Appendix A
Nuclear Waste Technical Review Board Members

Dr. John E. Cantlon was first appointed in January 1989. He was reappointed as chair of the Board in May 1992. Dr. Cantlon is vice president emeritus of research and graduate studies and former dean of the graduate school at Michigan State University. His field of expertise is environmental science.

Dr. Clarence R. Allen was first appointed in January 1989. He was reappointed to the Board in May 1992. Dr. Allen is professor emeritus of geology and geophysics in the seismological laboratory at the California Institute of Technology, Pasadena.

Dr. Garry D. Brewer was appointed to the Board in May 1992. He is dean of the School of Natural Resources and Environment and professor of resource policy and management at the University of Michigan in Ann Arbor, Michigan. Dr. Brewer's of expertise is public policy.

Dr. Edward J. Cording was appointed to the Board in June 1992. Dr. Cording is professor of civil engineering at the University of Illinois at Urbana-Champaign. His expertise lies in the area of geotechnical engineering and applied rock and soil mechanics.

Dr. Patrick A. Domenico* was appointed to the Board in May 1990. He currently is the David B. Harris Professor of Geology at Texas A&M University, College Station, Texas. Dr. Domenico's area of expertise is ground-water hydrology.

Dr. Donald Langmuir was first appointed to the Board in January 1989. He was reappointed in June 1992. Dr. Langmuir is professor emeritus of geochemistry in the Department of Chemistry and Geochemistry at the Colorado School of Mines in Golden, Colorado.

Dr. John J. McKetta, Jr. was appointed to the Board in February 1992. Dr. McKetta is the Joe C. Walter Professor of Chemical Engineering emeritus at the University of Texas, Austin.

Dr. Dennis L. Price* was first appointed to the Board in January 1989. He was reappointed in July 1990. Dr. Price is a professor of industrial and systems engineering and director of the Safety Projects Office at the Virginia Polytechnic Institute and State University in Blacksburg, Virginia. His areas of expertise are human factors and system safety engineering.

Dr. Ellis D. Verink, Jr.* was first appointed to the Board in January 1989. He was reappointed in October 1990. Dr. Verink is Distinguished Service Professor emeritus of Metallurgy and former chair of the Department of Materials Science and Engineering of the University of Florida, Gainesville, Florida. His areas of expertise are materials selection and corrosion.

**Term expired on April 19, 1994; continuing as a consultant pending Presidential appointment/reappointment.*

Appendix B
Panel Organization

1. Panel on Structural Geology & Geoengineering

Chair:	Dr. Clarence R. Allen	Staff:	Mr. R.K. McFarland
Members:	Dr. Edward J. Cording		Dr. Leon Reiter
	Dr. Dennis L. Price*		

2. Panel on Hydrogeology & Geochemistry

Chair:	Dr. Donald Langmuir	Staff:	Dr. Victor V. Palciauskas
Members:	Dr. Edward J. Cording		
	Dr. Patrick A. Domenico*		
	Dr. John J. McKetta, Jr.		

3. Panel on the Engineered Barrier System

Chair:	Dr. Donald Langmuir	Staff:	Dr. Carlos A.W. Di Bella
Members:	Dr. John J. McKetta, Jr.		
	Dr. Dennis L. Price*		
	Dr. Ellis D. Verink, Jr.*		

4. Panel on Transportation & Systems

Chair:	Dr. John J. McKetta, Jr.	Staff:	Dr. Sherwood C. Chu
Members:	Dr. Garry D. Brewer		
	Dr. Dennis L. Price*		
	Dr. Ellis D. Verink, Jr.*		

5. Panel on the Environment & Public Health

Chair:	Dr. Garry D. Brewer	Staff:	Dr. Daniel J. Fehringer
Members:	Dr. John E. Cantlon		Dr. Daniel S. Metlay
	Dr. John J. McKetta, Jr.		

6. Panel on Risk & Performance Analysis

Chair:	Dr. Garry D. Brewer	Staff:	Dr. Leon Reiter
Members:	Dr. Patrick A. Domenico*		Dr. Daniel S. Metlay
	Dr. Dennis L. Price*		
	Dr. Ellis D. Verink, Jr.*		

7. Panel on Quality Assurance

Chair:	Dr. John E. Cantlon	Staff:	Dr. Sherwood C. Chu
Members:	Dr. Clarence R. Allen		
	Dr. Donald Langmuir		

** Term expired on April 19, 1994; continuing as a consultant pending Presidential appointment/reappointment.*

Appendix C
Meeting List for 1994 – 1995*

January 10, 1994

Board Business Meeting
Arlington, VA
Minutes available

January 11-12, 1994

Full Board Meeting
Arlington, VA
Topic: Systems engineering performance assessment, public trust and confidence / alternative licensing strategies, site characterization update

February 24, 1994

Publication of Board's *Ninth Report*, **the** *Letter Report*

March 8-9, 1994

Meeting
Panel on Structural Geology & Geoengineering
San Francisco, CA
Topic: Probabilistic assessment of seismic and volcanic hazards

March 10, 1994

Meeting
Panel on the Engineered Barrier System
Pleasanton, CA
Topic: Current and planned EBS research

March 11, 1994

Tour
Panel on the Engineered Barrier System
Pleasanton, CA
Topic: Tour of the Lawrence Livermore National Laboratory

March 21, 1994

Tour
Panel on the Environment & Public Health
Las Vegas, NV
Topic: Field trip to Yucca Mountain

** Unless otherwise indicated, transcripts are available for all Board meetings.*

March 22, 1994

Meeting
Panel on the Environment & Public Health
Las Vegas, NV
Topic: Review of the Yucca Mountain Environmental Program

April 11-12, 1994

Full Board Meeting
Reno, NV
Topic: Use of science in site assessment, saturated zone hydrology, site characterization update

April 13, 1994

Board Business Meeting
Reno, NV
Minutes available

May 6, 1994

Publication of Board's *Tenth Report*

May 21-28, 1994

International Trip (closed)
Tokyo, Misawa, Kamaishi, Tajimi, and Mito
Topic: Japan's nuclear waste management program

June 13-14, 1994

Meeting
Panel on Structural Geology & Geoengineering
Las Vegas, NV
Topic: ESF/Repository design and construction

June 15, 1994

Meeting
Panel on the Engineered Barrier System
Richland, WA
Topic: Repository development and defense high-level waste

June 16, 1994

Tour
Panel on the Engineered Barrier System
Richland, WA
Topic: Tour of Hanford site

July 11, 1994

Board Business Meeting
Denver, CO
Minutes available

July 12-13, 1994

Full Board Meeting
Denver, CO
Topic: Transportation issues, radionuclide migration / retardation, site characterization update

September 9, 1994

Meeting
Presentation before the NRC Commissioners
Washington, DC
Topic: Board's view on the DOE's proposed program approach

September 12-13, 1994

Meeting
Panel on Hydrogeology & Geochemistry
Las Vegas, NV
Topic: DOE's proposed program approach to ground-water travel time

October 11, 1994

Board Business Meeting
Las Vegas, NV
Minutes available

October 12, 1994

Full Board Meeting
Las Vegas, NV
Topic: DOE approach to the site-suitability decision

October 13-14, 1994

Board Business Meeting
Las Vegas, NV
Minutes available

October 20, 1994

Trip to Finland
Helsinki
Topic: Visit with TVO, Ministry of Trade and Industry, and STUK officials

October 24-28, 1994

Trip to Sweden
Luleà, Oskarshamn, Forsmark
Topic: KASAM seminar on "A process for participation in decision," tour of Aspö, CLAB, and SFR

November 17-18, 1994

Meeting
Joint Panels on Structural Geology & Geoengineering and Hydrogeology & Geochemistry
Washington, DC
Topic: Thermal management for a high-level waste repository

January 9, 1995

Board Business Meeting
Las Vegas, NV
Minutes available

January 10-11, 1995

Full Board Meeting
Beatty, NV
Topic: Socioeconomic issues, updates on environmental issues, the ESF and the DOE waste isolation strategy, and program priorities

April 19-20, 1995

Full Board Meeting
Las Vegas, NV
Topic: TBD

July 11-12, 1995

Full Board Meeting
Salt Lake City, UT
Topic: TBD

October 17-18, 1995

Full Board Meeting
Arlington, VA
Topic: TBD

Appendix D
List of Presenters

The following people participated in Board or panel meetings held from January 1, 1995, through December 31, 1995. This list is arranged alphabetically. The Board also wishes to thank those who made presentations to Board or panel members during various trips and tours taken during recent months.

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Appendix E
NWTRB Statements Before Congress

As part of its interactions with the U.S. Congress, the NWTRB was asked to testify twice during 1994, on March 14 and on August 3. Included here are copies of the testimony presented by Chairman John E. Cantlon. Also included are the answers to follow-up questions submitted to Congress on March 18, 1994.

Statement of Dr. John E. Cantlon, Chairman, Nuclear Waste Technical Review Board

(Before the Subcommittee on Energy and Power, Committee on Energy and Commerce, U.S. House of Representatives, August 3, 1994)

Chairman Sharp and members of the Subcommittee.

I am John Cantlon, Chairman of the Nuclear Waste Technical Review Board. With me today is another member of the Board, Dr. Donald Langmuir. We are pleased to be here to provide the Board's perspective on challenges facing the civilian radioactive waste management program.

As you know, largely as a result of the leadership and efforts of Chairman Sharp, Congress created the Nuclear Waste Technical Review Board in the 1987 amendments to the Nuclear Waste Policy Act. The Board's charge is reviewing the technical and scientific validity of activities undertaken by the Department of Energy related to the management of spent nuclear fuel and some defense high-level radioactive waste. These activities include packaging, transporting, storing, and disposing of the waste as well as characterizing a site at Yucca Mountain, Nevada, to determine its suitability as a location for a permanent underground high-level waste repository.

Mr. Chairman, you have asked hearing participants to respond to three questions related to efforts to store and ultimately dispose of radioactive high-level waste. Some aspects of your questions are outside the technical purview of the Board, but we are pleased to provide our perspective on progress and our concerns related to the program. I also would like to outline some basic principles that we have articulated in the past that can provide guidance for the DOE as it develops its revised approach to site characterization and repository development. In addition, I will comment briefly on the Board's thinking about legislative proposals.

The Board's charter is a technical one. However, as the Board has conducted its review of the civilian radioactive waste management program during the past five years, it has become clear to us that in many cases a thorough evaluation of the technical and scientific aspects of the program must include an understanding of the institutional factors that are affecting them. Those institutional factors include schedule and budget constraints, and the question of when and how the DOE can accept spent nuclear fuel from nuclear utilities.

Scheduling and budget considerations have significantly affected the direction, scope, and quality of the civilian radioactive waste management program since it was initiated by Congress in 1987. For the past several years, the OCRWM proposed a comprehensive set of site-characterization activities that were driven by very ambitious schedules and an expectation of large budget increases. Despite this, the DOE did not ask for or receive the resources it said were necessary to accomplish the job it set out for itself. Furthermore, a large share of the money it did receive went to fund overhead and infrastructure rather than direct project costs. Consequently, with each new budget cycle, important technical and scientific work was deferred, while the backlog of funding the OCRWM said it needed increased along with the balance in the Nuclear Waste Fund.

On several occasions, the Board drew attention to the fundamental inconsistency inherent in the relationships among the work the OCRWM said needed to be done, the resources being allocated to do the work, and the optimistic schedule the OCRWM had established for completing the work. The Board suggested that the DOE make three changes: (1) establish a waste management system with set priorities and intermediate goals, (2) allocate more money to scientific studies and less to overhead and infrastructure costs, and (3) set realistic target dates for achieving important intermediate goals, such as beginning underground excavation and testing and determining site suitability.

Last fall, when Dr. Dreyfus took over as director of the Office of Civilian Radioactive Waste Management, he and his staff recognized that problems had been created by the previous approach; they began to develop a plan to address these concerns. The Board commends the DOE's recognition of these problems as well as the willingness of current OCRWM leadership to tackle a job made more difficult by years of overly optimistic budget projections and unrealistic schedule deadlines.

To try to address these problems, the OCRWM has proposed a number of efforts referred to collectively as the proposed program approach or PPA. As yet we do not know much about the details of the PPA, but as presented at our last OCRWM briefing, the basic elements of this new approach include (1) beginning to provide multipurpose canisters or MPCs to utilities by 1998 for on-site waste storage, (2) focusing Yucca Mountain site-characterization activities on the early determination of site suitability, (3) extending the period of waste retrievability, and (4) eliminating or deferring some testing until a confirmatory testing phase that would begin after a license is obtained from the NRC to construct the repository.

The specifics of this proposed approach are still evolving. As a result, it is not possible at this time for the Board to make a technical assessment of the PPA. However, we can say that, from what we know now, there appear to be risks as well as opportunities associated with this new approach. Among the risks are the increased technical and scientific uncertainties that would be created because less data and analysis than previously planned would be provided "up front" for determining site suitability and for applying to the NRC for a license to construct a repository. The potential opportunities include another chance to better focus and streamline the program and to demonstrate progress by achieving clear, near-term goals.

The Board will review the details of the PPA as they become available — the fiscal year 1995 plan should be available in September, the out-year plans by next fall. In the meantime, to make a meaningful contribution to the development of this new approach as it evolves, it may be most useful for the Board to reiterate some of the fundamental and still relevant technical and scientific recommendations it has made during the past several years and to note OCRWM's intent in so far as we can.

First, to expedite the determination of site suitability, begin underground exploration and testing as soon as possible. The Board first made this recommendation in 1991, and it remains pertinent. Getting underground to look at the site's complex geology is critical in determining whether the site is suitable for repository development. As we understand it, current plans call for beginning full operation of the tunnel boring machine in January of 1995. To have any chance of completing underground excavation by the dates in the current schedule and initiating key long-term tests at the repository level, operation of the tunnel boring machine should commence as soon as possible. The most expeditious and cost-effective tunneling approach requires around-the-clock work shifts with as little interference from other activities as possible. This approach is standard practice in the construction industry.

Second, look at the management of high-level radioactive waste as a system and set priorities accordingly. In the past, program plans and activities have not been well integrated. Furthermore, the DOE has not given adequate consideration to the interdependent nature of the elements of the waste management system, from the generation of the waste through its storage, transport, and ultimate disposal. Using a systems view — based on a coherent waste isolation strategy — becomes even more critical now if a process will be used that increases reliance on postemplacement confirmatory testing — as opposed to providing comprehensive data and analysis prior to applying to the NRC for a license to construct the proposed repository. Misjudgments, if

they are made, might not be recognized until a later date, which could make them much more difficult, time consuming, and costly to correct.

Third, set realistic schedules for achieving important intermediate milestones such as getting underground and determining site suitability. Although schedules are vital to maintain program momentum and measure progress, it is important that technical and scientific activities that previously were considered critical are not truncated or eliminated simply to meet arbitrary schedule deadlines. The Board understands the DOE's desire to demonstrate program progress and deal with perceived contractual obligations, but we believe that *unrealistic* schedule deadlines serve only to increase frustration and erode confidence when they are missed. Another concern is that the current schedules allow little time to accommodate the kinds of surprises that have been encountered worldwide in underground projects, once underground excavation has begun.

Fourth, increase the resources available for research and development of a robust, long-lived waste package. Since it issued its first report in March 1990, the Board has underscored the importance of research related to the development of engineered barriers, including a robust, long-lived waste package, to help reduce uncertainties and enhance the long-term safety of the repository system. It appears the OCRWM plans to increase funding for waste package development — a move the Board strongly endorses.

Fifth, allocate program funds so that more money goes to scientific and technical work and less to indirect overhead and infrastructure costs. Provide a coherent organizational structure to enhance the effectiveness of the people and organizations involved with the program. Dr. Dreyfus already has completed a reorganization of federal personnel at OCRWM headquarters and at the Yucca Mountain Site Characterization Project Office and has indicated that in the future a greater share of available funds will be going to scientific and technical work than to overhead and related costs. However, the number of contractor organizations still seems quite large, and growth in staffing has continued. It remains unclear how successful the DOE will be in eliminating the duplication of effort that seems to have occurred in the past. The Board hopes the changes that have been initiated will have the intended result.

Now, I would like to respond to the Subcommittee's invitation to comment on possible legislative action. The Board views its role in this area to be one of providing technical and scientific information to policy makers as they make important policy decisions — such as the need for legislative changes. Consequently, the Board has not taken a position on the need for legislative action. The Board can of course evaluate the technical and scientific implications of legislative proposals if and when they are introduced.

At the appropriate time, one area the Congress may want to look at, given the new program approach, is the adequacy of funding for very long-term testing, monitoring, and possible retrieval once the waste has been emplaced. As part of our technical and scientific evaluation of the program, the Board has discussed the need to ensure that, in the interest of safety, adequate funding be guaranteed during the full retrievability period both to complete the testing the DOE has indicated will be part of its new program approach and to cover the costs of retrieving the waste for any purpose.

In closing, I would like to repeat that until the specifics of the OCRWM's new program approach have been developed and the Board has an opportunity to review them, we will not be in a position to assess the technical and scientific implications of the PPA. However, we do feel that the current OCRWM leadership should be commended for recognizing the fundamental inconsistency that has existed for the past several years among schedule, money, and the amount of work that needs to be done. Furthermore, there appear to be potential opportunities associated with some aspects of the DOE's proposed program approach; for example, emphasizing site suitability, setting priorities, and reallocating funds to focus on the development of a long-lived waste package and on other important scientific work. An improved interface between the DOE and the NRC also could be a benefit of this midcourse correction to the program.

On the other hand, we would like to caution that the basis for setting priorities should be a waste management systems approach that includes a coherent waste isolation strategy — not just a sorting out of how much

testing can be done given time and budget constraints. The Board also will be taking a close look at the greater uncertainty inherent in the PPA's licensing approach and the timetables that have been established to complete important site-characterization activities, including underground excavation and testing and the determination of site suitability.

And finally Mr. Chairman, on behalf of the other Board members and myself, I would like to convey our appreciation for your leadership on issues related to this vital national program as well as your personal interest in and support of the Board's work. You will be missed.

Thank you.

Statement of Dr. John E. Cantlon, Chairman Nuclear Waste Technical Review Board

(Before the Subcommittee on Energy and Water Development, Committee on Appropriations, U.S. House of Representatives, March 14, 1994)

Mr. Chairman and members of the Subcommittee: I am John Cantlon, Chairman of the Nuclear Waste Technical Review Board. With me this morning is another member of the Board, Dr. Warner North. We are pleased to be here today to present the Board's appropriation request for fiscal year 1995.

I will begin, this morning, by briefly summarizing our appropriation request. In addition, I will outline three recommendations concerning the civilian radioactive waste management program that were included in a letter report that was submitted by the Board to the Secretary of Energy and Congress three weeks ago. A detailed document containing the specifics of our request and supporting data is attached to this statement.

