, 2000, and March 30, 2001, that the neutralization was not consistently defined and suggested that the program conduct an alternative analysis in which barriers would be *incrementally added* to the repository system to determine the contribution of each barrier to overall repository performance. To the Board's knowledge, the DOE has not implemented this suggestion, particularly with respect to the new TSPA carried out as part of the *SSPA*.

Lack of a rationale for going forward in the face of unresolved issues. The disagreements between the DOE and the Nuclear Regulatory Commission's staff and consultants over igneous consequence models seem unlikely to be resolved before the scheduled site recommendation. Thus far, the DOE has not presented a clear and persuasive rationale for going forward with a site recommendation before resolving this important issue.

The DOE asserted at the Board's September meeting that water in the bulkheaded part of the cross-drift was the result of condensation, not seepage. However, no data supporting this conclusion were presented. In addition, we understand that significant amounts of moisture have been found in that portion of the cross-drift within the last two weeks.

To facilitate the Board's November deliberations, we request that you send to the Board as soon as it is available any additional information or letter reports that relate to the issues raised above or to ongoing work that will be completed before a decision on site recommendation is made. If the analyses referred to in the examples cited above will not be available before the DOE's decision is made, we would appreciate receiving the DOE's rationale for why they are not important for site recommendation as well as any plans for subsequently conducting the work if the site is recommended and approved for repository development.

In addition, we encourage additional communication at the staff level in the following weeks to explore details in relevant DOE documents that will aid our understanding of some of the subtleties in the documents. We realize that this may create an additional burden on program staff who are already working at capacity to meet program milestones. However, the Board must have all relevant information before the end of November so that it can adequately review the DOE's technical documents while trying to accommodate the time constraints imposed by the DOE's schedule for decision-making.

Thank you again for participating in the Board's meeting and for your cooperation. We look forward to receiving additional information on the issues raised in this letter and other relevant issues as we prepare for our November review.

Sincerely,

{signed by}

Jared L. Cohon
Chairman

cc: Robert G. Card



Department of Energy

Washington, DC 20585

NOV 26 2001

NOV 20 2001

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

Dear Dr. Cohon:

Thank you for your letter of October 17, 2001, providing the Board's perspective on information presented by the Department of Energy (DOE) at the Board's September meeting and from the Board's preliminary review of recent DOE/contractor reports. These reports included the Yucca Mountain Science and Engineering Report, the Preliminary Site Suitability Evaluation, and the Supplemental Science and Performance Analysis Report. The Board's letter indicates that there are some specific gaps in data and analyses that are making the Board's evaluation of the status of the Department's program more difficult. In an attempt to help the Board's evaluation process, we have provided the Board with reports, such as the Technical Update Impact Letter Report, that contain additional information on the Board's specific concerns, as noted in enclosure 1. DOE and contractor staff have been in regular and frequent contact with the Board's staff, as suggested in your letter. We trust that the information provided to your staff through telephone conversations and transmittals of requested information has been helpful to your understanding of the program.

We look forward to continuing our discussion on these issues with the Board.

Sincerely,

A handwritten signature in black ink, appearing to read "Lake Barrett", written over a horizontal line.

Lake Barrett, Acting Director
Office of Civilian Radioactive
Waste Management

Enclosures



**Department of Energy Responses to the October 17, 2000, Letter
From the Nuclear Waste Technical Review Board**

The following text addresses the four key examples of the Board's concerns that there may be gaps in data and analyses as was highlighted in the October 17, 2000, letter from the Board:

The Board expressed concern that there is not, as yet, a complete comparison of high- and low-temperature repository designs

As was discussed in its May 30, 2001 letter to the Board, the DOE is preparing a more complete integrated evaluation and comparison of high- and low-temperature operating modes, based on available information. This comparison draws on the postclosure performance analyses in the *Supplemental Science and Performance Analyses (SSPA)* and the preclosure safety analyses in the *Preliminary Preclosure Safety Assessment for Monitored Geologic Repository Site Recommendation Report*. It also considers economic costs and the timeframe for construction, operation, ventilation, and closure. All of this information exists in various documents and reports that are available to the public. DOE plans to complete this comparison in the January timeframe.