Background

The disposal of the country's high-level radioactive waste is an issue of long-standing importance. In 1957, the National Academy of Sciences (NAS) first examined the problems associated with waste disposal. At that time, the NAS recommended permanent isolation of the waste in mined geologic formations. There is a continuing worldwide scientific consensus that deep geologic disposal is the safest, long-term option for high-level radioactive waste disposal. It is the primary approach being pursued in the United States and in other countries.

Congress has given the Department of Energy (DOE) the responsibility for managing the nation's high-level nuclear waste — spent fuel from civilian nuclear plants, along with some high-level defense waste from reprocessing. As directed by Congress, the DOE is characterizing a site at Yucca Mountain, Nevada, to determine its potential suitability for construction of a permanent radioactive waste repository. The Nuclear Waste Technical Review Board (Board) was created in 1987 by Congress to provide an unbiased source of expert advice on the technical and scientific aspects of the DOE's work in this area.

During its five-year review, and especially during the past year, the Board has witnessed considerable progress in the program. For example, after several delays, underground excavation of the exploratory facility at Yucca Mountain has begun, and the management and operating contractor is beginning to integrate all the components of the waste management system. The Board believes strongly that the momentum of these activities should be maintained.

The Board also has been encouraged by Secretary O'Leary's recent efforts to improve the program. For example, she has created the position of chief scientist; she is proceeding with a financial and management review of the Yucca Mountain project; and, she has taken steps toward broadening stakeholder participation in the program.

The Board is encouraged by these actions. However, we believe much remains to be done. And from comments he has made to the Board and others, it is apparent that in the very short time he has been director of the Office of Civilian Radioactive Waste Management (OCRWM), Dr. Daniel Dreyfus has recognized that a number of key issues need to be addressed in the coming months.

In an effort to provide timely and constructive comments on some of these important issues, the Board on February 24, 1994, submitted a short letter report to the Secretary and Congress. The letter report contains the following three recommendations.

Summary of Recommendations

First, the Board reiterates its recommendation of a year ago that an independent review of the entire OCRWM's management and organizational structure should be initiated as soon as possible. The review of the *project* that has been initiated by the Secretary could be part of this overall review, however, it is not an adequate substitute for the more comprehensive review of organizational structure and management of the *entire* program we are recommending.

The Board believes that such an independent review of OCRWM will provide an excellent basis for the needed reshaping of the program, regardless of future funding scenarios. Considering the proposed changes in both the method and levels of funding for the OCRWM in fiscal year 1995, this review is needed now more than ever. The Board believes that improving the program's management and organizational structure will contribute to the quality and timeliness of the scientific and technical bases for important site-characterization activities or other critical research essential to an effective program.

Such a review should not take long, nor should it require a large staff. More important, the Board believes that program activities should not be impeded while this review is taking place. In fact, we believe that the review we have recommended could help avoid costly mistakes and actually speed real program progress.

Second, the Board believes that whether or not the program receives the funding it has requested, program management should ensure sufficient and reliable funding for site-characterization and performance assessment activities. During the past three years, the OCRWM has cited a lack of funds as the reason for postponing or slowing critical site-characterization activities, including underground excavation and surface-based testing, as well as research related to engineered barriers such as a robust, long-lived waste package. At the same time, however, the number of contract employees working on the program has continued to grow. The Board believes that relatively too little funding has been allocated to the direct costs of determining whether the Yucca Mountain site is a suitable location for a permanent repository.

Program managers need to place a greater emphasis on a number of critical activities; these include underground excavation, surface-based testing and mapping, underground thermal and corrosion testing, waste package development, and performance assessment. At the very least, sufficient monies should be guaranteed for those activities that will expedite finding any features that could disqualify the site.

Finally, the Board recommends that the OCRWM build on the Secretary's new public involvement initiative by expanding current efforts to integrate the views of the various stakeholders into the civilian radioactive waste management program during the decision-making process — not afterward.

In conclusion, Mr. Chairman, the Board recognizes that, in the United States as well as in all other countries dealing with these issues, there are no quick fixes for the challenges associated with the safe, permanent disposal of nuclear waste. With that said, however, the Board strongly believes that, no matter what future program funding trends may be, implementing these recommendations will help to achieve a more efficient and cost-effective program.

As the only agency charged by Congress with providing an independent review of all technical and scientific aspects of the DOE's efforts to dispose of high-level radioactive waste, the Board looks forward to continuing to report to Congress and making recommendations to the Secretary as we work together to improve progress in this important program.

Thank you.

The Nuclear Waste Technical Review Board

Background Information

The Nuclear Waste Technical Review Board (Board) was established as an independent agency within the executive branch of the Federal government on December 22, 1987, as part of the Nuclear Waste Policy Amendments Act (NWPAA) of 1987.

The Board is charged to evaluate the technical and scientific validity of activities undertaken by the Secretary of Energy, including

(1) site-characterization activities, and

(2) activities related to the packaging or transport of high-level radioactive waste or spent nuclear fuel.

The NWPAA authorized a Board of 11 members who serve on a part-time basis; who are eminent in a field of science or engineering, including environmental sciences; and who are selected solely on the basis of distinguished service. The law stipulates that Board members shall represent a broad range of scientific and engineering disciplines relevant to nuclear waste management. Members are appointed by the President from a list of candidates recommended by the National Academy of Sciences (NAS).

On January 18, 1989, eight members were appointed to the Board; an additional member was appointed in May 1990. One of the original appointees resigned in July 1991 and a replacement has not yet been appointed. Our first Chairman, Dr. Don U. Deere, left the Board when his term expired in April 1992. Three new members were appointed in 1992 resulting in the current ten members:

Dr. John E. Cantlon replaced Dr. Deere as Chairman of the Board in April 1992. Dr. Cantlon is vice president emeritus of research and graduate studies and former dean of the graduate school at Michigan State University. His field of expertise is environmental science.

Dr. Clarence R. Allen is professor emeritus of geology and geophysics in the seismological laboratory at the California Institute of Technology, Pasadena.

Dr. Garry D. Brewer is dean of the School of Natural Resources and Environment and professor of resource policy and management at the University of Michigan.

Dr. Edward J. Cording is professor of civil engineering at the University of Illinois.

Dr. Patrick A. Domenico is the David B. Harris Professor of Geology at Texas A&M University, College Station, Texas.

Dr. Donald Langmuir is professor emeritus of geochemistry in the Department of Chemistry and Geochemistry at the Colorado School of Mines in Golden, Colorado.

Dr. John J. McKetta, Jr. is the Joe C. Walter Professor of Chemical Engineering emeritus at the University of Texas, Austin.

Dr. D. Warner North is a principal of Decision Focus, Inc., in Los Altos, California; a consulting professor at Stanford University; and associate director of the Stanford Center for Risk Analysis.

Dr. Dennis L. Price is a professor in the Department of Industrial Engineering and Operations Research, and is director of the Safety Projects Office at the Virginia Polytechnic Institute and State University in Blacksburg, Virginia.

Dr. Ellis D. Verink, Jr. is a Distinguished Service Professor emeritus of Metallurgy and former chair of the Department of Materials Science and Engineering of the University of Florida, Gainesville, Florida.

The terms of four current members will expire on April 19, 1994. Also, there is one unfilled position on the Board — a radiobiology / health physics expert. Nominees to fill all five of these vacancies have been sent by the National Academy of Sciences to the White House for review.

The Board staff

The NWPAA limits the size of the Board's professional staff to ten positions, all of which are now filled. In addition, we have hired nine, full-time employees to support the professional staff and Board members. Because of the comprehensive nature of the program, the diversity of Board member experience and expertise, and the part-time availability of Board members, this small, highly qualified professional staff is employed to its fullest capacity in supporting the Board's comprehensive review of the program. The Board offices are located in Arlington, Virginia.

The Board's reporting requirements

The Board reports to the U.S. Congress and to the Secretary of Energy at least twice each year. In its past reports, the Board has made numerous recommendations to the DOE on the civilian radioactive waste management program. The DOE's responses to Board recommendations are published in subsequent Board reports.

To provide the public with information on its activities, the Board periodically publishes a newsletter, which is mailed to more than 1,500 individuals and/or groups.

Board activities

During the past five years, the Board has sponsored numerous panel meetings and technical exchanges with representatives of the DOE and its contractors, the Environmental Protection Agency (EPA), the Nuclear Regulatory Commission (NRC), the state of Nevada, the U.S. Geological Survey, the Bureau of Reclamation, Indian tribes, the utilities, and state utility regulators. Members and staff have attended a variety of relevant technical conferences, symposia, and workshops. They have participated in many field trips to examine geologic and ecological features in the state of Nevada, especially the area around the proposed repository site at Yucca Mountain.

Board and panel meetings are open to the public and are announced in the Federal Register four to six weeks prior to each meeting. Press releases also are issued on most of the Board's activities. The Board has held three public hearings in Nevada to solicit the views of the public on transportation of high-level radioactive waste and on the potential effects associated with repository development activities. A fourth hearing on transportation issues was held in August 1991 in Denver, Colorado. Transcripts of meetings and minutes of business sessions are available to the public through the Board's library.

The Board's review of international programs

In an effort to learn about potential ways to increase the technical validity, efficiency, and cost-effectiveness of the U.S. program, Board members and staff have examined high-level radioactive waste programs in Belgium, Canada, Finland, France, Germany, Japan, Sweden, Switzerland, and the United Kingdom. In each country, Board members met with key technical experts and heard presentations on overall program activities, ongoing research and development, transportation systems, waste packages, and public information efforts. The Board has recommended that the DOE and Congress consider some approaches used in these countries when evaluating the U.S. civilian radioactive waste management program.

Board accomplishments

The Board has provided concrete contributions to the DOE program in the form of important technical recommendations. For example:

- In response to Board and NRC recommendations, the DOE has made several important changes to its design of the exploratory studies facility (ESF). Although the DOE's proposed 25-ft-diameter tunnels are, in the Board's view, larger than required for site-suitability assessment, the new ESF design is a substantial improvement over earlier versions.

- The DOE has adopted the Board's recommendation to use tunnel boring machines (TBMs) for excavating exploratory tunnels. As compared with proposed drilling and blasting, TBMs cause less rock disturbance of the tunnel walls, are less costly per tunnel mile, and excavate considerably faster.

- The thermal-loading strategy selected by the DOE will directly affect the final repository design and will have important implications for all aspects of the waste management system from storage through disposal. Based on a Board recommendation, the DOE management and operating (M&O) contractor is evaluating alternative thermal-loading strategies to determine how they could potentially affect the repository and the waste management system.

- The Board has repeatedly urged the DOE to develop a robust, long-lived waste package that will work together with geologic barriers to provide long-term isolation of the radioactive waste from the accessible environment. Also, the use of such waste packages should facilitate repository licensing and can help improve confidence in the long-term performance of a repository. The M&O contractor has begun to evaluate the potential contributions of such long-lived waste packages.

- The Board also has recommended that the DOE develop a waste management system that will minimize as much as possible the number of times waste will be handled, especially when shielding from high-level radiation is required. For example, the use of a multipurpose cask system, in which the waste can be stored, transported, and disposed, could result in much less handling than called for in the DOE's current baseline plan. The DOE is currently evaluating such a system.

- The Secretary of Energy has indicated that the DOE will emphasize intermediate goals and that efforts to adhere to final deadlines will not compromise technical requirements. This was one of the recommendations contained in the Board's March 1993 Special Report to Congress and the Secretary of Energy.

One very important role the Board plays is that of catalyst for the technical community. By scheduling meetings and asking questions, the Board is able to affect the DOE's technical and scientific program as it unfolds. The Board helps the DOE to continuously evaluate its own activities; to examine the fundamentals of the program; and to set priorities and define the program's technical objectives. The Board also has been instrumental in increasing communication and promoting cooperation within the DOE and among the DOE contractors and other organizations involved with high-level waste disposal issues.

Drawing on the significant expertise of its members, consultants, and professional staff, the Board has provided an in-depth review of the technical aspects of the DOE's waste management program in other areas, including seismology, hydrology, geochemistry, risk and performance assessment, and public health and safety.

Focus of future activities

There are several important issues to which the Board will turn its attention in the near future. Among these are:

- a continuing evaluation of efforts under way at the Yucca Mountain site to begin construction of the underground exploratory studies facility;

- a review of spent fuel storage options in view of possible repository and MRS schedule delays;

- monitoring progress in the DOE's implementation of top-level system studies;

- a review of the DOE environmental program at the Yucca Mountain site;

- a review of the DOE drilling and testing priorities during characterization of the Yucca Mountain site;

- a consideration of the impacts of the disposal of defense waste on the repository system;

- following the evolution of the radiation safety standard and its current review by the NAS; and

- a review of other technical topics, including issues related to the engineered barrier system and the potential effects of changes in climates on the site.

As the only agency providing an independent review of *all* technical and scientific aspects of the DOE's efforts to dispose of high-level radioactive waste, the Board believes it has a continuing and vital role to play in the progress of this important program.

Questions from the House Subcommittee on Energy and Water Development, Committee on Appropriations

(Hearing on Fiscal Year 1995 Appropriation Request, March 14, 1994)

From Chairman Bevill

Q#1: *Chairman Cantlon, you and your board have recommended that an independent review be conducted of the organizational structure of the DOE civilian nuclear waste program. Please explain your recommendation.*

A: This question was answered by Dr. Cantlon at the subcommittee hearing on March 14, 1994.

Q#2: *The Secretary of Energy has made a number of changes to the civilian nuclear waste program. Do you believe an independent review of the program should be postponed until these changes are in place?*

A: The changes that have been announced are primarily at the Yucca Mountain Site Characterization project office. The Board is encouraged by the direction of the reorganization that is taking place there and believes it will have a positive impact on the organizational structure and operation of the *project*. However, we continue to believe that a similar effort is needed at the *program* level. The review the Board recommended could help Dr. Dreyfus identify and implement needed changes in the program's organizational structure and management. In addition to addressing problems in these two areas, an independent review could provide program managers with a framework that would allow, for example, (1) better integration of the science and engineering in the program, (2) more informed judgments about opportunities for reducing duplication of efforts by multiple contractors, and (3) a restructuring of the program while maintaining the momentum and continuity of scientific and technical activities.

In a recent meeting, Dr. Dreyfus indicated that he shares many of the concerns the Board has raised about program management and that he is taking steps to address these management challenges. I share the concern, expressed by Dr. Dreyfus in our meeting, that an outside review at this time might delay needed near-term program decisions. The Board coupled its recommendation for an outside review of the organizational structure with the recommendation to maintain momentum in site-characterization activities. I am willing to accept postponement of an outside review, based on the need for continued program momentum and the hope that Dr. Dreyfus's initiatives can bring about needed management improvements. The Board will continue to watch the progress of the DOE program, and we will reiterate our recommendation for the outside review if we think it is needed.

Q#3: *The Administration's budget for civilian nuclear waste has proposed an alternative funding mechanism to increase the budget for the program. Is an increase in funding the answer to the problems of the civilian nuclear waste program?*

A: There is no question that scientific and technical work is being delayed for lack of funds. In the past, the DOE has chosen to allocate the majority of its funding to overhead and infrastructure costs leaving relatively too little for actual site-characterization activities. This has resulted in the delay of some important activities, such as underground excavation and initiation of thermal and corrosion testing necessary for the development of a long-lived waste package. If this trend continues, progress on scientific activities may still be impeded. In addition, some of the scientific and technical activities having to do with thermal loading and waste package materials research will take years to complete. Because of past delays, there may not be time to conclude these tests prior to the DOE's 2001 target date for submitting a license application to the Nuclear Regulatory

Commission. Consequently, it is possible that the DOE may enter the formal licensing process with some important scientific issues unresolved. This could delay or even jeopardize the licensing of the repository. Increased funding, together with program improvements in organization and management, will be needed to ensure adequate and timely progress.

Q#4: *In past reports, you have indicated that the civilian nuclear waste program's organizational structure is multilayered, program entities are geographically dispersed and responsibility for decision making is spread among the many managers. Do you see this situation improving?*

A: The organizational structure of the federal staff at the Yucca Mountain project office is being restructured, and in our opinion, the changes should eventually produce positive results. Dr. Dreyfus has indicated that similar but unspecified changes are in the works at the program headquarters in Washington. Although it is too early to evaluate the effects of these changes, we are encouraged by Dr. Dreyfus's candid acknowledgement that improvements are needed and his understanding of the kind of changes that will be necessary.

Q#5: *The committee has repeatedly expressed its concern that the civilian nuclear waste program has placed a disproportionately high percentage of its funds on management overhead rather than site characterization activities. What are your views on the DOE's use of their funds?*

A: The Board has expressed concern over the years that too much of the funding available for the repository program was being allocated to overhead and infrastructure costs leaving relatively limited amounts for site-characterization and other critical research. Dr. Dreyfus has said that he intends to reverse that trend and we are encouraged by his statements in this regard. We look forward to seeing tangible evidence of this change in emphasis.

Q#6: *The Department of Energy's civilian nuclear waste program employs more than 2,500 contract employees. Do you believe the Department's efforts are staffed appropriately?*

A: We have expressed our concern that the high overhead and infrastructure costs necessary to support the very large number of contractor employees working on the program have reduced the amounts of money available for scientific work. We have not looked specifically at the appropriateness of the DOE's staffing arrangements as part of our technical review of the program. However, our interactions with the DOE lead us to believe that there may be duplication of effort in some areas while other areas are understaffed. Because this situation can affect the technical and scientific activities, we believe it should be addressed as part of the program restructuring referred to by Dr. Dreyfus.

From Representative McDade

Q#1: *The Board has once again recommended the initiation of an independent review of the OCRWM's management and organizational structure.*

a. Does this review come under the purview of the Board? Would authorizing language be necessary to allow the Board to undertake such an evaluation?

A: The Board's mandate is to review the technical and scientific validity of the program. Consequently, management issues that affect the progress of the technical and scientific program do fall within our purview. The Board is made up of experts in the fields of science and engineering. The kind of review we have recommended would require experts with experience managing large projects. For this reason, the Board has suggested that the Secretary appoint a small, independent group of internationally recognized experts with extensive experience in managing large, complex programs and in system acquisition to conduct this review. Although necessary, knowledge in the nuclear waste management field alone would be insufficient to carry out the review. Given these kinds of experts, such a review should not take long, nor require a large staff. Furthermore,

we do not believe the program should be halted or even delayed while a review is conducted.

b. Last year, 18 audits and 50 surveillances of contractors were performed of YMP. The Secretary of Energy is currently reviewing the program with the assistance of outside consultants. Why do you believe it is necessary to conduct yet another review of OCRWM? Shouldn't these other reviews and audits be sufficient to identify problems and their potential impact on YMP?