This evaluation builds on previous work that addressed the risk/cost/benefit aspects of repository performance as a function of postclosure thermal conditions. In 1999, the DOE conducted a series of meetings and workshops on the topic culminating in the License Application and Design Selection Report (LADS)(CRWMS M&O 1999¹). Board members and staff attended and contributed to many of those internal meetings. The final report and its supporting documents were transmitted to the Board as they were completed. A number of studies and reports have looked at the design concepts and performance implications of operating the repository in a below boiling configuration. They include:

- Draft Environmental Impact Statement (EIS) for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County Nevada and Supplement to the Draft EIS
- License Application Design Selection Report
- Operating a Below-Boiling Repository: Demonstration of Concept
- Natural Ventilation Study: Demonstration of Concept
- Three Lower Temperature Operating Mode Scenarios - Aging, Waste Package Spacing, and Drift Spacing
- Yucca Mountain Science and Engineering Report
- Supplemental Science and Performance Analyses Report
- Life Cycle Cost Analysis for Repository Flexible Design Concepts

¹ CRWMS M&O 1999, *License Application Design Selection Report*. B00000000-01717-5705-00131 REV 00. Las Vegas, Nevada.

- December 12, 2000, PORB Position Paper
- July 9, 2001, Memorandum from Michael Anderson to Elwood Stroupe: Repository Thermal Operating Curves for Nominal and 120 meter Drift

Each of these documents is briefly summarized with respect to examining cold operating modes in enclosure 2.

The repository design is flexible, and can be constructed and operated in various modes to achieve specific technical objectives, accommodate policy decisions, and address new information. As the Board has noted, the performance assessment results described in the SSPA do not show significant differences over the long term between the lower-temperature operating mode (LTOM) and the higher-temperature operating mode (HTOM). There are, however, measurable differences in performance at the subsystem level. Differences at the subsystem level do not appear at the total system level primarily because the duration of these changes is relatively short-lived (hundreds of years) in comparison to the duration of the regulatory time period (10,000 years) and to the time to calculated peak dose (~1,000,000 years). The degree of uncertainty associated with performance analyses during the first few thousand years may well be greater for the HTOM case than for the LTOM and uncertainty in the risk analysis could vary between different design/operating mode options. However, in either case the performance is well below limits set by the EPA and NRC for public health and safety.

To better understand uncertainties, DOE has conducted numerous tests and analyses, performance assessments, and peer reviews, over the last ten years. This helped to assure that uncertainties are appropriately identified and addressed in documentation supporting any Site Recommendation decision. We have also relied upon the reviews by the NRC, the Board, and other oversight bodies, as well as comments from the public and the State of Nevada as valued input into this process. DOE is confident that the following activities have addressed uncertainties at a level appropriate for the Site Recommendation decision:

- Scientific testing and analysis to quantify the uncertainty
- Iterative performance assessments to assess the significance of uncertainties
- Peer reviews of scientific bases to assess strengths, weaknesses, and the degree of confidence in projections of performance
- Reviews by the Nuclear Regulatory Commission, Nuclear Waste Technical Review Board and other oversight groups
- Comments by the public, Clark and Nye Counties and the State of Nevada

Each of these activities is briefly discussed in enclosure 2.

The DOE is continuing to investigate the sensitivity and uncertainty of performance analyses to design and operating mode decisions and to identify specific activities that will enhance the evaluation of lower temperature operating modes. This work is being done in anticipation of development of a license application and for other research needs,

should the site be designated. Planned work related to uncertainties in thermal conditions, beginning in FY 2002, includes:

- Continued waste package passive film corrosion material testing program to better understand underlying fundamental scientific processes.
- Continued review and modification of the Performance Confirmation Plan to provide for continued performance testing in the preclosure operational phase to better quantify performance uncertainties.
- Continued modeling activities to incorporate multiple lines of evidence for processes that affect long term performance.
- Performance of additional uncertainty and sensitivity analyses to better understand major contributors to long term performance.
- Continued review and validation of parameter ranges and Features, Events and Processes (FEP's) screening to ensure proper insight into total system performance.