A: The audits and surveillances of contractors referred to in Dr Dreyfus's statement are part of the ongoing oversight of the program's contract and regulatory compliance. This is very different from the programwide review of the organizational structure and management called for by the Board. The purpose of the review recommended by the Board one year ago would be to provide program managers with the tools they need to address very broad-based structural and management problems so that the program can move ahead efficiently and expeditiously — while maintaining and enhancing the technical integrity of the many scientific activities that are part of the site-characterization process. The Secretary has initiated a review of the *Yucca Mountain Project*, which is one part of the civilian radioactive waste management *program*. We feel that a similar effort is needed at the program level. Dr. Dreyfus has acknowledged that he shares many of the concerns expressed by the Board and has indicated that he is taking actions to improve program management. The Board will continue to monitor the program's progress on the management and organizational issues, and we will reiterate our recommendation for the outside review if we find that Dr. Dreyfus's initiatives have not dealt adequately with these issues.

From Representative Meek

Q#1: *I note that the Technical Review Board recommends more studies as I understand it. Dr. Cantlon, one of the ways of preventing something from happening is to study it to death.*

a. Will the studies recommended by your Board delay the opening of Yucca Mountain?

A: We have stated that any review of the program should be conducted concurrently with site characterization to avoid reducing the momentum of important scientific and technical studies. Correcting the program's organizational structure and management problems could help avoid costly errors that would require time and money to correct. Therefore, a review of this kind could actually help avoid delays and speed program progress over the long term.

b. Do any of these studies duplicate any which have already been conducted?

A: The review that has been initiated by the Secretary of Energy involves the *project* not the *program* as a whole. The kind of review we have suggested — completely independent, focused on the organizational structure and management of the entire program — has never been done. Dr. Dreyfus has indicated a number of changes he intends to pursue. The Board is hopeful that these changes will be successful and timely and that a review of the kind we have called for will not be necessary. However, the Board will continue to monitor the program's progress in resolving these organizational and management problems, and we will reiterate our recommendation for the outside review if we find that they have not been addressed adequately.

Appendix F
List of Questions to the OCRWM About Scenario A; OCRWM Responses

On May 17, 1994, the NWTRB submitted to the DOE a series of technical questions about the DOE's emerging changes to the civilian radioactive waste management program, at that time called "Scenario A." On June 30, 1994, the OCRWM responded with answers to those questions. Both the Board's questions and the OCRWM responses are included here.

UNITED STATES
NUCLEAR WASTE TECHNICAL REVIEW BOARD
1100 Wilson Boulevard, Suite 910
Arlington, VA 22209

May 17, 1994

Dr. Daniel Dreyfus
Director
Office of Civilian Radioactive Waste Management
U.S. Department of Energy
1000 Independence Avenue, S.W.
Washington, DC 20585

Dear Dr. Dreyfus:

At the March 22, 1994, meeting of the Board's Panel on the Environment & Public Health and later at the April 11, 1994, Board meeting, members of your staff made presentations on the Administration Funding Proposal, otherwise called "Scenario A." As we understand it, Scenario A appears to have two fundamental goals: (1) to facilitate federal acceptance of spent fuel from the utilities beginning in 1998 and (2) to enable the DOE to apply for NRC authorization to construct a repository at Yucca Mountain in 2001.

Scenario A marks a departure from the past. We believe several of the following actions proposed in pursuit of Scenario A have potential implications for the technical and scientific program, including:

- obtaining increased funding for fiscal year 1995 and subsequent years,
- delivering multipurpose canisters (MPCs) to utilities beginning in 1998,
- focusing the site-characterization program so that the DOE can determine the suitability of the Yucca Mountain site in 1998,
- deferring some site-characterization and testing activities until after the start of repository construction or until repository operation begins,
- designing the repository to allow waste retrievability for up to 100 years,
- initiating the National Environmental Policy Act (NEPA) process as soon as possible, and
- involving stakeholders and the public prior to making key decisions.

Board members would like to understand more fully the logic and substance behind Scenario A. As a result, we are enclosing a list of questions that reflect many of the issues we have raised during the last four years.

Telephone: 703-235-4473 Fax: 703-235-4495

The Board has an appreciation for the evolving nature of the proposed new program design and recognizes that answers may not yet be available to all of our questions. Still, even partial answers that are as specific as possible will help to begin a continuing dialogue between the DOE and the Board in which the implications of the proposed new program design can be understood and thoroughly ventilated.

Because we would like to include a more detailed discussion of Scenario A and the DOE's responses to the enclosed questions at our July 12-13 Board meeting in Denver, we would appreciate receiving written responses by July 1. The Board invites you, or your senior management designee, to participate in discussions of Scenario A at that meeting.

Finally, the Board was very pleased with the outcome of its April meeting in Reno. Those who shared with us their experiences in assessing sites for other critical facilities contributed greatly to the meeting's success. We believe that many of their comments are directly applicable to the Yucca Mountain program. On behalf of the NWTRB, I also would like to thank you and your staff for the DOE's contribution to the Board's April meeting.

I look forward to hearing from you.

Sincerely,

John E. Cantlon

John E. Cantlon
Chairman

Enclosure

JEC136Vb

Questions About the Administration Funding Proposal

1. (a) What are the specific technical bases for the decisions that led to the development of Scenario A? (b) Will the *Site Characterization Plan* be modified to reflect the new program design? (c) If so, what process will be used to modify it? (d) If not, what will be the status of the existing *Site Characterization Plan* in structuring the technical investigations at Yucca Mountain?

2. At the January 1994 Board meeting, you said that "institutionalizing stakeholder interaction" was one of the OCRWM program's important short-term goals.

(a) How does the DOE decide which decisions are "key decisions," requiring stakeholder input? (b) How and to what extent did the DOE obtain stakeholder and public input *prior* to formulating Scenario A? (c) Which stakeholders were involved? (d) What specific mechanisms is the DOE using to obtain stakeholder and public input?

3. Scenario A calls for increased budgets, a decreased scope of near-term site-characterization activities (e.g., potentially less tunneling), and a demanding schedule. (a) What specific studies previously planned under the SCP and in the study plans (i) will be completed before application for a license to begin repository construction, (ii) will be deferred until after repository construction, (iii) will be deferred until after repository operation begins, and (iv) will be deleted? (b) What criteria were used to assign particular studies to one of the four categories?

4. The OCRWM has asked for increased program funding because it believes that the scientific work has been underfunded. (a) If Congress provides the requested funding for Scenario A, specifically how much will allocations to underground excavation, waste package and materials research, and other site-suitability activities be increased? (b) How much will be allocated to overhead and infrastructure? (c) Will these allocation priorities change if funding to the program is not increased to the level requested?

5. Scenario A calls for the completion of a five-mile main loop with additional drifting *only if necessary*. (a) What is the technical basis that supports this change from the current program design? (b) What technical criteria will the DOE use to decide whether the five-mile loop is sufficient for a decision on site suitability? (c) If a five-mile loop is insufficient, how will the DOE decide how much additional underground excavation will be needed?

6. Thermal loading is a key parameter associated with various waste isolation strategies and repository / waste package designs. (a) Under Scenario A, when will a preliminary decision about thermal loading be made? (b) When will a final decision be made? (c) What specific information does the DOE believe will be required to make sound technical decisions on (i) repository design and (ii) a waste package design that is compatible with the MPC? (d) How will the timing of the DOE's application to the NRC for a construction license affect the DOE's thermal-loading decision?

7. Under Scenario A, the waste will "remain retrievable" for 100 years. (a) What contingency plans for retrieving the waste will be developed before deciding whether to adopt Scenario A? (b) When will retrieval plans be developed? (c) How will these plans affect the total system life cycle cost (TSLCC) and the adequacy of the 1-mil-per-kilowatt-hour fee?

8. Descriptions of Scenario A refer to a "site suitability evaluation," "technical site suitability," and a "site recommendation report." (a) When and how will the DOE identify the specific tests and data necessary to support these site-suitability determinations? (b) Does the DOE believe the siting guidelines of 10 CFR Part 960 are adequate for determining site suitability under Scenario A? (c) If not, what amendments are envisioned and what process will be used to adopt them?

9. The NRC's regulations (10 CFR Part 60) require the DOE to demonstrate, prior to repository construction, that there is "reasonable assurance" that the facility will perform safely. The SCP outlines a testing plan that implies an agreement between the NRC and the DOE about how "reasonable assurance" will be demonstrated. Under Scenario A, some of the tests will be postponed until after repository operation begins. (a) How will the DOE demonstrate the level of assurance in the performance of the repository that would have been obtained under the SCP? (b) Will it be necessary to reinterpret or change the level of assurance? (c) If so, how will it change?

10. According to presentations made at the panel meeting on March 22, 1994, by representatives of the Council on Environmental Quality and the DOE's General Counsel Office, the Yucca Mountain Environmental Impact Statement should include a discussion of various repository and waste package design alternatives. (a) Under Scenario A, what alternatives will be sufficiently well understood to be evaluated? (b) Will separate impact statements be prepared for MPC procurement, repository development, and transportation? (c) How will the interdependencies among those activities be analyzed?

Department of Energy
Washington, DC 20585

June 30, 1994

Dr. John E. Cantlon
Chairman
Nuclear Waste Technical Review Board
1100 Wilson Boulevard
Arlington, Virginia 22209

Dear Dr. Cantlon:

Enclosed is the Department of Energy's response to the questions contained in the Nuclear Waste Technical Review Board's letter dated May 17, 1994. To comply with your request for a timely response, we have attempted to capture the current state of the development of the Proposed Program Approach (previously referred to as Scenario A), which is still undergoing review and revision based upon further analysis and external comment.

One of the foremost strategic goals of the Department is to resolve the disconnect between the program's expectations and its ability to achieve them. As these expectations have evolved over the years, the program has lost its ability to meet the original intent of the Nuclear Waste Policy Act of 1982, as amended. Therefore, the Proposed Program Approach is an attempt to realign the program closer to the original intent of the legislative and regulatory framework, and to develop a set of goals and a schedule that has a reasonable probability of success and is consistent with the resources that can be allocated to it.

The Proposed Program Approach incorporates many of the Board's past recommendations and is also consistent with the recommendations made by the National Academy of Sciences in its 1990 report, *"Rethinking High-Level Waste."* That report stressed that it is not practical to assume that all information would be available prior to constructing a repository. The Proposed Program Approach lays out a stepwise approach to repository development through a series of decisions based on an increasing knowledge base that is fully consistent with the existing regulatory framework. The approach also addresses the realities of near-term storage of spent fuel.

As we continue to develop the Proposed Program Approach, we welcome the Board's specific comments and recommendations regarding our technical program.

We also intend to continue to inform the Board as we further refine the proposal in response to external comments and more detailed analysis. Please contact me at (202) 586-6842, if you wish to discuss the current status of the proposal further.

Sincerely,

Daniel A. Dreyfus, Director
Office of Civilian Radioactive
Waste Management

Enclosure

Department of Energy
Responses to Questions Contained In
Nuclear Waste Technical Review Board's Letter
Dated May 17, 1994

In a letter to Daniel A. Dreyfus, the Director of the Office of Civilian Radioactive Waste Management (OCRWM) dated May 17, 1994, the Nuclear Waste Technical Review Board posed ten questions regarding Scenario A, currently referred to as the Proposed Program Approach. The Department of Energy's (DOE) response to these questions is provided below.

Question 1:

(a) What are the specific technical bases for the decisions that led to the development of Scenario A? (b) Will the *Site Characterization Plan* be modified to reflect the new program design? (c) If so, what process will be used to modify it? (d) If not, what will be the status of the existing Site *Characterization Plan* in structuring the technical investigations at Yucca Mountain?

Response:

The basis for the decisions that led to development of the Proposed Program Approach (the successor to "Scenario A") was the recognition by DOE that the expectations for the program could not be achieved given the historical funding levels. Specifically, the realities of the near-term, at reactor, storage of spent commercial fuel must be addressed, and a technical approach to the determination of the suitability of the candidate Yucca Mountain site for a geologic repository must be articulated. This approach must include the production of the requisite environmental and regulatory documents required to support decision making within both budget and schedule constraints. Additionally, DOE recognized that science could not meet unrealistic expectations regarding the level of knowledge and the uncertainty associated with the predictions of long-term repository performance required for licensing.

DOE believes that the Nuclear Waste Policy Act of 1982, as amended (NWPA), intended that site characterization would provide sufficient information for decision making with an implicit understanding that significant uncertainties associated with the prediction of long-term performance of a repository system would remain. The NWPA authorizes the development of geologic repositories through a process that includes a series of decisions which reflect an increasing base of knowledge. The Proposed Program Approach is a strategy to realign the program's direction with the original intent of the legislative/regulatory framework.

The Site Characterization Plan (SCP), issued in 1988, contained an extensive testing, design, and performance assessment program to acquire the data for decision making. The SCP was neither intended nor required to be revised, but, there was explicit recognition of the need to make specific revisions to the program as data is obtained.

Implementation of the Proposed Program Approach will not alter this premise. Changes to the site characterization program are reported semi-annually in the Site Characterization Progress Reports. Changes to the program are controlled through revisions to the Site Characterization Program Baseline and the Site Design and Test Requirements Document, as well as the supporting study plans. When the details of the Proposed Program Approach are further developed, resulting changes to the program will be documented in these and other documents using the program's baseline change control procedures. These changes will be identified over the next several months.

Question 2:

At the January 1994 Board meeting, you said that "institutionalizing stakeholder interaction" was one of the OCRWM program's important short-term goals. (a) How does the DOE decide which decisions are "key decisions," requiring stakeholder input? (b) How and to what extent did the DOE obtain stakeholder and public input prior to formulating Scenario A? (c) Which stakeholders were involved? (d) What specific mechanisms is the DOE using to obtain stakeholder and public input?

Response:

DOE's draft public participation policy recognizes public involvement as a fundamental component of program operations and directs program managers to identify "key decisions" (those where predecisional public input should be solicited) in consultation with their stakeholders. OCRWM is reviewing its plans to ensure they are consistent with the Department's proposed public involvement policy. DOE would welcome any suggestions the Board may have with respect to criteria that could be applied in determining the need for expanded stakeholder involvement.

To meet the time constraints of the Congressional budget cycle, DOE made a number of initial assumptions with regard to the framework of the Proposed Program Approach, which was supported by the Administration's Fiscal Year 1995 Budget Request. In making these assumptions, DOE considered the positions that its many stakeholders had communicated on a continuing basis to program officials. As the proposed strategy was being refined, DOE managers, both in Washington and in Las Vegas, interacted frequently with program stakeholders and Congressional staff. These interactions provided valuable input to the formulation of the Proposed Program Approach.

Specifically, DOE managers met with representatives from State, Tribal and local governments, industry groups and trade-associations, regulatory agencies, professional societies, environmental organizations, and labor organizations. These meetings included discussions about development of the scenarios used in the planning process. In addition, the program hosted several stakeholder meetings to discuss aspects of the Proposed Program Approach. In February, meetings were held in Washington and in Las Vegas to discuss the Administration's Fiscal Year 1995 Budget Request, which included a broad description of the program's proposed direction. In May, the program sponsored a major stakeholder meeting in Las Vegas to discuss with the Director the overall program direction, the Proposed Program Approach, and the site suitability evaluation process. Representatives of the OCRWM program also routinely participated in a variety of industry, governmental, and professional society meetings that provided opportunities to receive input and feedback regarding the program's plans and activities.

Once the program completed analysis of the strategic scenarios, a preferred approach was selected to propose to program stakeholders, the Congress, the Board, the Nuclear Regulatory Commission (NRC), and the public in the appropriate forums.

The identification of a preferred alternative does not predispose a decision to proceed. As the Board is aware, implementation of the Proposed Program Approach is predicated upon adequate funding. Securing this funding requires significant lead time and timely actions on the part of DOE. This will involve both Administration-wide and Congressional approval. The Congressional appropriation process is an open, public, and representative process, and the program's proposed approach in broad terms, was aired completely in that process in support of the funding request. Despite the preceding ac-

tions, DOE will continue to evaluate and refine elements of the Proposed Program Approach, based, in part, upon the input from its stakeholders and, of course, dependent upon the results of Congressional direction.

Question 3:

Scenario A calls for increased budgets, a decreased scope of near-term site characterization activities (e.g., potentially less tunneling), and a demanding schedule. (a) What specific studies previously planned under the SCP and in the study plans (i) will be completed before application for a license to begin repository construction, (ii) will be deferred until after repository construction, (iii) will be deferred until after repository operation begins, and (iv) will be deleted? (b) What criteria were used to assign particular studies to one of the four categories?

Response:

The detailed plans that identify which site characterization studies will be conducted, deferred, or eliminated are being developed and will be provided to the Board along with a description of the criteria used to make those determinations when they are available later this year. In general, however, such decisions will be consistent with the strategy articulated in the Proposed Program Approach, which recognizes the existing incremental process for repository licensing beginning with the submittal of the initial license application for construction authorization (10 CFR 60.24(a) and 60.31), followed by an updated application for authorization to receive and possess spent fuel and high-level waste (10 CFR 60.24(b) and 60.41), and a final application for an amendment to close the repository (10 CFR 60.51).

This strategy focuses near-term activities on the information required for determining the suitability of the candidate Yucca Mountain site, and if suitable, the requirements for obtaining a repository construction authorization, including ensuring the safety of repository operations and providing an adequate basis for confidence in waste package containment. A lower priority will be given initially to those tests that support demonstration of compliance with requirements related to longer term radionuclide transport and release. Sufficient testing and modelling will be conducted in this latter category to develop bounding analyses for the license application. Further testing would be deferred and conducted as part of the performance confirmation program required by 10 CFR Part 60.

Question 4:

The OCRWM has asked for increased program funding because it believes that the scientific work has been under funded. (a) If Congress provides the requested funding for Scenario A, specifically how much will allocations to underground excavation, waste package and materials research, and other site-suitability activities be increased? (b) How much will be allocated to overhead and infrastructure? (c) Will these allocation priorities change if funding to the program is not increased to the level requested?

Response:

The details of the testing program that would support the Proposed Program Approach are being developed. Consequently, the allocation of budgets among the various elements of the repository program are not available at this time. The re-baselined budget information should be available in early

Fiscal Year 1995 and will be provided to the Board at that time. The program has, however, stated that the proposed increase will predominately be allocated to work at Yucca Mountain. Compliance and management costs will be constrained.

The funding allocation will also reflect the program management improvements achieved in the reorganization of the Yucca Mountain Site Characterization Office, and the re-alignment of headquarters elements along with any recommendations or other actions resulting from the ongoing independent financial and management review of the Yucca Mountain Site Characterization Office. In any case, the funding allocation will be based on the program's priorities and will support only the minimum infrastructure and overhead required for achieving interim milestones and completing the program's mission.