Based on preliminary results from the latest evaluation of operating modes and results of all previous work, taken together with comments on the technical basis for Site Recommendation from the Board, USGS, Nye County, and other interested parties regarding the potential benefits of lower temperature postclosure conditions, the DOE is directing our contractor to implement work activities that will supplement information on the low-temperature operating mode. Updated results from the testing program will be used to expand the technical basis for this end of the flexible design for inclusion in a License Application. As was discussed in a recent meeting, DOE will invite the Board to participate in semi-annual meetings to discuss items of mutual interest such as the hot vs. the cold operating options. Updated information about the enhanced cold operating mode analyses is expected to be available to support the first of these meetings in the next several months.

The Board indicated that it still has questions about the contributions of natural and engineered barriers. In particular, the Board noted that it has suggested that the program conduct an alternative analysis in which barriers would be incrementally added to the repository system to determine the contribution of each barrier to overall repository performance.

An analysis was completed to provide some insight into the role of the natural and the engineered barriers, using the neutralization concept (*Figure 3-2, Revision 4 of the Repository Safety Strategy*²) and the TSPA model for Site Recommendation (TSPA-SR). This figure shows the annual dose without the benefit of any repository system barriers along with the annual dose for natural barriers alone, and the annual dose with full contribution of all barriers. The Electric Power Research Institute has used "Hazard Index" analyses to provide rough, quantitative estimates of the importance of important

² CRWMS M&O 2001. *Repository Safety Strategy: Plan to Prepare the Safety Case to Support Yucca Mountain Site Recommendation and Licensing Considerations*. TDR-WIS-RL-000001 REV 04 ICN 01. Two volumes. Las Vegas, Nevada.

features, events, and processes (FEPs) by artificially turning off all FEPs and then adding in successive FEPs to evaluate their contribution to the total reduction in Hazard Index (EPRI 2000³). DOE has begun additional analyses of this type using the TSPA-SR model. As these analyses are completed and reviewed, DOE will share them with the Board.

The Board expressed concern that there is a lack of rationale for going forward in the face of unresolved issues. In particular, the Board expressed concern that the DOE has not presented a clear and persuasive rationale for going forward with a site recommendation before resolving the issue of differences of between volcanism models and the issue of the origin of moisture in the Cross Drift.

As set out in DOE's site suitability guidelines, a site suitability determination requires not a determination by DOE that all issues have been resolved, but rather a determination that a repository sited at Yucca Mountain would likely meet EPA's radiation protection standards and hence be licensable. DOE is continuing the process of determining whether to recommend the Yucca Mountain site for the location of a repository. During this process and in the future, if the site is designated, the DOE will continue to evaluate issues identified from its own ongoing science investigations as well as those identified by the NRC, the Board, and other interested parties. DOE's evaluation of a given issue may include internal technical review, additional testing, additional analyses, or peer review to responsibly address the issue. If DOE finds an issue significant enough to stop the site recommendation or licensing process, the DOE will do so. As noted in the NRC letter⁴ (and its attachment) on sufficiency of site characterization, the NRC has reasonable confidence that, based on the information DOE has obtained or has agreed to obtain, development of an acceptable license application is achievable.

Igneous consequence models

Recent research sponsored by Center for Nuclear Waste Regulatory Analyses (Center) provides an initial attempt to model consequences of dike-drift interactions in more detail. These analyses suggest that more waste packages may be adversely affected than previously documented in performance assessment analyses (see the *Technical Update Impact Letter Report*, Section 4 and Appendices I and L). The Center-sponsored research focused on idealized conceptual models based on a single drift that is not reflective of the repository system. Their analysis did not address the probability of the various cases occurring, the probability distribution of one or more drifts being intercepted, the quantification of the number of packages damaged, or the extent of damage to the packages. To evaluate the potential implications of the Center-sponsored research, the DOE has completed a very rough estimate of the number of waste packages that may be affected, using the Center's idealized conceptual model. If one presumes that all the

³ EPRI 2000. *Evaluation of the Candidate High-Level Radioactive Waste Repository at Yucca Mountain Using Total System Performance Assessment, Phase 5*. 1000802. Palo Alto, California: Electric Power Research Institute.