As DOE reported to Congress, if the funding level in the Administration's Fiscal Year 1995 Budget Request is not obtained, and the prognosis for future budgets were to indicate that DOE will receive a level of funding consistent with past years, the entire OCRWM program will be re-evaluated. The resultant funding priorities for such a program would clearly be dependent on the nature of that program. Under such funding constraints, it is probable that a full program, carrying all licensing activities forward, would not be continued.

Question 5:

Scenario A calls for the completion of a five-mile main loop with additional drifting *only if necessary*. (a) What is the technical basis that supports this change from the current program design? (b) What technical criteria will the DOE use to decide whether the five-mile loop is sufficient for a decision on site suitability? (c) If a five-mile loop is insufficient, how will the DOE decide how much additional underground excavation will be needed?

Response:

The technical basis for reducing the amount of underground excavation to be conducted is an extension of underlying bases of the Proposed Program Approach, which was discussed in the response to Question 1. Our current thinking is that the site characterization program will be refocused to obtain the information that is critical to support DOE and NRC decisions pertaining to site suitability and licensing. In the Proposed Program Approach, the goal of the underground excavation program is not the completion of the five-mile (7.8 km) loop. Rather, emphasis is being placed on completing sufficient excavation to support two critical activities: (1) constructing at least two exploratory drifts off the main drift in the Topopah Spring Level to obtain information on the water content and age in the Ghost Dance Fault and (2) starting the Exploratory Studies Facility (ESF) heater tests in the North Ramp Extension as soon as possible . Depending on what is found in the Ghost Dance Fault, a decision will be made about the appropriate exploration of the Calico Hills unit. Such a decision would obviously impact the timing for the completion of the 7.8 km loop.

Further details on the proposed drifting sequence follow, keeping in mind that this is our current thinking subject to discussion with the Board and other stakeholders:

According to the strategy in the Proposed Program Approach, ESF excavation will begin in August 1994 in the North Ramp using the 7.6 meter tunnel-boring machine (TBM #1). Acquisition will be made of a second, smaller diameter TBM (TBM #2) during Fiscal Year 1995, concurrent with North

Ramp excavation. Once TBM #1 has completed the North Ramp and "turned the corner" into the Topopah Spring Level main drift, TBM #2 will be erected, and the North Ramp Extension will be excavated. This will be concurrent with Topopah Spring Level main drift excavation by TBM #1.

TBM #1 will proceed south along the Topopah Spring Level main drift until it passes the northernmost of the two Ghost Dance Fault exploratory drifts. This drift will then be driven, approximately 120 to 150 meters, through the Ghost Dance Fault. TBM #1 will proceed south in the Topopah Spring Level main drift past the southernmost Ghost Dance Fault drift. Once again, TBM operations will be halted long enough to start the second Ghost Dance Fault exploratory drift. After completion of the second Ghost Dance Fault exploratory drift, TBM #1 will proceed with completion of the 7.8 km loop. The rate of advance will be dependent on resources needed for other ESF excavation activities. TBM #2 will finish the North Ramp Extension shortly after the time period that the Ghost Dance Fault drifts are excavated. After completion of the North Ramp Extension, several parallel drifts will be driven to the north off the North Ramp Extension to house heater tests.

A decision on excavation into the Calico Hills unit will be made once information is available from the Ghost Dance Fault drifting described above. If Calico Hills drifting is needed, it will likely be driven using TBM #2. The point of access and ultimate configuration of Calico Hills drifting is the subject of a study to be performed in early Fiscal Year 1995.

The adequacy of the information obtained through an integrated exploration and testing program will be determined through suitability evaluations, design development, and in the preparation of the initial license application. If the geologic data is deemed insufficient to support decision making, additional excavation and testing will ensue. The criteria used to determine the adequacy of data are under development and will be provided to the Board when they are available.

Question 6:

Thermal loading is a key parameter associated with various waste isolation strategies and repository / waste package designs. (a) Under Scenario A, when will a preliminary decision about thermal loading be made? (b) When will a final decision be made? (c) What specific information does the DOE believe will be required to make sound technical decisions on (i) repository design and (ii) a waste package design that is compatible with the MPC? (d) How will the timing of the DOE's application to the NRC for a construction license affect the DOE's thermal-loading decision?

Response:

Under the Proposed Program Approach, the range or ranges of thermal-loadings will initially be bounded in 1998. As further information becomes available, the bounding evaluations will be reviewed and updated, and will be included in the license application to construct the repository, scheduled to be submitted in 2001.

The Proposed Program Approach calls for making the thermal-loading decision prior to the completion of the updated license application for receiving and possessing waste. This updated license application is scheduled to be submitted in 2008. Thermal-loading will be confirmed as a result of data collected during the performance confirmation program.

An understanding of the mechanisms which influence the coupled Thermal-Mechanical-Hydrologic-Chemical performance of the natural barriers is required to make sound technical decisions relative to thermal-loading for repository and waste package design. The development of a variety of sub-models and a testing of their validity is included in the program's scientific and engineering programs. These models will provide the basis for thermal loading decisions.

(i) For repository design, the following are examples, and not necessarily a complete list, of the information being developed:

A description of thermal mechanisms for heat transfer, including the fraction of heat transferred by each mechanism (conduction, convection, and radiation).

A hydrologic model that will bound the hydrologic performance of the natural barriers. This model will incorporate information gathered on bulk permeabilities, saturation, fluid and vapor flow, and fracture/matrix coupling.

A model of the thermal-mechanical response of the host rock. This model will include data collected on rock compressive and tensile strength, thermal expansion coefficients, moduli (elastic, deformation, etc.), Poisson's ratio, and joint frequency and orientation.

A geochemical model of the response of the natural barriers will include information on reaction rates, water chemistry (Eh, pH) and the change with temperature, sorption coefficients, retardation rates, colloid formation, and dispersivity.

(ii) For waste package design, these and other models will be used to address:

Hydrologic and geochemical responses of the potential site as they impact the waste package environment.

Geomechanical response of the near-field environment and the potential for rock falls within the emplacement openings.

Metallurgical, mechanical, and corrosion behavior of containment barriers in response to temperature.

Thermal stability of each waste package/engineered barrier system component during its proposed lifetime.

DOE's license application to construct the repository is scheduled for submittal to NRC in 2001. Prior to this submittal, the impacts of a range of thermal-loadings will be analyzed and the results of those analyses reported with the initial license application. The analyses will support the use of particular bounds for thermal-loading to justify reasonable assurance of meeting the performance objectives of 10 CFR Part 60.

Question 7:

Under Scenario A, the waste will "remain retrievable" for 100 years. (a) What contingency plans for retrieving the waste will be developed before deciding whether to adopt Scenario A? (b) When will retrieval plans be developed? (c) How will these plans affect the total system life cycle cost (TSLCC) and the adequacy of the 1-mil-per-kilowatt-hour fee?

Response:

The criteria for retrievability of emplaced waste are under development. As part of the development process, different retrieval time periods and normal and abnormal retrieval conditions will be evaluated. To date, the program has developed a draft Concept of Retrieval Operations and revised the DOE Position on Retrievability and Retrieval for a Geologic Repository. That position was originally an appendix of the "Generic Requirements for a Mined Geologic Disposal System" (DOE OGR-B2) document produced in the mid- to late 1980s. The Concept of Operations addresses both normal and abnormal retrieval conditions.

To further examine this subject of extended retrievability, DOE has directed a study of the advantages and disadvantages of extended retrievability periods. The "Retrievability Period System Study" is scheduled to be completed by September 30, 1994, and will evaluate 50-, 100-, and 200-year retrieval periods, to focus the advanced conceptual design effort.

To maintain the option to retrieve for 100 years would mean extending the caretaker period by approximately 50 years. As used in the last published TSLCC analysis (DOE/RW-0236, May 1989), the caretaker period is the interval of time from the last waste package emplacement until the end of the retrieval period. Using the same cost model and assumptions as used in the May 1989 TSLCC analysis, the increased cost due to a 50-year extension of the caretaker period would be $1,224 million (in 1993 dollars). As with the May 1989 TSLCC analysis, this does not include retrieval costs, but does include costs for removing a small number of waste packages for performance confirmation testing. The Proposed Program Approach affects multiple aspects of the program scope (and costs) and hence the May 1989 TSLCC analysis and the December 1990 Addendum (DOE/RW-0295P) are out of date with respect to the Proposed Program Approach. An adequate revision to the TSLCC cannot be done until sufficient engineering design is completed in early Fiscal Year 1995. It is estimated that the next revision to the TSLCC will be completed by the end of Fiscal Year 1995. Upon completion of that effort, the fee adequacy issue can be addressed.

Question 8:

Descriptions of Scenario A refer to a "site suitability evaluation," "technical site suitability," and a "site recommendation report." (a) When and how will the DOE identify the specific tests and data necessary to support these site-suitability determinations? (b) Does the DOE believe the siting guidelines of 10 CFR Part 960 are adequate for determining site suitability under Scenario A? (c) If not, what amendments are envisioned and what process will be used to adopt them?

Response:

DOE is preparing Fiscal Year 1995 and out year planning guidance for project participants that will incorporate the concepts from the Proposed Program Approach, including proposed milestones for the suitability decision schedule. This guidance will start the process of identifying the specific tests and data necessary to support the site suitability determinations that were proposed in the Proposed Program Approach. The results of this planning will be documented in a Technical Implementation Plan for site investigations for Fiscal Year 1995 and in the long-range plan for the out years. The Fiscal Year 1995 Technical Implementation Plans will be finalized in September 1994. The Long-Range Plan should be finalized in mid-1995.

DOE believes that the siting guidelines are adequate for determining site suitability under the Proposed Program Approach. The Proposed Program Approach simply provides a phased schedule for a site suitability decision. This schedule allows DOE to evaluate specific guidelines or groups of guidelines when sufficient data and analyses are available for the evaluation. Using this phased approach, DOE has an opportunity to make earlier decisions on specific guidelines as the data become available, rather than waiting until 1998 or later to produce an overall evaluation of all guidelines.

Although DOE is not adapting the siting guidelines for the Proposed Program Approach, DOE has elected to re-examine the siting guidelines in light of past statutory and regulatory changes. The purpose of this initiative is to determine if sections of the guidelines might require formal clarification, or even revision, before suitability evaluations begin. DOE has requested input to this decision from program stakeholders in an April 25, 1994, *Federal Register* Notice of Inquiry, and at the May 21, 1994, stakeholders meeting. Once the public comment period has closed, DOE will review these comments and decide what process, if any, will be used to clarify or revise the siting guidelines.

Question 9:

The NRC's regulation (10 CFR Part 60) requires the DOE to demonstrate, prior to repository construction, that there is "reasonable assurance" that the facility will perform safely. The SCP outlines a testing plan that implies an agreement between the NRC and the DOE about how "reasonable assurance" will be demonstrated. Under Scenario A, some of the tests will be postponed until after repository operation begins. (a) How will the DOE demonstrate the level of assurance in the performance of the repository that would have been obtained under the SCP? (b) Will it be necessary to reinterpret or change the level of assurance? (c) If so, how will it change?

Response:

The extensive site characterization program originally outlined in the SCP, including subsequent changes, reflects the expectations of data and analyses required to predict long-term repository performance and go beyond what is actually needed to comply with the regulatory requirements. Our current thinking is that the amount of information needed to support the decisions embodied in the Proposed Program Approach will provide a sufficient basis for a "reasonable assurance" finding. In developing the underlying rationale for the Proposed Program Approach, we evaluated both the letter and intent of 10 CFR Part 60 to ensure that the Proposed Program Approach was consistent with the flexibility already inherent in the existing regulation. For example, at the time of submittal of the license application, 10 CFR 60.24(a) requires that: *"The application shall be as complete as possible in the light of information that is reasonably available at the time of docketing."* Furthermore, DOE believes that NRC expects that the "reasonable assurance" finding will be based on limited information. 10 CFR 60.102 states:

> *While these performance objectives and criteria are generally stated in unqualified terms, it is not expected that complete assurance that they will be met can be presented.... Proof of the future performance... over time periods of many hundreds of many thousands of years is not to be had in the ordinary sense of the word. For such long-term objectives and criteria, what is required is reasonable assurance, making allowance for the time period, hazards, and uncertainties involved, that the outcome will be in conformance with those objectives and criteria.*

Question 10:

According to presentations made at the panel meeting on March 22, 1994, by representatives of the Council on Environmental Quality and the DOE's General Counsel Office, the Yucca Mountain Environmental Impact Statement should include a discussion of various repository and waste package design alternatives. (a) Under Scenario A, what alternatives will be sufficiently well understood to be evaluated? (b) Will separate impact statements be prepared for MPC procurement, repository development, and transportation? (c) How will the interdependencies among those activities be analyzed?

Response:

In response to the Secretary of Energy's June 1994 Policy on the National Environmental Policy Act (NEPA), and the suggestions made by interested parties in the past year, OCRWM is reviewing its NEPA strategy. This review will include an evaluation of alternative approaches for implementing the NEPA requirements for the various program activities and the proposed methodology to address the interdependencies among those activities. The issues raised by the Board will also be addressed in scoping activities that will be associated with implementation of NEPA requirements.

Appendix G

Board Letter to the OCRWM and Comments About Exploration and Testing for Site-Suitability Determination

On December 6, 1994, the Board sent to the OCRWM a letter with enclosed comments on the OCRWM's new program approach to developing and licensing the nation's first spent fuel and high-level waste repository. The Board's comments summarize the site studies and other activities it believes are most important for reducing the current uncertainties about the suitability of the Yucca Mountain site.

UNITED STATES
NUCLEAR WASTE TECHNICAL REVIEW BOARD
1100 Wilson Boulevard, Suite 910
Arlington, VA 22209

December 6, 1994

Dr. Daniel A. Dreyfus, Director
Office of Civilian Radioactive
Waste Management
U.S. Department of Energy
Washington, DC 20585

Dear Dr. Dreyfus:

During the past six months, the Nuclear Waste Technical Review Board has met on several occasions with representatives of the Department of Energy (DOE) to gain a better understanding of your new program approach to developing and licensing the nation's first spent fuel and high-level waste repository. Ideally, one should be able to discern in the program a direct linkage among a waste isolation strategy, key decisions, technical activities, budgets, and schedules. Although the program has not yet reached this level of integration, the Board is encouraged that the program seems to be moving in this direction. It is in this spirit that we offer our comments on the evolving civilian radioactive waste management program.

The Board understands that many details of the program approach have yet to be worked out; however, we have some concerns that we believe should be brought to your immediate attention. The points listed briefly below are discussed in more detail in the enclosed document.

- A clearer definition of "technical site suitability" is needed now to establish a sound basis for future program efforts.

- The DOE should continue to develop a waste isolation strategy to provide an improved technical basis for deciding which site-characterization tests will be completed, deferred, or deleted.

- Perhaps the single most important goal in characterizing the site is predicting (or placing bounds on) the amount and significance of water that could reach the repository, corrode waste packages, and transport radionuclides to the environment.

- The effects of waste heat on repository performance must be understood well enough to permit confident predictions of (or bounds on) repository performance for alternative thermal loadings.

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- A few alternatives for the thermal loading of a Yucca Mountain repository should be carried forward until a better technical basis has been developed for choosing a preferred loading.

- The Board believes that substantially more underground excavation will be needed for a technical site-suitability decision than currently is planned.

The enclosed document also summarizes the site studies and other activities that the Board believes are most important for reducing current uncertainties about the suitability of the Yucca Mountain site.

In closing, let me emphasize that the Board views the new program approach as an excellent opportunity to streamline the scope of site-characterization activities and to improve the technical bases for program decisions. However, completing the necessary site studies and repository design efforts within the current schedule will be a significant technical and managerial challenge, especially considering the need for external reviews by and coordination with the Nuclear Regulatory Commission, the National Academy of Sciences, and other groups. The Board looks forward to continued interaction as the program evolves.

Sincerely,

John E. Cantlon

John E. Cantlon
Chairman

Enclosure:
Recommendations for
Evaluating Site Suitability

Recommendations for Evaluating Site Suitability

Two recent meetings of the Nuclear Waste Technical Review Board, in October and November 1994, focused on the U.S. Department of Energy's (DOE) plans for evaluating the suitability of the Yucca Mountain candidate repository site and the technical studies (especially thermal testing) to be conducted at the site. As a result of those meetings, the Board has reached three conclusions that require your attention. These conclusions are discussed in the following paragraphs. The Board then identifies the areas of technical uncertainty that it believes are most important for evaluating the suitability of the Yucca Mountain site. Finally, this document offers some general recommendations for exploration, testing, and analytical activities needed to produce a technically defensible evaluation of the suitability of the Yucca Mountain site, as well as some areas where current efforts could be reduced.

The Board is unable to say that these activities are absolute requirements, nor can the Board guarantee that these activities will prove sufficient. In fact, revisions to plans for site characterization will be inevitable as information from the exploratory studies facility and other surface-based and laboratory activities is collected and evaluated. However, based on today's knowledge of the site, on the anticipated legal and regulatory requirements for further repository development, and on the current uncertainties about the specifics of the DOE's waste isolation strategy, the Board believes that the activities identified in this document represent a prudent suite of studies for evaluating technical site suitability.

Conclusions from our recent meetings

1. *A clearer definition of "technical site suitability" is needed.* The DOE needs to identify the technical requirements for its technical site-suitability decision and the additional requirements for the licensing stage of repository development. Clear definitions of "technical site suitability" and other program goals are very important if the DOE is to develop a streamlined program of site-characterization activities that will produce all necessary technical information within existing budget and schedule constraints. A clear definition of technical site suitability is also important because the DOE's site recommendation decision will presumably initiate a politically important and potentially controversial sequence of activities that may include a Presidential recommendation to develop a repository at the site, a state veto of that recommendation, and a congressional override of the state's veto. Uncertainty about what the DOE means if it declares the site "technically suitable" may adversely affect the nation's efforts to move forward with repository development.

2. *Development of a waste isolation strategy should continue.* The Board was pleased to learn that a waste isolation strategy, or waste disposal concept, is beginning to emerge within the DOE's program. The waste isolation strategy should identify and quantify the roles of the repository features and/or barriers that will provide waste isolation, and should be based on the defense-in-depth philosophy that has long been a fundamental aspect of repository planning. The strategy can then provide one of the major bases for planning and prioritizing tests. However, two important parts of the strategy are still needed: (1) a decision on the extent to which engineered barrier system features outside the waste packages will be used and (2) a definition and quantification of the features and functions of the geosphere that can serve as essential natural barriers to release of waste. The strategy presented to the Board by J. Younker needs to be clarified and expanded.