⁴ Richard A. Meserve to Robert G. Card, letter and attachment dated November 13, 2001.

assumptions and conservatisms contained in the Center's model are valid and incorporates these assumptions into the DOE's supplemental performance model, the

number of damaged waste packages is not expected to increase more than an order of magnitude. The dose, in turn, is also not expected to increase by more than an order of magnitude over the 0.08 mrem/yr dose calculated for the combined probability-weighted mean dose for direct and indirect releases during the regulatory period, reported in the *Preliminary Site Suitability Evaluation*. Therefore the releases would remain below the EPA standard.

The DOE and NRC have reached agreement on a path forward for further analyses of igneous consequences to resolve the differing points of view. Having considered the Center's research, the DOE continues to believe that the technical basis for igneous consequences is sufficient to support evaluations of site suitability. Some observations that support this position include the following:

- Low probability of an event,
- Robustness of the hazard estimate,
- Waning character of volcanism in the region,
- Localization of igneous activity away from Yucca Mountain, and
- Conservatism included in the consequence analyses

Water in the bulkheaded section of the Cross-Drift

Recent observations and test results from the Cross-Drift Bulkhead Moisture Monitoring test are summarized in the *Technical Update Impact Letter Report* (Section 4 and Appendices B and L). Based on the observations of moisture in the most recent bulkhead entry, the DOE has decided not to move the bulkhead at station 17+63 in the cross Drift so that monitoring can continue over the same section of the Cross Drift. Results of analyses to date indicate that water sampled behind the bulkhead is low in chloride and silica, consistent with condensate as the source of the water. The DOE is collecting additional water samples to further evaluate the source of the water. In terms of postclosure performance, it is important to note that condensate water has little effect on waste-package and drip-shield corrosion models. These models assume aqueous conditions at low relative humidities and are not sensitive to the quantities of water present. In addition, there is little effect of seepage or condensation on transport in the unsaturated zone. Condensate might result in more advective releases from waste packages, but the impact of this is not expected to be large, especially considering the range of percolation and seepage included as uncertainty in the analyses. The potential impact on dose is expected to be minor.

Activities DOE has undertaken to examine cold operating modes

While these documents may not have fully addressed the Board's concerns, the following is a brief summary of documents that discuss activities DOE has undertaken to examine cold repository operating modes. For completeness we list all documents that relate to the cold operating mode:

Published Reports

Draft Environmental Impact Statement (EIS) for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County Nevada (DOE 1999) and Supplement to the Draft EIS (DOE 2001)

While it contains no new or original evaluations of the operating modes, the Draft EIS does include an evaluation of the environmental impacts of high, intermediate, and low thermal load scenarios. The Supplement to the Draft EIS includes an evaluation of impacts over a range of thermal operating modes from higher-temperature (equivalent to Draft EIS intermediate thermal load) and lower-temperature (equivalent to the range between the Draft EIS low and intermediate thermal loads).

License Application Design Selection Report (CRWMS M&O 1999)

This report evaluated five Enhanced Design Alternatives (EDA) which range in thermal operating modes from "cool" (boiling at the drift wall) to "hot" (above boiling) at the drift wall and throughout the pillar. These five EDAs easily meet postclosure performance (peak dose in 10,000 years) standards. The recommended Design Alternative is known as EDA-II, and its thermal operating mode is characterized by "boiling" at the drift wall and "below boiling" in a portion of the pillar. This design is a moderate thermal load compared to others considered and the Viability Assessment Design.

Operating a Below-Boiling Repository: Demonstration of Concept (CRWMS M&O 2000)

This study demonstrates that the Site Recommendation design can be operated below boiling. The below-boiling repository can be achieved, by various combinations of: staging on the surface, changing the distance between waste packages within the emplacement drifts, and/or adjusting emplacement drift ventilation duration.