Ideally, one should be able to discern in the program a direct linkage among a waste isolation strategy, key decisions, technical activities, budgets, and schedules. The waste isolation strategy is particularly important because it can provide a more technically defensible basis for deciding which site-characterization studies will be completed, deferred, or deleted. For example, one of the more important decisions that requires an improved technical rationale is the sharply reduced scope of surface-based drilling to be completed before the technical site-suitability decision. Results of total system performance assessments, in conjunction with a clearly articulated waste isolation strategy, should be used to determine the amount of surface-based drilling that is needed. Prioritization of other site studies should similarly be linked to the waste isolation strategy through performance assessments.

3. *A few thermal management alternatives should be carried forward.* The DOE has made a tentative decision to seek an initial license for a Yucca Mountain repository based on a low thermal-loading design, while retaining the option to amend the license at a later time to increase the thermal loading. The basis for this decision is the expectation that it will be easier to obtain regulatory approval for designs with lower thermal loadings. There is no clearly articulated or documented technical basis for this decision. The DOE needs to more clearly define its concept of a "low" thermal-loading design and needs to document the technical rationale for its selection.

The technical information and analyses currently available are inadequate to select a preferred thermal-loading strategy. Therefore, the Board recommends that the DOE preserve the option to further develop a few alternative thermal-loading strategies, such as the extended-dry concept, the base case in the site-characterization plan, and a below-boiling design. Preserving these alternatives may be the only practical way for the DOE to reach technically defensible decisions within the program's current schedule since the long-term in-situ thermal tests required to select a preferred strategy cannot be completed before the 1998 scheduled date of the technical site-suitability decision, or even by the 2001 target date for the license application for construction authorization. Our concept of preserving thermal management alternatives does *not* require a significant engineering design effort for each. However, the DOE should develop appropriate measures to ensure that decisions regarding design and testing activities will not preclude the adoption of any of the alternative thermal management strategies in the future as better technical information becomes available.

Most important technical uncertainties

One of the most important features of the Yucca Mountain site is the deep water table and the apparently minimal amount of water present in, and moving through, the unsaturated zone. The presumed dryness of the site is a pervasive factor in the DOE's developing waste isolation strategy because the dryness influences the performance of both engineered and natural barriers. Perhaps the single most important goal in characterizing the site is predicting (or placing bounds on) the amount and significance of water that could reach the repository, corrode waste packages, and transport radionuclides to the environment. This determination must include both spatial and temporal variations in hydrologic properties, the influence of fractures, and the potential for processes or events (e.g., climate change) to alter the hydrologic conditions, at least to the extent that waste isolation might be affected.

A second major concern is the effect of heat generated by radioactive waste on repository conditions. Heat can significantly alter hydrologic conditions by vaporizing liquid water and by inducing convective movements of air and water vapor. Heat can also alter rock properties either directly through thermally induced mechanical, chemical, or mineralogical changes or indirectly through inter-

actions with water (e.g., dissolution, transport, and eventual precipitation of dissolved minerals when the temperature changes or when water vaporizes). The kinetics of reactions affecting engineered barrier performance (e.g., waste package corrosion and radionuclide dissolution) are likely to be temperature dependent. It is important that the effects of waste heat on repository performance be understood well enough to permit confident predictions of (or bounds on) repository performance.

The third major area of concern at Yucca Mountain is the extent of fracturing and faulting, and the transmissive properties of fractures and faults, in the repository block and in overlying, underlying, and neighboring strata. If high-permeability faults or fractures represent conduits for the movement of water, especially episodic flow after high-precipitation events at the surface or reflux of water mobilized by radioactive decay heat, highly fractured portions of the repository block may be unsuitable for waste emplacement. If faults are found that are capable of movement following waste emplacement, it might also be necessary to restrict waste emplacement to areas where mechanical damage to waste packages is less likely. A moderate amount of fracturing or faulting may not be a cause for concern. In fact, under certain conditions, faults or fractures could serve as "drains" to channel water away from waste packages. However, if the repository contains extensive faults and fracture systems with hydrologic significance, there may be so little useable waste emplacement area that the site might be judged unsuitable. Underground exploration, characterization, and testing in the repository block must be sufficiently extensive to determine whether there will be adequate emplacement space for the projected inventory of waste, given the thermal-loading strategy ultimately adopted for the repository.

Specific recommendations

Based on current knowledge of the major features of the Yucca Mountain site, the Board recommends the following as the minimum suite of site-characterization studies needed to produce a technically defensible evaluation of the suitability of the site. It is important to emphasize, however, that the following paragraphs are not intended to be a comprehensive study plan for characterizing the Yucca Mountain site. Additional studies may be needed to produce information for licensing or to provide greater confidence that the site can be shown to be suitable. Changes to planned studies also may be warranted as site information from surface-based testing and underground exploration is acquired and its significance evaluated through the iterative performance assessment process.

Hydrogeologic & geochemical tests. Hydrologic studies to support the technical site-suitability decision should emphasize identification of potential fast flow paths, the significance of those fast paths for waste isolation, and the significance of perched water within the unsaturated zone. The DOE's planned studies of hydrologic and geochemical conditions, including moisture content, composition, and age-dating for water in the rock matrix and in fractures, seem generally appropriate. However, more emphasis on isotopic studies is needed because age-dating of ground waters through those studies provides the most valuable information available about potential fast flow paths and pneumatic pathways. More schedule flexibility also may be needed to permit completion of an adequate scope of tests. The DOE recognizes that more extensive studies of the radionuclide dilution potential of the saturated zone may be needed to evaluate compliance with a dose-based standard for repository performance, if such a standard should be developed by the U.S. Environmental Protection Agency. The Board recommends that the scope of planned studies be reviewed as the form of the repository performance standard becomes clearer.

Thermal testing. The DOE presently plans two sets of in-situ thermal studies — relatively short-term, accelerated tests to provide early information to support an application for construction authorization in 2001 and longer-term tests to provide information needed to apply for a license to receive and possess waste in 2008. The planned 1998 technical site-suitability decision will be based on information from early G-tunnel studies and from later laboratory and, if available, large-block heater tests. As now planned, preliminary results of the accelerated in-situ heater tests may be available in 2000 to support a recommendation of the Yucca Mountain site for repository development.

Ideally, several years of in-situ thermal test data should be available to support a technical site-suitability evaluation. The Board recognizes that the data available to the DOE at the time it plans to make a technical site-suitability decision are not likely to include in-situ thermal testing results. However, it is possible that the more limited data to be produced by the DOE's planned large-block heater tests, combined with very preliminary information from accelerated in-situ tests, could be sufficient *if* the DOE were to conduct analyses to identify the thermally induced physical and chemical changes that could cause failure of the repository system *and* could show convincingly that such changes are not credible or can be prevented by appropriate waste package / engineered barrier / repository design. Analyses of the effects of heat on repository performance should be initiated immediately, should continue throughout the site-characterization process, and should be used to identify (or modify) thermal tests to be carried out from site characterization through repository performance confirmation.

Finally, data from the accelerated tests *cannot* be presumed to provide positive confirmation of present theories on thermal effects. Information may prove to be inadequate. Or, test results could diverge significantly from the results of laboratory tests, large-block heater tests, or the conceptual / failure mode studies mentioned above. Under any of these circumstances, it may be necessary to delay the recommendation to the President for repository development until better information from the long-term tests can be obtained.

Underground excavation. The Board believes that substantially more underground excavation will be needed than currently is planned by the DOE. Sufficient underground exploration is needed to confirm at repository depth the continuity and orientation of structures already identified by surface investigations, to identify structures not evident at the surface, and to permit testing of structures and formations to determine their significance for long-term waste isolation. The influence of geologic structures and formations on the hydrologic properties of the repository block is the primary issue of concern. To the extent that faults serve as potentially fast water flow paths or may be capable of movement following waste emplacement, determination of an appropriate offset distance for waste emplacement will be necessary. Specifically, the Board believes that the following excavation is needed for a technical site-suitability determination.

1. As now planned, excavate the north ramp to the repository level and excavate a "main drift" through the center of the repository block in an approximately north-south direction parallel to and just west of the Ghost Dance Fault zone.

2. Explore faults and structures in the central portion of the repository block east of the main drift. The planned intersection of the Ghost Dance Fault at two locations with small diameter drifts is appropriate. An eastern extension of one of these drifts is needed to fully cross the Ghost Dance Fault zone. Further extension of the drift into the Imbricate Fault as far as the eastern boundary of the block may be needed unless adequate information about the Imbricate Fault can be obtained from the north ramp.

3. Explore faults and structures in the repository block to the west of the main drift, particularly in the area of fracturing and suspected faulting identified by Scott and Bonk. Most of the proposed repository area is located to the west of the main drift, and at least one tunnel is needed in the area of suspected faulting extending west to the Solitario Canyon Fault to evaluate the suitability of that portion of the repository horizon.

4. Excavate a thermal test area in a suitable zone of the Topopah Springs formation at or near the repository block. For the best understanding of the effects of heating on mechanical and hydraulic conditions near the excavated surface, machine excavation of the test area is needed.

5. Excavate into the Calico Hills formation from a portal separate from the existing north portal. This excavation should cross the Ghost Dance Fault zone at least once at a location immediately below one of the crossings at the Topopah Spring level.

It is unclear whether the DOE is developing a thorough waste isolation strategy that includes reliance on the Calico Hills formation as a barrier to release of waste. However, because the Calico Hills may be one of the most effective geologic barriers at the Yucca Mountain site, the Board believes that exploration into the Calico Hills formation (and incorporation of the Calico Hills as a possible barrier in the waste isolation strategy) would be prudent. Exploration in the Calico Hills may help to resolve hydrologic and structural geologic uncertainties that cannot be studied adequately using only surface-based testing.

Completion of this tunneling within the DOE's announced schedules may require (1) more aggressive schedules for operating the current tunnel boring machine than the present planning suggests, (2) simultaneous excavations with additional smaller machines, (3) contracting for large sections of tunnel rather than buying more equipment, and (4) faster and more economical acquisition of equipment for small-scale excavation of alcoves (e.g., by lease by contractors rather than purchase by the DOE). In addition, we have recommended before the establishment and use of a geotechnical engineering board by the DOE. We continue to believe that such a board would help the DOE more quickly resolve the problems that inevitably occur during major underground construction projects.

Depending on the waste isolation and thermal-loading strategies chosen and on the results of initial tunneling, additional underground exploration may be required. For example, if the DOE's repository design is based on a low thermal-loading strategy that requires use of "expansion areas" outside the existing repository block, exploration of those areas also will be required. Plans for additional exploration should be developed now so that those excavations can be carried out quickly if they become necessary.

Source term. A realistic representation of the source term — the release of radionuclides from the engineered barrier system — must be developed for a range of alternative thermal loadings. For example, for the unsaturated conditions expected at Yucca Mountain, data are needed on the effects of temperature on radionuclide solubilities and retardation factors, on the applicability of retardation factors obtained from batch tests, and on the importance of colloid mobility. Also, for the large, drift-emplaced waste package, those portions of the engineered barrier system outside of the waste package have been essentially ignored. Concepts such as the use of backfill or waste package fillers to modify the thermal, chemical, or hydrological environment or the use of capillary barriers should be evaluated.

Additional studies. Although not of the highest priority in terms of timing, additional studies are needed for a technically defensible site-suitability decision. Some of these include:

1. Studies of disruptive processes and events (especially volcanism) are needed to evaluate compliance with the siting guidelines and to support the probability estimates required by a total system performance assessment.

2. Ongoing detailed surface mapping of faults should be completed and the potential for displacement on faults found within and near the repository block should be determined. As appropriate, this information should be used to help guide underground excavation to the areas of most importance for waste isolation.

3. At least three years of long-term corrosion research, under conditions relevant to design of waste packages and engineered barriers, should be completed prior to the technical site-suitability determination. The Board believes that approximately 10 years of corrosion research will be necessary to support a licensing decision to permit repository operations. The waste isolation capabilities of engineered barriers other than the waste package (e.g., capillary barriers) should also be evaluated to support a license application.

4. Expert judgment will be especially important in many areas such as identifying conservative bounding assumptions that are an important part of the DOE's planned site-suitability evaluation. Procedures for eliciting and using expert judgment should be defined, fully analyzed, and shown to be acceptable for licensing.

5. A method needs to be defined for dealing with conceptual model uncertainty, such as a weighted combination of available models or use of bounding analyses.

6. Since an environmental impact statement will be required to make a site recommendation, studies should be completed to support its preparation including measurements of soil moisture uptake by desert plants for at least two years under a variety of seasonal, soil, and other conditions; examination of shrub cover along areas of faulting to help determine the role of fracture-rooted plants in evapotranspiration where soils are thin and underlying rocks are fractured; and completion of at least two years of study of the ecosystem response to soil and fractured rock heating.

7. To establish a better understanding of the steep hydrological gradient to the north of the proposed repository site and to evaluate its potential to affect water table depths under the repository, at least one more suitably located deep well will be needed.

Areas where emphasis can be reduced

As the DOE's waste isolation strategy becomes more fully developed, it should be possible to identify areas of on going study that can be assigned a lower priority or eliminated entirely. Candidate areas that might be considered for a lower priority now include the following.

1. Earthquake shaking should *not* be an issue for evaluating the technical suitability of the site since the repository and its critical structures can readily be designed to withstand any design seismic loading that is likely to be specified for the site. In the Board's view, designing for shaking is well within current engineering capabilities.

2. New studies of volcanic rock dates are not likely to change probability estimates for volcanism.

3. For the technical site-suitability evaluation, it should *not* be necessary to measure the in-situ thermomechanical response of rocks in the range of temperatures associated with the thermal-loading strategies under consideration by the DOE. Conservative assumptions for designing a repository will adequately compensate for uncertainties caused by lack of geomechanical testing in the thermal test area. However, thermomechanical effects on rock stability are important considerations in repository design. For repository licensing such measurements should, as much as possible, be integrated into the thermohydrological tests.

The Board does not believe that a complete understanding of Yucca Mountain is possible or necessary for licensing a safe geologic repository. What is required is an understanding that is sufficient to confidently demonstrate that waste disposal at the site will be safe. The Board urges the DOE to develop a clearer waste isolation strategy as soon as feasible and, consistent with that strategy, to aggressively seek opportunities to further streamline and prioritize its planned site-characterization studies.

Appendix H
Department of Energy Responses to the Recommendations in the Board's Reports

As part of its effort to keep the Nuclear Waste Technical Review Board informed of its progress, the Department of Energy (DOE) submits a summary of initial responses to recommendations the Board makes in its reports. Included here are the DOE's responses to the (1) *Letter Report to Congress and the Secretary of Energy* (February 21, 1994), and (2) *Report to the U.S. Congress and the Secretary of Energy — January to December 1993* (May 6, 1994). Inclusion of DOE's responses does not imply Board concurrence.

Department of Energy
Washington, DC 20585

September 15, 1994

Dr. John E. Cantlon
Chairman
Nuclear Waste Technical Review Board
1100 Wilson Boulevard
Arlington, Virginia 22209

Dear Dr. Cantlon:

Enclosed is the Department of Energy's response to the Nuclear Waste Technical Review Board's *Letter Report to Congress and the Secretary of Energy* that was issued on February 24, 1994.

The Department is aware of the Board's concerns with the management of the Civilian Radioactive Waste Management Program and is in the process of addressing them. To focus the Department's efforts on the underlying concerns with the program's implementation, Secretary Hazel O'Leary asked Dr. James A. Thurber, Director of the Center for Presidential and Congressional Studies at The American University to prepare an independent study of past reports, papers, and significant comments regarding the program. The Department has received this report and is preparing a response, which should be issued shortly. In the meantime, the Secretary instructed the Office of Civilian Radioactive Waste Management to analyze the report and determine which changes have been made and what further changes are appropriate.

It is important to note that a new management team is in place, and that team has already taken significant steps to improve management practices. We believe these steps will help to ensure that the increased funds requested for program expenditures will be effectively utilized to complete our priority activities. For example, a reorganization of the Yucca Mountain Site Characterization Office became effective on March 11, 1994. The reorganization addresses the Board's concern with the diffuse nature of the organization by defining and establishing clear lines of responsibility and accountability related to project goals. The program's headquarters organization has also been realigned, effective on July 10, 1994, to place emphasis on the near-term issues of waste acceptance and the major management needs of overall program integration. The contractor establishment is being restructured both in Washington D.C. and in Las Vegas, Nevada, to reflect the same philosophy.

In addition, the independent financial and management review of the Yucca Mountain Site Characterization Office is underway and the results will be used to assess the effectiveness of our changes and determine additional actions that may be required. The Department will consider the need for a wider management review, as recommended by the Board, after the results of these first steps are analyzed and the impacts are evaluated. At that time, we encourage the Board to provide us with its views on the adequacy of these steps in addressing the Board's specific concerns.

The Department is continuing to focus the program on its highest priority activities including the development of near-term storage technologies and the suitability evaluation of the candidate Yucca Mountain site. We agree that the momentum of these activities should be maintained while we address the Board's concerns.

The Board's support of our recent initiatives to broaden the public's participation in the decision-making process is appreciated. We understand that earning public trust and confidence is a long process that will be effective only through persuasive and consistent actions, and that we may never achieve the trust of some of our stakeholders. We are nonetheless committed to working with all groups to improve relationships to any extent possible to earn increased confidence in the program. We intend to expand on the activities noted in our response as we develop a framework for constructive interaction as the Board recommends.

The Department welcomes the Board's recommendations regarding our technical program. We intend to continue to work with the Board to resolve these concerns as we move forward to implement a safe and cost-effective solution to the management of spent nuclear fuel and high-level radioactive waste. If you have any questions, please contact me at (202) 586-6850.

Sincerely,

Daniel A. Dreyfus, Director
Office of Civilian Radioactive
Waste Management

Enclosure

Department of Energy Response to the Nuclear Waste Technical Review Board's

Letter Report to Congress and the Secretary of Energy, February 1994

(Submitted to the NWTRB on September 15, 1994)

The Nuclear Waste Technical Review Board's Letter Report to Congress and the Secretary of Energy, issued on February 24, 1994, includes three recommendations on important programmatic issues. The Department of Energy and the Office of Civilian Radioactive Waste Management have evaluated these recommendations and other comments contained in the report, and are in the process of taking steps to address those concerns. The Department's response to the Board's latest recommendations are presented in this report.