Natural Ventilation Study: Demonstration of Concept (CRWMS M&O 2000)

This study concluded that a combination of forced ventilation and natural ventilation is a technically viable option for keeping repository temperatures substantially lower. Certain

combinations of forced air ventilation and natural ventilation would result in below boiling drift wall temperatures.

Three Lower Temperature Operating Mode Scenarios - Aging, Waste Package Spacing, and Drift Spacing (CRWMS M&O 2000)

This analysis documents that the Site Recommendation reference design can be modified so that the waste-package surface temperature after closure remains at or below 85°C for the majority of waste packages. Three scenarios were evaluated; these included increasing drift spacing and allowing 300 years of active ventilation; a combination of aging, increasing waste package spacing, and at least 75 years of active ventilation; and increasing the drift spacing and 100 years of active ventilation.

Yucca Mountain Science and Engineering Report (DOE 2001)

This report provides a summary of analyses to assess the performance of a flexible design concept that includes lower- and higher-temperature operating modes.

Supplemental Science and Performance Analyses Report, Volume 1 (BSC 2001)

The effects of a range of thermal operating modes were evaluated. At the process model level, analyses indicate that the thermal operating mode does not significantly influence the natural processes over the long term. Lower temperature operating modes have less impact effects on the processes operating in the thermally perturbed region near emplacement drifts. For the higher temperature operating modes, the effects of coupled processes are generally small, and relatively short-lived. At the repository system level, the maximum differences in annual dose are approximately a factor of 10 while still achieving acceptable performance. The choice of thermal operating mode does not strongly influence overall conclusions from these supplemental analyses.

Life Cycle Cost Analysis for Repository Flexible Design Concepts (BSC 2001)

This report documents a life cycle cost analysis for repository flexible design and operating modes to provide input to the total system life cycle cost estimate for Site Recommendation and the Final Environmental Impact Statement.

YMSCO Internal Documents

December 12, 2000, PORB Position Paper

This position paper defines six scenarios that illustrate combinations of operating parameters to achieve goals for operating the reference repository design in lower-temperature operating modes. It also provides criteria to be met by a potential representative low-temperature operating mode for the Monitored Geologic Repository.

July 9, 2001, Memorandum from Michael Anderson to Elwood Stroupe: Repository Thermal Operating Curves for Nominal and 120 meter Drift

Repository thermal operating curves were generated to assess the difference in repository thermal performance for the nominal drift separation of 81 meters and an extended drift separation of 120 meters. These were evaluated for a peak waste package-surface temperature of 85°C.

Activities the Department of Energy has Undertaken to Improve Quantification of Uncertainties in Projections of Post Closure Performance

DOE is constantly seeking to improve the characterization of the Yucca Mountain site and engineered barriers that are potentially important to the assessment of post closure performance. Part of this characterization is to improve the sound scientific basis for the models used to project performance for the 10,000-year regulatory time period and longer. This characterization recognizes that residual uncertainties will remain after each characterization phase and that these uncertainties need to be evaluated to provide a meaningful assessment of risks to decision makers and the public.

To this end, DOE has conducted several activities to assure that uncertainties are appropriately identified and addressed in the development of the Site Recommendation. Each of these activities is briefly discussed below.

Scientific Testing and Analysis to Quantify Uncertainty

The scientific method is one of developing hypotheses and testing those hypotheses and, as additional testing is conducted, modifying hypotheses as necessary. This method includes subjecting scientific bases to reviews by peers. This method has been used for over 20 years of site characterization and engineered materials testing for the Yucca Mountain Project. This testing has formed the basis for models of post closure performance and provided uncertainty distributions in the forms of a) alternative models that explain the observations, b) spatially variable geologic and hydrologic properties that define the range of the environments expected, and c) parameter uncertainty associated with the behavior of the waste packages and waste forms in this range of environments.