Recommendation 1:

Independent Program Review Needed Now More Than Ever

Response:

The Department is aware of the criticism regarding the organization and management of the Civilian Radioactive Waste Management Program. As noted in the Board's report, the Department has put in place a new management team that is confronting these challenges, and is committed to making the necessary changes to ensure that program resources are allocated more efficiently to the highest priority activities. To respond to the widespread criticism regarding program organization and management, the new management team determined that a realignment of the Office of Civilian Radioactive Waste Management was required to focus the program on achieving its strategic goals and to maximize efficiency. The first step, reorganization of the Yucca Mountain Site Characterization Office, was completed in March 1994. The Office's new organization is task oriented, and is structured along the functional lines in the areas of suitability and licensing, scientific programs, engineering and field operations, environment, safety, and health, public affairs, and administration. The reorganization defines and establishes clear lines of responsibility and accountability related to project goals.

The next step, the realignment of the headquarter's elements, was completed in July 1994. The new alignment of the program's headquarters organization emphasizes the near-term issues of waste acceptance and the major management needs of overall program integration. These alignments will provide the basis for critically reviewing the program's need for contractors and is expected to lead to further consolidation and improved efficiency in the program's implementation. In addition, a program-wide strategic plan is being prepared that charts the path the Department will follow in fulfilling its mission. The details of this plan were presented to the Board for review at its 1994 Spring and Summer Full Board Meetings and further updates are planned as our plans are refined. To solicit specific predecisional input from our stakeholders on the program's strategic goals and its plans for achieving them, public meetings are scheduled for later this year. The new management team will be tasked with implementing the plan consistent with Congressional budget direction.

As part of her review of the program, Secretary Hazel O'Leary also commissioned an independent study of past reports, papers, and significant comments written about the program during the previous five years. This review was conducted by Dr. James A. Thurber, the Director of the Center for Presidential and Congressional Studies at The American University in Washington, D.C., and deliv-

ered to the Secretary on March 1, 1994. The Department's response to this report will be issued shortly. In the meantime, the Secretary directed the Office of Civilian Radioactive Waste Management to analyze the report, determine which changes have been made and what further changes are appropriate. To further address these concerns, an independent financial and management review of the Yucca Mountain Site Characterization Office has been initiated at Secretary O'Leary's direction. Since the Yucca Mountain Site Characterization Office's expenditures make up over 70% of the overall program's budget, the review will assess the majority of the program, including the Board's concerns regarding the management of large complex projects and related systems acquisitions. This review will encompass financial and business management techniques, the project schedule and the credibility of project milestones, contracting practices, internal planning processes and organizational effectiveness. The review will also address the adequacy of funding levels and funding priorities, including infrastructure costs. The independent panel overseeing the review is presently selecting a contractor to conduct the detailed analyses and we expect preliminary results of this review next year. These results will be used to assess the effectiveness of our changes and determine additional actions that may be required.

The Department believes that these actions are a step in addressing the Board's concerns while maintaining the momentum of the program. The Department also believes that the most prudent approach is to integrate the results of the independent financial review of the Yucca Mountain Site Characterization Office into its internal evaluation of program status as the new organization is implemented, before authorizing additional reviews. Once these steps have been completed and the results evaluated, the Department will determine whether there is a need for an additional independent management review of the overall program.

Recommendation 2:

Maintain the Momentum of Site-Characterization Activities

Response:

The Department fully agrees that program momentum must be maintained while we address the concerns of our stakeholders. With regard to ensuring efficient progress toward determination of suitability of the candidate Yucca Mountain site, Secretary O'Leary determined that site suitability can best be evaluated by exploration of the underground geology and hydrology by means of tunnel excavation as recommended by the Board (December 1991, June 1992, December 1992). The Secretary directed the program to continue excavation and tunneling activities for the Exploratory Studies Facility at Yucca Mountain during the period that program objectives are being reevaluated, and the program is implementing this direction. As discussed with the Board at the June 1994 meeting of its Panel on Structural Geology and Geoengineering, the first tunnel boring machine has been delivered to the Yucca Mountain site and is presently undergoing final system checks. The Department plans to initiate the test-phase operation of this machine in early September 1994.

The Department also agrees that iterative performance assessments should serve as the basis for prioritizing site testing activities. Total system performance assessments were completed in 1991 and 1993 and the results have been used to further refine priorities in the testing and design programs. We appreciated the Board's insightful review and comments regarding these efforts. The current emphasis is on developing and refining detailed process models (e.g., waste package corrosion, unsaturated zone transport) that serve as the basis for the total system models.

Despite substantial progress, the new management team has determined that expectations established by the Nuclear Waste Policy Act of 1982, as amended, cannot be met within the budget and appropriations framework previously established. The Administration's Fiscal Year 1995 budget request proposes a new funding approach that will allow the program to pursue the policy goals expressed in the Nuclear Waste Policy Act, as amended. The Administration has proposed an increased annual funding profile for the program over the next several years and has made it clear that this funding profile is critical to cost-effective accomplishment of the program's mission.

Recommendation 3:

Expand Efforts to Integrate Stakeholder Views

Response:

The Department agrees with the Board that stakeholder involvement is crucial to the Civilian Radioactive Waste Management Program's success and for building public trust and confidence in its activities. Overcoming public mistrust is one of the Department's most difficult and perplexing challenges, but is essential to achieving its missions. Nevertheless, we are committed to conducting our business in such a way that earns trust and engenders confidence, and we will continue to build on efforts that invite the active and ongoing participation of all those who are interested in the Civilian Radioactive Waste Management Program.

In its *Letter Report*, the Board encourages the Secretary to consider a "long-term framework for constructive interaction on high-level waste issues" with program stakeholders similar to the Environmental Protection Agency's recently completed year-long superfund study. In reviewing the Final Consensus Report of that study, we note that the Office of Civilian Radioactive Waste Management has established many public involvement mechanisms similar to those discussed in the report (e.g., public information offices, working groups, and technical assistance grants). On May 21, 1994, the Office of Civilian Radioactive Waste Management convened a stakeholder meeting in Las Vegas, Nevada. The meeting followed the stakeholder briefings on the Administration's Fiscal Year 1995 budget proposal given earlier this year, and provided an opportunity for continued stakeholder involvement in setting the program's direction. This meeting focused on the new Proposed Program Approach and the site suitability evaluation process. A summary of the comments received at the meeting has been prepared and provided to the meeting attendees for comment. These comments will be considered in the continued development of the Proposed Program Approach and the site suitability evaluation process.

In addition, the Department has prepared a follow up to our August 10, 1993, Stakeholder Workshop ("August 10, 1993 Workshop Follow-up Report: Next Steps for Program Implementation"). In this report, we respond to the comments on the draft report and propose to implement many of the suggestions identified by the stakeholders who participated in the workshop. We believe that our future work with stakeholders to further develop and implement these recommendations will serve as the foundation for the long-term framework for constructive interaction the Board urges. For example, the program has taken the initiative to seek stakeholder participation in the site suitability determination process. The program recently conducted several in-depth workshops in Las Vegas, Nevada, and Washington, D.C., to discuss the proposed process with stakeholders and to seek their input. In order to systematically address this issue, the program is also preparing a public participation plan that will prove to be a vehicle for addressing stakeholder involvement in the decisionmaking process. This plan is scheduled for issuance in draft form in the fall of 1994.

In addition, as part of this continuing interaction, the program has opened to the public many of its meetings to encourage early stakeholder involvement in key program activities. To augment this new openness, the program now widely distributes the *OCRWM Calendar* enabling stakeholders to determine their own level of involvement. In addition, the program has increased the number of opportunities for stakeholders to provide input into program decisions and conducted a series of public workshops to enable stakeholders early involvement and access to information on key program activities (e.g., workshops on the Section 803 Report, the Draft Multi-Purpose Canister Conceptual Design Report, and the system architecture study). The program also inaugurated bimonthly meetings between the Yucca Mountain Site Characterization Office and affected units of government to discuss specific issues of concern to governments that have proximity to or jurisdiction over the characterization site.

The *Letter Report* also notes "that public perceptions about the potential risks associated with nuclear power and the waste it generates must be addressed." The program recognizes that an informed public is a prerequisite to informed predecisional participation. To that end, the program conducts a comprehensive public information effort and maintains several information centers, a toll-free telephone number for public inquiries, and informational displays used at conferences. The program issues a quarterly newsletter and videotaped programs for general distribution. The program provides financial support to nonpartisan organizations, such as the League of Women Voters, the National Conference of State Legislatures, the National Congress of American Indians, and the National Association of Regulatory Utility Commissioners to inform the public about radioactive waste. Some of the program's public information and outreach activities conducted in the past year include:

- A second televised workshop on our new secondary school curriculum; *Science, Society, and America's Nuclear Waste*
- 6 public update meetings conducted on the Yucca Mountain studies
- 400 Yucca Mountain Site Characterization Office presentations given to civic, educational, business, and professional groups
- 18,000 students provided classroom presentations
- 10,000 inquiries answered by the Civilian Radioactive Waste Information Center; questions originating from all 50 states and 35 countries and territories
- 500,000 publications and approximately 5,400 videos distributed to the public.

The activities described above are designed to inform and involve the public in the Civilian Radioactive Waste Management Program's decision-making process. The Department recognizes that the highly contentious nature of disposing of highly radioactive waste may preclude a national consensus from ever being reached. However, we believe that we have a responsibility to continue our efforts to ensure that the program is implemented based on sound scientific and engineering practice and that all parties will have an opportunity to be heard.

Department of Energy
Washington, DC 20585

December 27, 1994

Dr. John E. Cantlon
Chairman
Nuclear Waste Technical Review Board
1100 Wilson Boulevard
Arlington, Virginia 22209

Dear Dr. Cantlon:

This letter transmits the Department of Energy's response to the Nuclear Waste Technical Review Board's *Report to the U.S. Congress and the Secretary of Energy: January to December 1993*, which was issued on May 6, 1994.

As noted in the Board's report, the Civilian Radioactive Waste Management Program has changed significantly since the new Administration took office in 1993. We realize that the timing of the Board's report precluded a review of these changes; however, our response to the Board's recommendations reflects the current thinking of the Department regarding the program and its new direction. We believe that the modifications already initiated and those recently proposed by the Department represent improvements over previous plans and we look forward to receiving the Board's specific comments and recommendations regarding these actions.

We appreciate the Board's concern with our efforts to develop, and possibly implement, a multi-purpose canister-based system and its specific concerns regarding the compatibility of the canisters used for storage and transportation with disposal requirements. We have made the integration of these activities a high priority and we look forward to presenting the results of the efforts at an upcoming Board meeting. In addition, we have included performance-based specifications, which cover the disposal interface, in the recently issued Request for Proposals for multi-purpose canister design and certification.

The Department believes it has established a plan for adequately and dependably pursuing and funding the program's highest priority activities, including the development of near-term storage technologies and the suitability evaluation of the candidate Yucca Mountain site. We agree that the momentum of these activities should be maintained while recognizing that the implementation of this effort is contingent upon Congressional appropriations. If funding levels consistent with the Administration's Funding Proposal are not forthcoming in future years, it will be necessary to revise the program in consultation with Congress and our stakeholders.

The Department appreciates the Board's constructive review and recommendations regarding our technical program. We are looking forward to receiving the Board's views on the detailed plans supporting the new program approach as we move forward in a technically sound and cost-effective manner. If you have any questions, please contact me at (202)586-6850.

Sincerely,

Daniel A. Dreyfus, Director
Office of Civilian Radioactive
Waste Management

Enclosure

Department of Energy Response to the Report Released on May 6, 1994 By The Nuclear Waste Technical Review Board

Report to the U.S. Congress and the Secretary of Energy, January - December 1993

(Submitted to the NWTRB on December 27, 1994)

INTRODUCTION

The Nuclear Waste Policy Amendments Act of 1987 established the Nuclear Waste Technical Review Board to evaluate the technical and scientific validity of activities undertaken by the Department of Energy in the Office of Civilian Radioactive Waste Management. The Board is required to report, not less than two times per year, to Congress and the Secretary of Energy, its findings, conclusions, and recommendations. The Board has issued ten reports to date. The Board's tenth *Report to the U.S. Congress and the Secretary of Energy*, which was released on May 6, 1994, reviews the Board's conclusions and recommendations, resulting from the Board's activities primarily during the 1993 calendar year. This report included 22 technical recommendations in six broad areas: (1) transportation and systems; (2) the engineered barrier system; (3) structural geology and geoengineering; (4) risk and performance assessment; (5) the environment and public health; and (6) resolving difficult issues — climate change. These recommendations and the Department's response are presented in this report. Each recommendation is quoted verbatim from the Board's report of May 6, 1994, and is followed by the response.

TRANSPORTATION AND SYSTEMS

Recommendation 1:

The Board recommends that the DOE complete the systems analysis necessary to support decisions about MPC development. This analysis should determine if the various potentials of the MPC concept can be achieved in a practicable way. It should also provide a technical basis for decisions related to MPC performance attributes and design features and for developing schedules and milestones. (page 19)

Response:

The Department believes that it has conducted appropriate systems analyses to support the decision to proceed with the multi-purpose canister (MPC) design and certification process. The results of these systems analyses are reflected in the System Requirements Documents for the Civilian Radioactive Waste Management System, the MPC System Request for Proposals, and *Volume V - MPC Supporting Studies and Reports of the Multi-Purpose Canister Implementation Program Conceptual Design Phase Report*.

The analysis for development and implementation of the MPC system was performed using a systems engineering approach as recommended by the Board. This approach is documented in *Multi-Purpose Canister System Evaluation - A Systems Engineering Approach*, a report recently issued by the

Department. This report presents information that has previously been available in a variety of reports in a logical manner so that the systems engineering approach that was used in the development of the MPC system can be clearly seen. This document has been provided to the Board.

The following systems analyses were performed in support of MPC system development decisions:

- A concept of operations was developed to set the system assumptions, parameters, and boundary conditions;
- Conceptual designs were developed for the MPC, MPC transportation cask, MPC-based Monitored Retrievable Storage facility, and Utility Transfer System;
- The logistics for the MPC system were developed based on the concept of operations and the conceptual designs for the MPC system.

These analyses provided the basis for performing the system study evaluations. Those evaluations supported the decision to proceed with the design and certification of the components of the MPC system. A number of system issues were evaluated and documented for the MPC system. They include:

- *Health and Safety Impacts Analysis for the Multi-Purpose Canister System and Alternatives Report*;
- *Mined Geologic Disposal System Multi-Purpose Canister Design Considerations Report;*
- *Life Cycle Cost Comparison for the Multi-Purpose Canister System*;
- *Regulatory Considerations Report for the Multi-Purpose Canister System*;
- *At-Reactor Dry Storage Issues Report*;
- *Stakeholder Involvement Report for the Multi-Purpose Canister System*;
- *Programmatic Risk and Contingency Analysis for the Multi-Purpose Canister System Report*;
- *Evaluation of Alternative Cask/Canister Systems Report*.

All of these systems analyses and studies are included in Volume V of the *Multi-Purpose Canister Implementation Program Conceptual Design Phase Report*.

These system studies determined that the MPC system is a viable concept and that it offers significant advantages over other alternative systems. These studies also determined that the MPC system could be developed and implemented in a practicable way at a system cost competitive with other alternatives.

To facilitate in the development of the MPC system, performance-based MPC design specifications have been developed to direct design of the components of the MPC system by private industry. These design specifications state required performance of system components, rather than prescribing specific design solutions.

The MPC system studies also indicated that a schedule could be met to have the MPC system ready for initial deployment in the 1998 timeframe. The schedule developed for MPC implementation is ambitious, but achievable provided that interim milestones are aggressively pursued. The Department met with its stakeholders including utility, regulatory, and vendor representatives to validate this schedule.

The Department will ensure that additional system studies will be performed in a timely manner to support future decisions regarding the deployment of MPCs and the Department will keep the Board informed of the status and findings of these activities.

Recommendation 2:

To avoid prematurely dropping the disposal function, the Board recommends that DOE begin to address in a technically substantive way the issue of how a true multipurpose container can evolve and be implemented given what is known today and the technology that is practical today, despite all the uncertainties associated with repository design. (page 19)

Response:

On June 3, 1994, the Department issued a Request for Proposals for designing the MPC system to support spent fuel storage, transport, and disposal. The Request for Proposals includes performance-based design procurement specifications which cover disposal interface requirements related to issues such as criticality, thermal loading, containment, and materials.

The Department recognizes that operational and regulatory environments of storage and transportation are well understood, while significant uncertainties remain with respect to disposal. The Department plans to continue to evaluate the interfaces as the disposal conditions and regulations are defined to maximize the likelihood that the MPC can serve as part of the disposal system. The interfaces between the MPC and the waste package are discussed below.

Thermal Issues:

Our analyses indicate that the global behavior (“far-field”) of the repository is not affected by the MPC, regardless of the capacity and heat load of the container. The local, near-field rock temperatures are affected by the MPC heat load, although the internal details of the MPC have negligible effect upon the rock temperature. The Department recognizes that the heat output of the Large MPC challenges the drift wall rock temperatures limits. This may be mitigated through waste package spacing, or aging of the fuel prior to emplacement. These issues will continue to be addressed through the repository and waste package design efforts and the integration activities associated with MPC development.

Materials:

Long-term corrosion resistance is desirable for the materials of the MPC and is consistent with the repository requirements. The MPC material requirements have been established through interactions with the repository design staff. Under these requirements the MPC basket should have adequate corrosion resistance to outlast the spent fuel assemblies. As long as the fuel is intact, the structural support, heat transfer, and criticality control functions provided by the MPC basket are unimpaired. Subsequent to fuel failure, preliminary analyses indicate that heat transfer would not be a problem, but criticality control would still be required. Under these conditions, the Department plans to demonstrate compliance with criticality requirements through the consideration of burnup credit.

If the corrosion resistance of the MPC basket materials is determined to be inadequate when the repository becomes operational, the addition of filler materials to the MPC has been considered as an option. The most direct means of adding filler materials is to cut off the upper end of the MPC. Provisions are included in the MPC conceptual design to facilitate this contingency action. Specifically, sufficient length above the active fuel is provided to insure that the cutting operation does not damage the fuel, and a means of lifting the MPC with the upper end removed has been included to facilitate handling operations during the filling process.

Criticality:

Acceptance by the Nuclear Regulatory Commission for the consideration of fuel burnup in criticality calculations is being pursued for the demonstration of compliance with criticality requirements in transportation and disposal with MPCs. Since the Small MPC does not require the use of burnup credit for the demonstration of regulatory compliance, failure to obtain regulatory approval for the consideration of fuel burnup will not preclude use of MPCs. However, operations would be limited and the associated costs would be higher due to the lower capacity of the Small MPC.

The Department recognizes that the complex issues related to predicting the population of fission product neutron absorbers may prove difficult to resolve by 1998, and is considering contingency plans such as a less complex approach that takes credit for only the uranium depletion (and plutonium production). This form of burnup credit would be sufficient to allow use of the Large MPC for pressurized water reactor fuel in transportation. Burnup credit is not required for transportation of boiling water reactor fuel in Large MPCs. If credit for neutron absorbers contained within the MPC basket is not allowed for disposal, regulatory approval for the beneficial effect of fission product neutron absorbers would be required for disposal.

Containment:

Since the shell of the MPC is not presently considered as a containment barrier, the MPC has no effect upon the repository containment issues other than the interface requirements related to waste package performance. However, should the filler option be exercised for criticality control purposes, a cast solid filler material such as a zinc alloy could contribute to fission product retention within the disposal container.

Structural:

There are no outstanding structural issues specific to the MPC.

Shielding:

The overpacks provide the required shielding in the MPC-based system and there are no outstanding shielding issues specific to the MPC.

Operation:

The size and weight of a conceptual waste package containing an MPC has been reviewed and found acceptable for repository operations.

Conclusion:

In conclusion, the Department is continuing to address all of the technical issues regarding final disposal of the MPC. We believe that the MPC is compatible with the currently known requirements of the repository as documented in the *Multi-Purpose Canister Implementation Program Conceptual Design Phase Report*. Results of the Department's technical evaluations of repository issues will be factored into the development of the MPC System, and the evolving MPC design will be considered in the focused advanced conceptual design of the repository and waste package. The Department plans to keep the Board fully appraised of these activities and welcomes the Board's comments and recommendations.

ENGINEERED BARRIER SYSTEM

Recommendation 1:

The Department should continue and extend its examination of the assumptions used for its MPC conceptual designs, ensuring that the examination includes all of its design assumptions. The potential effects of these assumptions on waste package maximum capacity as well as on waste package performance, safety, and costs should be carefully evaluated. (page 25)

Response:

As discussed in the Department's response to the above recommendations concerning the MPC, the Department recognizes the importance of integrating the disposal requirements into the MPC development process, and conversely, examining the potential impacts of the assumptions in the MPC design in the repository and engineered barrier system development process. The MPC conceptual design and its adaptability for disposal in the potential repository continue to be evaluated as a key part of the development of the waste package and engineered barrier system. All assumptions concerning the MPC conceptual design will be examined in order to achieve a waste package utilizing the MPC that will perform satisfactorily and that can be designed, licensed, fabricated, and deployed with a high degree of safety and reliability and at the lowest reasonable cost.

Recommendation 2:

In consultation with the NRC, the DOE should change the baseline designs for the repository and the waste package to reflect current thinking. (page 25)

Response:

The Department agrees with the intent of the Board's recommendation that the current baseline conceptual designs for the repository and the engineered barrier system (which includes the waste package) should be updated to reflect the revisions to the design concepts. However, the Department believes that these updates must be controlled to ensure that the systemwide impacts of alternatives are thoroughly evaluated prior to being implemented. Therefore, the Department believes that the baseline should represent approved changes to the design concept, instead of simply representing current thinking. To this end, the Yucca Mountain Site Characterization Office is developing the revisions to the conceptual design baselines for the repository and the engineered barrier system as part of the Advanced Conceptual Design activities. To support these revisions, the Yucca Mountain Site Characterization Office is reexamining and updating the system functional analyses and developing a new concept of operations for the system. In parallel with this work, the requirements assumptions are being developed, which will be checked for consistency with the concept of operations. The revisions will include the changes to the Mined Geologic Disposal System concept such as the use of MPCs. The Advanced Conceptual Design baseline will be updated no later than fiscal year 1997 with the completion of Advanced Conceptual Design via the approved Advanced Conceptual Design Summary Report.

Recommendation 3:

The Board encourages the DOE to examine seriously the principle of extended retrievability for a geologic repository and to avoid designs and decisions that could forestall implementation of the concept. (page 26)

Response:

A Retrievability Period Systems Study is being performed to systematically evaluate the advantages and disadvantages of extended retrievability. The results of the study should provide retrieval concepts for the 10 CFR Part 60 retrieval requirements as well as for periods beyond the Nuclear Regulatory Commission's (NRC) requirements. This study should be completed in early fiscal year 1995 and will be provided to the Board when it is available.

Recommendation 4:

The DOE should develop plans for examining fillers. Even if specific filler materials are not selected until later, methods for using or retrofitting with fillers in the perhaps soon-to-be-deployed MPCs should be developed now. (page 26)

Response:

The Department agrees with the need to develop plans for fillers. The processes that are to be developed, including the potential use of filler materials, are documented in the Waste Package Engineering Development Task Plan, issued in September 1993. The Department plans to initiate testing of potential filler material during Title I design of the waste package scheduled to begin in fiscal year 1998.

As noted in response to the Board's recommendations regarding transportation and systems, specific provisions for adding filler material have been incorporated into the MPC conceptual design. These provisions were developed in consultation with the waste package design staff to ensure compatibility with the waste package concepts being considered.

Recommendation 5:

The DOE should continue to examine the role of zircaloy cladding as a barrier and should recommence and accelerate research on metal joining and nondestructive evaluation of metals and welds. (page 26)

Response:

The Department is continuing to examine the potential role of zircaloy cladding as an additional containment barrier and its potential contribution to the control of the release of radionuclides from the engineered barrier system. The reasons to expect significant cladding performance and the uncertainties in expected cladding life have been examined and were presented to the Board's Panel on the Engineered Barrier System on March 10, 1994, in Livermore, California. Some scoping experimental studies are planned to be initiated next year. These studies will be directed at narrowing the conditions under which cladding will fail in the emplacement environment.

The Department agrees that there is a need for research on metal joining and nondestructive evaluation of metals and welds. The work previously done on metal joining provided valuable basic information, but it was focused on issues associated with the waste package concepts contained in the Site Characterization Plan. Research and development activities focused on the design and fabrication of the large waste packages currently envisioned are being planned. The development work that may be needed has been defined in the Waste Package Engineering Development Task Plan issued in September 1993, and includes approaches to minimizing residual stresses, welding techniques, and methods for nondestructive evaluation of waste package integrity including the remote examination of closure welds. This work will be started when the waste package concepts and preliminary designs, including selection of materials, are further developed.

STRUCTURAL GEOLOGY AND GEOENGINEERING

Recommendation 1:

The Board continues to encourage the DOE to operate the tunnel boring machine as continuously as possible while excavating the portal-to-portal main loop. Machine operations should be delayed only to recover those data that otherwise would be irretrievably lost. (page 31)

Response:

The Department's current plans place a high priority on continuous tunnel boring machine (TBM) operations. The Department's focus on determining the technical suitability of the site in 1998, however, requires that certain data be acquired as soon as possible even though they are not considered to be "otherwise irretrievable."

To support the technical suitability evaluation, contact radial borehole tests in Alcoves 3 and 4 and the two Ghost Dance Fault exploratory drifts have been added to the schedule to be excavated during the development of the main loop. Previously, the only alcove-based testing during the main loop excavation was associated with fault properties at the Bow Ridge Fault and Drill Hole Wash structure. Development of Alcoves 3 and 4 and of the Ghost Dance Fault drifts should not delay the TBM excavation operation for more than a few weeks.

Another addition is the development of a turnout to serve as a TBM starter tunnel for a second smaller-diameter TBM. The 7.62-meter TBM will develop this 60-meter long turnout before pulling back and resuming work in the main loop. The second TBM will excavate the North Ramp Extension concurrent with main loop operations. This should not significantly delay the main loop because the facility and its utilities are designed to accommodate multiple, simultaneous excavation operations.

The Department has prioritized the excavation of the North Ramp Extension so that the heater test may be initiated as soon as possible. While the Department does not believe that significant heater test data will be required for the evaluation of site suitability, it recognizes that, due to the long-term nature of the testing, it is important to get these tests started early so that as much information as possible can be gathered in support of the initial License Application if the site is found suitable.

In summary, the Department realizes that TBM operations are expensive and that the tunneling costs can best be minimized by minimizing unnecessary delays to the TBM operation. Accordingly, the Department's places a high priority on TBM operation, and only those testing activities that either are critical to the evaluation of site suitability, are of a long-term nature, or that collect data that would be irretrievably lost if deferred will be allowed to interrupt the TBM operations. These interruptions will be minimized to the extent practicable.

Recommendation 2:

Regardless of the funding level, the program should be restructured to ensure that critical site characterization activities be funded adequately and dependably. (page 31)

Response:

As noted in the Department's response to the Board's *Letter Report to Congress and the Secretary of Energy*, which was released in February 1994, the Department agrees that critical site characterization activities need to be adequately and dependably funded. To resolve the disconnect between program funding and the expectations established by the Nuclear Waste Policy Act of 1982, as amended. The Administration has proposed an increased annual funding profile for the program over the next several years and has made it clear that this funding profile is critical to cost-effective accomplishment of the program's mission.

As was discussed with the Board on April 11, 1994, and again on July 12, 1994, the basis for the streamlining being conducted as part of the Proposed Program Approach is to focus the site characterization program on those activities that are critical to Department decisions regarding suitability and licensing. In addition, the Department will ensure that the opportunity to collect site data will not be irretrievably lost even under a level-funding program. As noted in the Department's response to the Board's letter of May 17, 1994, the detailed testing plans will be provided to the Board as they are developed. We look forward to receiving the Board's comments on these plans.

Recommendation 3:

The Board recommends that the DOE develop a contingency plan and schedule for the site-characterization project that reflects a relatively level budget. The plan should favor activities critical to determining the suitability of the site, incorporate a rigorous prioritization of activities, and encourage a greater sensitivity to cost control by the DOE and its contractors. In the event that the budget is increased, a well-defined plan will provide a good basis for expanding site-characterization efforts. *(page 31)*

Response:

The Department believes that if future funding consistent with the Administration Funding Proposal is not forthcoming, and if the outlook for program funding is consistent with historical levels, it will be necessary to revise the program in consultation with Congress and its stakeholders. As the Department presented to the Board at its Spring Full Board Meeting held April 12-13, 1994, in Reno, Nevada, the strategic planning process that led to the development of the Proposed Program Approach, included a preliminary evaluation of various scenarios and the development of limited contingency plans. One of those scenarios (referred to as the "Level Funding Outlook") assumed that the program would receive funding similar to that which has been received over the past several years. Since the development of MPCs for interim storage would still be considered, the funds available for Yucca Mountain might be decreasing in future years as the MPC funding requirements increase. This funding profile would be insufficient to carry out the program of developing geologic disposal capability as contemplated in the Nuclear Waste Policy Act of 1982, as amended (Act).

Under this scenario, development of MPCs would continue to preserve the ability to provide MPCs to the utilities beginning in 1998. However, work at Yucca Mountain would focus solely on evaluating the technical suitability of the site as soon as possible, within the funding constraints. According to some preliminary estimates, a program based on such level funding would result in a determination of technical site suitability by the Department no earlier than 2003. This determination, however, could not support a Secretarial recommendation to the President and subsequent license application, as intended in the Act. The activities supporting the National Environmental Policy Act process, site recommendation, and preparation of the initial license application, if the site is suitable, would have to be completed in sequence.

The Department believes that the preliminary evaluation discussed above is sufficient contingency planning at this time, and a more detailed evaluation at this point, without any definitive alternative funding outlook, would not be cost-effective. However, the Department is taking a number of steps to address the Board's concerns with program management and ensure that effective cost controls are in place as site characterization activities are expanded. As the Board is aware, the Office of Civilian Radioactive Waste Management and its Yucca Mountain Site Characterization Office have completed realignments, which provide a more streamlined organization focused on the strategic goals of the program. This alignment is providing the basis for a critical review of the contractor support requirements as detailed budget and implementation planning is conducted. In addition, the independent financial and management review of the Yucca Mountain Site Characterization Office is underway and will be used to assess the effectiveness of our changes and determine the need for further actions.

Recommendation 4:

The Board recommends that the DOE consider hiring commercial drilling companies to provide the needed drilling capacity in lieu of purchasing additional LM-300 drill rigs. (page 31)

Response:

The Department recognizes the Board's concerns with the cost effectiveness of the drilling program and has taken steps to address them. The Department plans to continue implementation of a flexible downhole drilling, sampling, and testing-and-monitoring program by entering into "firm fixed price" contracts with commercial vendors where appropriate, utilizing the existing contractor with existing government equipment, and utilizing Interagency Agreements with other governmental departments.

The Department believes that its current approach will address the Board's concerns. For example, in its budget planning for the next fiscal year, the Department has not included capital expenditures for additional LM-300 drill rigs and will address its needs for increasing drilling capacity through alternative means. In the detailed planning process for Fiscal Year 1995 and the out-year plans, consideration is being given to those portions of the drilling program that are amenable to developing a well-defined work scope, schedule, and unit price elements that can be procured through "firm fixed-price contracts." However, it should be noted that some portions of the drilling program may be more suited to the contractual relationship with the project's construction contractor, Reynolds Electrical and Engineering Company, utilizing the existing LM-300 and other government-owned drilling equipment. Additionally, the Department has increased its flexibility in the development and implementation of the drilling, sampling, and testing-and-monitoring program by entering into an Interagency Agreement with the Department of Interior for specialized and short-duration drilling operations. The Department was successful with the initial operation in February of this year, and two additional short-term drilling operations should be completed this fiscal year. These drilling exercises, through the Interagency Agreement are focused, efficient, and can be arranged on relatively short notice. Nor do these drilling activities require a long-term commitment of people or equipment. The Department would appreciate receiving the Board's views on the adequacy of the current approach in addressing the Board's concerns.

RISK AND PERFORMANCE ANALYSIS

Recommendation 1:

The DOE should prepare and implement a plan to increase the quality and effectiveness in the use of expert judgment in the high-level waste program. This plan should include:

(a) establishing guidelines for the use of expert judgment in both programmatic studies and performance assessments;

(b) increased involvement of management in planning and monitoring the use of expert judgment;

(c) increased use of outside (of the DOE and its contractors) expert judgment; and

(d) development of an experience base that includes the use of expert judgment in both internal studies and those involving interaction with external groups such as the NRC. (page 35)

Response:

The Department shares the Board's interest in ensuring the effective use of expert judgment in the high-level waste program. The Department is also concerned that the use of experts, through both internal and external processes, be appropriate and cost-effective. The Department's philosophy and future plans on the use of expert judgment were presented at the November 1992 workshop on expert judgment in Albuquerque, New Mexico. The previous use of expert judgment has been clearly defined on a task-by-task basis. These activities include the Test Prioritization Task, the Calico Hills Risk Benefit Analysis, the Integrated Test Evaluation, the National Research Council's Panel on Coupled Processes, the Unsaturated Zone Hydrology Peer Review, Geophysics Peer Review, and Total System Performance Assessments, to name a few. These efforts have involved both internal Department and external experts. Currently, a panel of outside experts is evaluating the work of the volcanism task and will provide an independent assessment of the probability of future volcanism. Further use of expert judgment and guidelines for its use will continue to be defined and monitored by Department managers on a task-by-task basis.

The Department's plans for the evaluation of site suitability were presented to the Board at its Fall Full Board Meeting in Las Vegas, Nevada, which included the use of expert judgment in several ways. The Department will finalize these plans after considering the comments received from these meetings. Currently, these plans include peer reviews that will be conducted when data synthesis on a particular topic is complete such as postclosure rock characteristics, hydrology, geochemistry / transport, and others. These peer reviews will take place after internal reviews have been completed and will involve experts from outside the Department. Additional external peer reviews on selected narrowly focused topics will be necessary prior to the final peer reviews. One area in which the Department plans to conduct an external peer review in 1995 is in thermohydrologic models and their application in the testing program. As the Department approaches the technical site suitability decision, it will increasingly be making decisions as to which program and technical issues will require expert judgment as decision-aiding strategies.

The Department has developed an experience base in the use of expert judgment on various projects requiring licensing. This experience base included internal projects and those involving other groups. The Department maintains an extensive record of information on each of these projects and adds to the information base as it becomes aware of additional projects that are utilizing expert judgment in various decision-making capacities. The Department will draw on this experience base as a resource for deciding which steps of the licensing process and which issues will be addressed most effectively by the use of expert judgment.

HYDROGEOLOGY AND GEOCHEMISTRY

Recommendation 1:

The DOE should develop a more coherent plan for using total system performance assessment (TSPA) studies and related sensitivity analyses to (a) focus future source term model development and (b) guide data collection both in terms of prioritizing research and establishing when sufficient information has been obtained. (page 39)

Response:

The Department agrees and is using total system performance assessments to focus site characterization activities to the extent that the preliminary state of site characterization, waste package design and testing, and model development will allow. For example, in the most recent Total System Performance Assessment (TSPA 1993: Andrews et al. and Wilson et al., 1994), the focus was in large part on the source term. A number of specific recommendations for obtaining information needed for source term model development, were made as a result of this performance assessment and its sensitivity studies. Likewise, a number of specific recommendations were made for obtaining further site data.

The 1993 Total System Performance Assessment, with its attendant sensitivity studies, was also used to identify a number of near-field information and modeling needs and make recommendations for obtaining further site data. For example, it was found that it is still necessary to evaluate the effects of uncertain and spatially variable thermohydrologic properties of uncertain fracture-matrix conceptual models, and of uncertain thermal and hydrologic regimes as a function of time and space. As part of the 1993 Total System Performance Assessment, it was shown that it is relatively straightforward to abstract results from detailed models; but what is now required is more complete sensitivity and uncertainty analyses using the more detailed process-level models, many of which are still preliminary and under active development.

The Department believes that total system models need to be tested to see if they are capable of accurately representing the important processes identified through exercising the site-scale process-level models for flow and transport. Until this linkage has been formalized and evaluated, the Department maintains that it is premature to rigorously interpret findings based on the exercise of preliminary total system performance models. During Fiscal Year 1995, the first version of the site-scale process-level flow model will be provided to the performance assessment function for testing and abstraction. After the performance assessment models can be shown to credibly bound the results of this lower level, more detailed modeling, the Department believes that the total system performance assessment results should be interpreted in terms of how much data is enough.

Recommendation 2:

The DOE should improve its capability to model radionuclide sorption and to model fully coupled reactive transport. The DOE needs to carefully compare the merits of further development of EQ3/6 versus adoption and further development of simpler codes. (page 39)

Response:

The Department does not plan to fully couple a code like EQ3/6 with a transport code. For this reason, a comparison currently underway is examining the sensitivities to transport results of using a code like FEHM, which utilizes a bulk Kd approach and partially coupled transport rather than accounting for individual speciation of radionuclides, versus using a code like LEHGC that accounts for discrete speciation and sorption reactions at specified sorption sites. The results of this sensitivity analysis will determine whether the Department will reconsider adding the complexity of a fully coupled reactive transport module to a code like EQ3/6; but at the present time it has no such plans.