Iterative Performance Assessments

DOE has conducted five major performance assessments of the Yucca Mountain site and engineered barriers in the past 10 years. Each of these analyses has used continually refined models based on the most current science available. Each analysis has evaluated the uncertainty in the projected performance through a range of quantitative uncertainty and sensitivity analyses. These analyses have assisted in defining the key components of the repository system and the important uncertainties affecting the performance. These analyses by DOE have been compared to similar analyses conducted over the same time

frame by the NRC and the Electric Power Research Institute (EPRI) that have identified very similar key aspects and uncertainties affecting the performance of a Yucca Mountain repository.

Peer Reviews

An important part of the scientific method is subjecting work to review by peers. Within the Yucca Mountain project, all scientific work is internally reviewed by the contractor staff or staff of the DOE National Laboratories or the US Geological Survey. The work by the National Laboratory staff is also internally reviewed by the management of the labs to assure it is appropriate for the decisions at hand. In addition, DOE has chartered independent external reviews of the scientific activities in a number of crucial areas, including the waste package degradation model and the Total System Performance Assessment model. Also, several external groups, notably the USGS, have provided independent reviews of the science at critical decision points for the Project such as the Viability Assessment and now the Site Recommendation. These peer reviews have identified areas of scientific weakness and the need for additional testing in certain areas to enhance the confidence in the projections of performance.

External Reviews by NRC and NWTRB

The NRC has been reviewing the scientific basis and uncertainty characterization as well as the incorporation of this basis and uncertainty in the Yucca Mountain performance assessment since the development of DOE's Site Characterization Plan in 1987. These reviews benefited from NRC staff's own Iterative Performance Assessment analyses. These reviews culminated in a series of NRC Key Technical Issue Technical Exchanges on the scientific basis for the Site Recommendation models. Additional reviews have been conducted by the Nuclear Waste Technical Review Board. These reviews have resulted in recommendations for the quantification of uncertainty to aid the decision maker in fully exploring the range of possible performance projections.

Comments by the Public and Affected Units of Government

The science developed for the Yucca Mountain Project has been commented on in various forums by local governments and the State of Nevada consultants. Clark County commented on the Viability Assessment and both Nye County and the State of Nevada consultants have commented on the saturated zone modeling in the vicinity of Yucca Mountain. Some of the comments included recommendations for alternative interpretations and models. These alternative interpretations and models have been reviewed by DOE, contractor, and national laboratory staff in their development of the Site Recommendation.



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

December 11, 2001

The Honorable Spencer Abraham
Secretary
U.S. Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585

Dear Secretary Abraham:

The U.S. Nuclear Waste Technical Review Board (Board) was established by Congress in the Nuclear Waste Policy Amendments Act of 1987. The Board evaluates the technical and scientific validity of the Department of Energy's (DOE) activities associated with characterizing a potential repository site at Yucca Mountain to dispose of high-level radioactive waste and spent nuclear fuel.

Late last month, the Board held a three-day business meeting to review, among other things, the latest round of reports and analyses, which were submitted to it in the week of November 19, 2001, by the Office of Civilian Radioactive Waste Management (OCRWM). On the basis of that review and the results of the Board's ongoing evaluation of the civilian radioactive waste management program, the Board is preparing its comments for you and Congress on the technical and scientific validity of work that will form the basis of your decision on whether to recommend to the President that the Yucca Mountain site be developed for a repository. The Board intends to complete its comments within the next few weeks.

The Board appreciates the DOE's efforts to provide the OCRWM's latest studies so that this important information could be included in the Board's evaluation. The Board hopes that you will find its technical and scientific evaluation helpful in making your recommendation to the President.

Sincerely,

{Signed by}

Jared L. Cohon
Chair



Department of Energy
Washington, DC 20585

DEC 18 2001

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

Dear Dr. Cohon:

We appreciate the Nuclear Waste Technical Review Board's letter of December 11, 2001, informing us that the Board intends to complete its comments within the next few weeks.

We continue to value the Board's feedback and look forward to the Board's comments on the documents the Department submitted during the week of November 19, 2001. If you have any questions, please contact me at (202)586-6842.

Sincerely,

A handwritten signature in black ink, appearing to read "Lake H. Barrett".

Lake H. Barrett, Acting Director
Office of Civilian Radioactive
Waste Management