The Board's recommendation to compare the merits of further development of EQ3/6 versus adoption and further development of simpler codes implies that EQ3/6 would be used primarily for reactive transport modeling, if the code were to be further developed. However, EQ3/6 is used by the project in many other studies, such as modeling groundwater chemistry and rock/water interactions, mineral dissolution and precipitation, and mineral reactions.

Recommendation 3:

The Board recommends that, as a high priority, the DOE begin to collect and document data on mass-transport of radionuclides in near-field materials under partially saturated conditions. These data should then be incorporated into the DOE's source term model. (page 39)

Response:

The Department agrees and has established the Integrated Testing Task for testing the behavior of radionuclides in the presence of near-field materials under elevated temperatures and under variable degrees of saturation. The results of these tests are used directly in waste package performance assessment for development of its source term models. Integrated tests employ a complexity of variables whose interdependence cannot be understood in total combination until more simplified systems and interactions are explained. For this reason, the Department has planned the integrated tests sequentially to look first at the effect of elevated temperatures on near-field transport in the absence of waste package materials, and then to add engineered materials and conditions to the natural system under a variety of repository loading conditions. The added complexity has been phased into ongoing near-field studies of simpler systems beginning in 1995 and will continue into the performance confirmation period.

ENVIRONMENT AND PUBLIC HEALTH

Recommendation 1:

The DOE should develop studies of the dynamics of the Yucca Mountain ecosystem. Studies of water, energy, or nutrient transfers within the ecosystem should be considered, as should studies of the effects of repository heat on ecosystem processes. The goal of the studies should be to identify those components of the ecosystem that are most important for ecosystem health and the components that are likely to be the most sensitive to site-characterization activities, to repository construction and operation activities, and to the long-term presence of a reposi-

tory at the site. The Department should develop one or more models of the Yucca Mountain ecosystem based on water, energy, or nutrient transfers. This synthesis should come from integrating the environmental data with the geologic and hydrologic USGS data and models. The model(s) should be used to periodically (e.g., yearly) re-evaluate and prioritize future environmental studies. (page 46)

Response:

The Department plans to initiate efforts to identify and investigate ecosystem or process models that could be used to identify components of the ecosystem that are important for ecosystem health and which are likely to be sensitive to activities at Yucca Mountain. Data that are needed for these models will be obtained from various sources, including original studies, if necessary. The Department plans to keep the Board apprised of these efforts and looks forward to future comments as to the adequacy of specific studies and analyses.

Recommendation 2:

The DOE should pursue its plans to revise its ecological study plot design. The revised design should be reviewed by a statistician experienced in this type of monitoring before the new control plots are established. The DOE should consider conducting experiments in which disturbances would be deliberately applied to study plots to provide a basis for understanding the effects of site characterization on the Yucca Mountain environment. (page 46)

Response:

The Department is revising the study design for the site characterization effects study. This revised design was presented to the Board at the March 22, 1994, meeting of its Panel on the Environment and Public Health in Las Vegas, Nevada. The new approach includes an asymmetrical design (Underwood, 1993a, 1993b) without before-and-after measures. An asymmetrical design consists of more control areas than impact areas. The design will have three sampling areas, treatment plots, near-field control plots, and far-field control plots. Time-series analysis and statistical tests for parallelism in parameter response will be used to evaluate effects of site characterization activities through time (Skalski and Robson, 1992). The new design will be evaluated by a statistician before additional plots are established. The Department would appreciate receiving the Board's views on the adequacy of this approach in addressing the Board's concerns.

In response to the Board's recommendation, the Department will consider conducting experiments to gather data on effects of site characterization activities and the effects of a possible repository since this information may be required for developing the models discussed above.

Recommendation 3:

The DOE should accelerate its development of a strategy for acquiring the technical information needed to forecast the environmental effects of a Yucca Mountain repository. For purposes of evaluating the possible linkages between environmental effects and repository performance, the strategy should include an assessment of a "worst-case" scenario involving the elimination of all vegetation on Yucca Mountain. The scoping process for development of an environmental impact statement should be started as soon as practical to identify major programmatic decisions for which a formal evaluation of environmental impacts is required. (page 46)

Response:

The Department is planning to increase the effort to evaluate the environmental effects of a repository. This effort will involve modeling that was discussed in the Department's response to the Board's first recommendation regarding the environment and public health. The possible linkages between environmental effects and repository performance will be assessed. It must be emphasized that governing legislation such as the Nuclear Waste Policy Act of 1982, as amended, the National Environmental Policy Act of 1969, and other guidelines of the U.S. Nuclear Regulatory Commission and the U.S. Environmental Protection Agency, do not require evaluation of a "worst-case" scenario.

The Department concurs on the need to start the scoping process for the repository environmental impact statement. The Department plans to issue the Notice of Intent for the repository Environmental Impact Statement and begin the scoping process in mid-1995.

RESOLVING DIFFICULT ISSUES — FUTURE CLIMATES

Recommendation 1:

The DOE needs to develop a strategy for addressing climate-related issues that is based upon their significance to repository performance rather than the ability to predict future climate alone. (page 59)

Response:

The Characterization of Future Regional Climate and Environments (Study Plan 8.3.1.5.1.6) emphasizes the importance of focusing on potential future climate scenarios that are credible and potentially the most challenging to repository performance. The Department is fully cognizant of the importance of communication and integration between this study and the needs of the hydrology and performance assessment modeling community within the Yucca Mountain Site Characterization Office, and the Department is taking actions to further ensure an integrated and directed effort. The Department recognizes the difficulty, if not the impossibility, of accurately predicting future climate behavior with present knowledge and technology, and the study has been redirected accordingly.

Recommendation 2:

Future climate states should be estimated primarily through the use of paleoclimatic and paleohydrologic data. Numerical modeling can play a supplementary, but important, role in overcoming the limitations of the paleoclimate data and estimating the likelihood of adverse climate states. (page 59)

Response:

The Department believes that numerical modeling has an important complementary role in the overall climate program, while recognizing the vital contribution of paleoclimate and paleohydrologic data and interpretations. The Department believes that future climate effects cannot be estimated entirely through the use of paleoclimate data. The inherent unpredictability of climate evolution, particularly in view of anthrogenic inputs for which there are no direct analogues in the past, increases the

uncertainty in the reliance that may be placed on the record of the past. For the purposes of estimating future climate states, the future can be expected to yield climate extremes at least as great as those reflected in the past record. Analysis of past climate states are primary tools for synthesizing potential future climate variations.

Recommendation 3:

An external expert panel made up of atmospheric scientists, paleoclimate data analysts, hydrologists and specialists from other relevant disciplines should be formed to help guide the DOE in the integrated use of data and models. The chief scientist, when appointed, should play a key role in integrating the studies and coordinating the expert panel. (page 59)

Response:

The Department supports the utilization of expert opinion in developing a scientific consensus on the impacts of potential future climate change on repository performance. The Department agrees that the chief scientist, when appointed, will play a key role in integrating the studies and coordinating the use of expert judgment and the peer review process. Acknowledged professionals in the climate community are major contributors to the climate studies, publication in peer review journals are anticipated, and participation in internationally sanctioned benchmarking efforts are planned to enhance the credibility of Department-sponsored activities. Expert opinion input to the direction of the study and interpretation of conclusions is called for in the Characterization of Future Regional Climates and Environments Study.

Recommendation 4:

The range of future climate states at Yucca Mountain should be acknowledged input to repository design. (page 59)

Response:

The Department agrees that potential future climate impacts are an essential input to repository design. Much remains to be determined through the site characterization program, however, regarding the potential impact of climate change on repository performance.

Significant uncertainty exists in the climate-generated precipitation source term, the coupling of surface precipitation to subsurface infiltration and recharge, and potential effects on waste isolation and transport processes. While this uncertainty may be mitigated through considerations such as robust waste packages and engineered barriers, repository and emplacement geometries, and thermal-loading profiles, the anticipated behavior of the natural barriers, particularly as influenced by climatic effects of hydrologic characteristics, remains a significant uncertainty and a major program focus.

Appendix I

Japan — An Overview of the Waste Management System

Japan

Report Outline

I. Background

Japan consists of four main islands: Hokkaido, the northern most island; Honshu, the largest island; and Shikoku and Kyushu, two smaller islands south of Honshu (see Figure 1). Covering 145,882 square miles, Japan is just smaller than Montana, yet the country's population is 124.4 million — half that of the United States — and growing annually by 4 percent. *Despite its large population, most of Japan's people live on less than 5 percent of the total territory,* and 45 percent of the population can be found living in three major metropolitan areas: Tokyo, Osaka, and Nagoya, all of which are located on Honshu.

Japan sits in what has been called a "tectonic intersection." Four of the earth's shifting metal plates converge there. Japan is located in one of the world's most seismically active areas, which means that the ground literally moves under the feet of the Japanese people. Unfortunately this activity often leads to tragedy. As recently as January 1995, a major quake ripped through the urban centers of Japan's indus-

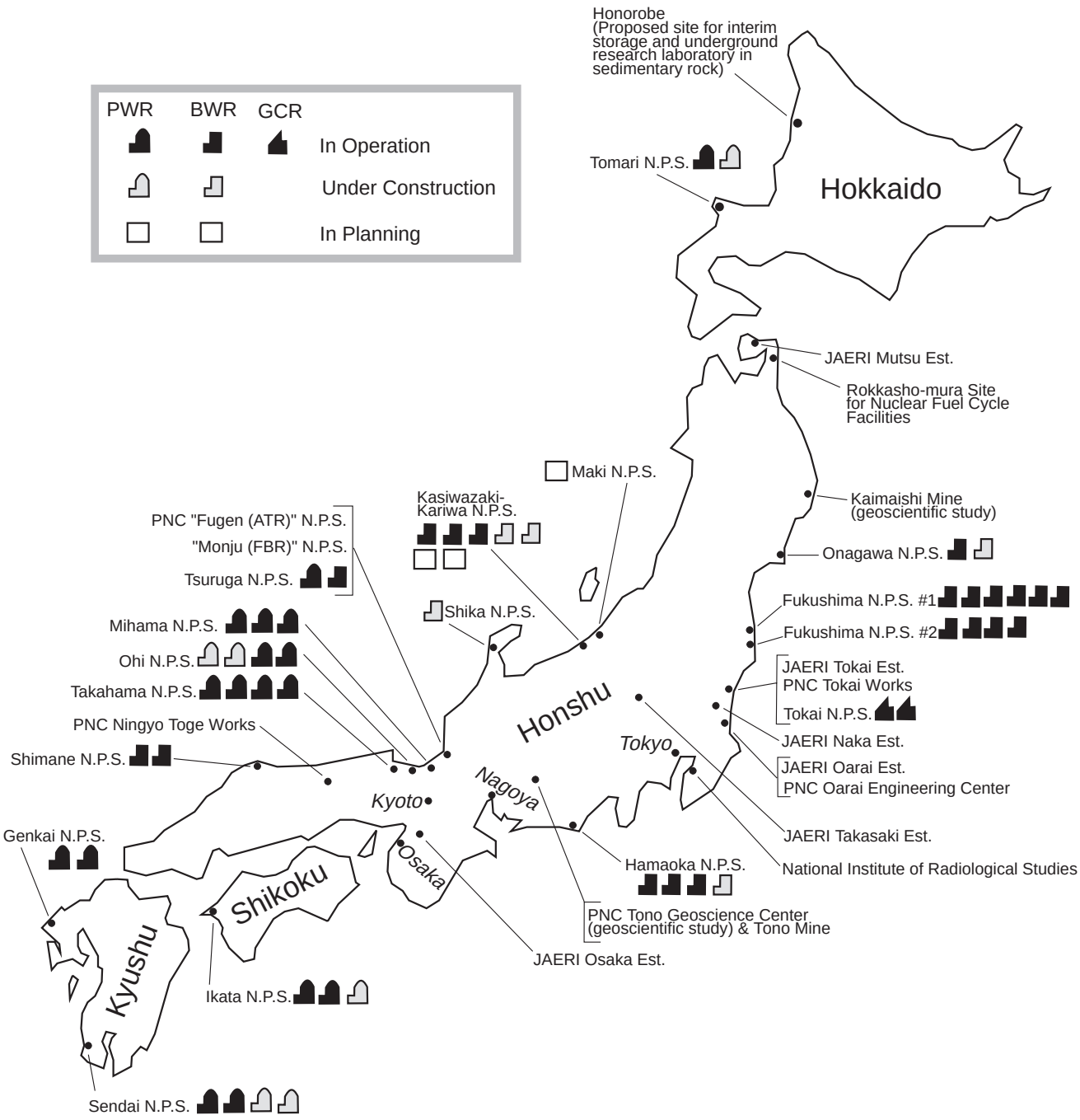
Table 1 — Energy Production in Japan*

Population	1989	124 million
Electric Power	1989	791.0 TWh
		32% oil
		23% nuclear
		19% gas
		15% coal
		11% hydro / geoth.
	1990	27% nuclear
	1995	31% nuclear
	2000	35% nuclear
Nuclear Power**	1991	32.1 GWe
	1995	39.3 GWe
	2000	45.5 GWe
Reactor Mix	1990	GCR — 1
		BWR — 21 (1970-90)
		7 (1993-97)
		PWR — 19 (1970-91)
		4 (1993-97)
		HWR — 1 (1979)
		FBR — 1 (1993)
Reactor Development		HWR (ATR), LMFBR, HTGR

* Source: PNL-9450-1 (PNL 1994)

** Policy: Strong nuclear power program to lessen dependence on foreign energy sources; install LWRs for near-term needs; develop advanced HWR (ATR); aim for commercial FBR operation ~2020-2030; supply domestic needs and build export business.

Figure 1 — Major Japanese Nuclear Facilities



Source: Map and information compiled from multiple sources.

trial midwest, killing thousands of people and injuring thousands more.

And earthquakes are not the only geologic threat to the population. The Japanese islands are volcanic in origin. Approximately 80 of the world's active volcanoes can be found on less than 1 percent of the earth's surface.

Last, but not least (from the perspective of finding a suitable site to dispose of high-level radioactive waste), Japan is a very wet country, blessed with abundant rainfall. As a result, the water table is very close to the surface. Given the abundance of ground water, the most likely potential transporter of radionuclides, and the dense population, developing a high-level radioactive waste management system presents a special challenge in Japan.

Despite what might appear from a U.S. regulatory perspective to be unsurmountable obstacles, the Japanese are working to site and build a permanent geologic repository for high-level and some transuranic wastes.

II. Nuclear Fuel Production and Energy Policy

In Japan, current nuclear power capacity is 38 GWe; nuclear power plants supply 28 percent of the country's electric power. By the year 2010, capacity is expected to double, reaching 72 GWe with nuclear power plants supplying 48 percent of the power. Figure 1 shows the location, type, and ownership of the major nuclear facilities in Japan.

Japan's long-term national energy policy was reformulated by the Atomic Energy Commission (JAEC) in 1994. The long-term goal now is to guarantee national self-sufficiency in the supply of nuclear fuel. To achieve this goal, the government will be promoting:

- the reprocessing of all spent fuel,
- the use of uranium and plutonium from reprocessing,
- the use of plutonium in LWRs and ATRs (advanced thermal reactors), and
- the implementation of safe and appropriate radioactive waste treatment and disposal.
- research and development on actinides recycling

To minimize the risk of becoming overly dependent on foreign technology and production capability, the Japanese are developing domestic commercial capability for all parts of the fuel cycle (except for uranium conversion). The Japanese are developing advanced reactors (ATR and FBR) to improve efficiency, and they are in the process of developing commercial enrichment, fuel fabrication, and reprocessing capabilities, although they still currently depend in part on foreign services for enrichment and reprocessing.

III. Types of Waste

According to the *Long-term Program for Research, Development and Utilization of Nuclear Energy* (JAEC 1994), the basic categories of waste in Japan are:

1. High-level wastes: wastes resulting from reprocessing of spent nuclear fuel to recover uranium and plutonium. Radioactivity in this waste is high, so special attention must be paid to the long-term protection of humans and the environment.

2. Low-level wastes: waste water used in nuclear power stations, filters and ion exchange resins used to clean waste water, wastes such as cloths, paper, and metal objects. The radioactivity of these wastes is low. The major radioactive material is cobalt-60, which has a relatively short half-life. The radioactivity in these wastes are expected to decay to very low levels within 300 years.

3. Wastes containing transuranic (TRU) nuclides: wastes generated from operations of reprocessing plants and the plutonium-uranium mixed oxide fuel fabrication plant. TRU wastes containing alpha-bearing nuclides less than approximately 1 GBq / ton and beta- and gamma-bearing nuclides of low concentrations may be disposed of in shallow land facilities. Wastes containing alpha-bearing nuclides of

more than about 1 GBq/ton (TRU wastes) shall be disposed of using engineered barriers, geologic disposal, etc.

4. Uranium wastes: special class of low-level waste which includes residue, mill tailings, and sludges from uranium operations.

5. Returned wastes: high- and low-level radioactive waste returned from abroad after reprocessing.

IV. Organizational Structure

In Japan, a complex organizational structure exists for managing nuclear waste. The government appears to do business by way of exploration, examination, and consensus building. There are commissions, ministries, and agencies (similar to those found in the U.S.) with wide-ranging authorities. Most interesting, however, is that a large number of committees have been created *in addition* to the bureaucracies. For example, both the Atomic Energy Commission and the Nuclear Safety Commission have special committees serving them. Also, an Advisory Committee for Energy, which has subcommittees and special committees, was established in June 1965 to advise the Ministry of Trade and Industry (MITI).

Figure 2 is a basic diagram on nuclear waste management in Japan. This figure does not include the roles played by all of the organizations involved, but does illustrate the relationships among the central organizations involved in the program.

Below is a very abbreviated summary of the role of some of the key organizations assume in Japan's nuclear waste management program:

Atomic Energy Commission (JAEC) — established in 1956. The JAEC advises the Prime Minister on all issues pertinent to energy research, development, and use. The Advisory Committee on Radioactive Waste Management is one of many JAEC committees.

Nuclear Safety Commission (NSC) — organized in 1978 as part of the Prime Minister's office. The NSC executes national policies pertinent to nuclear safety and security in energy R&D and use. Staff support for the NSC comes from the Nuclear Safety Bureau in the Science and Technology Agency (STA). Two committees of the NSC are: Special Committee on Safety Regulations of Radioactive Waste and the Special Committee on the Safety Standards of Radioactive Waste.

Science and Technology Agency (STA) — established in 1956 as a bureau in the Prime Minister's office. STA is responsible for the comprehensive administration of science and technology. Three bureaus make up the STA: (1) the Nuclear Safety Bureau (NSB), which is responsible for assuring nuclear safety; (2) the Atomic Energy Bureau (AEB), which is responsible for promoting R&D; and (3) the National Institute of Radiological Studies (NIRS), which is responsible for conducting studies and training programs on radiation hazards.

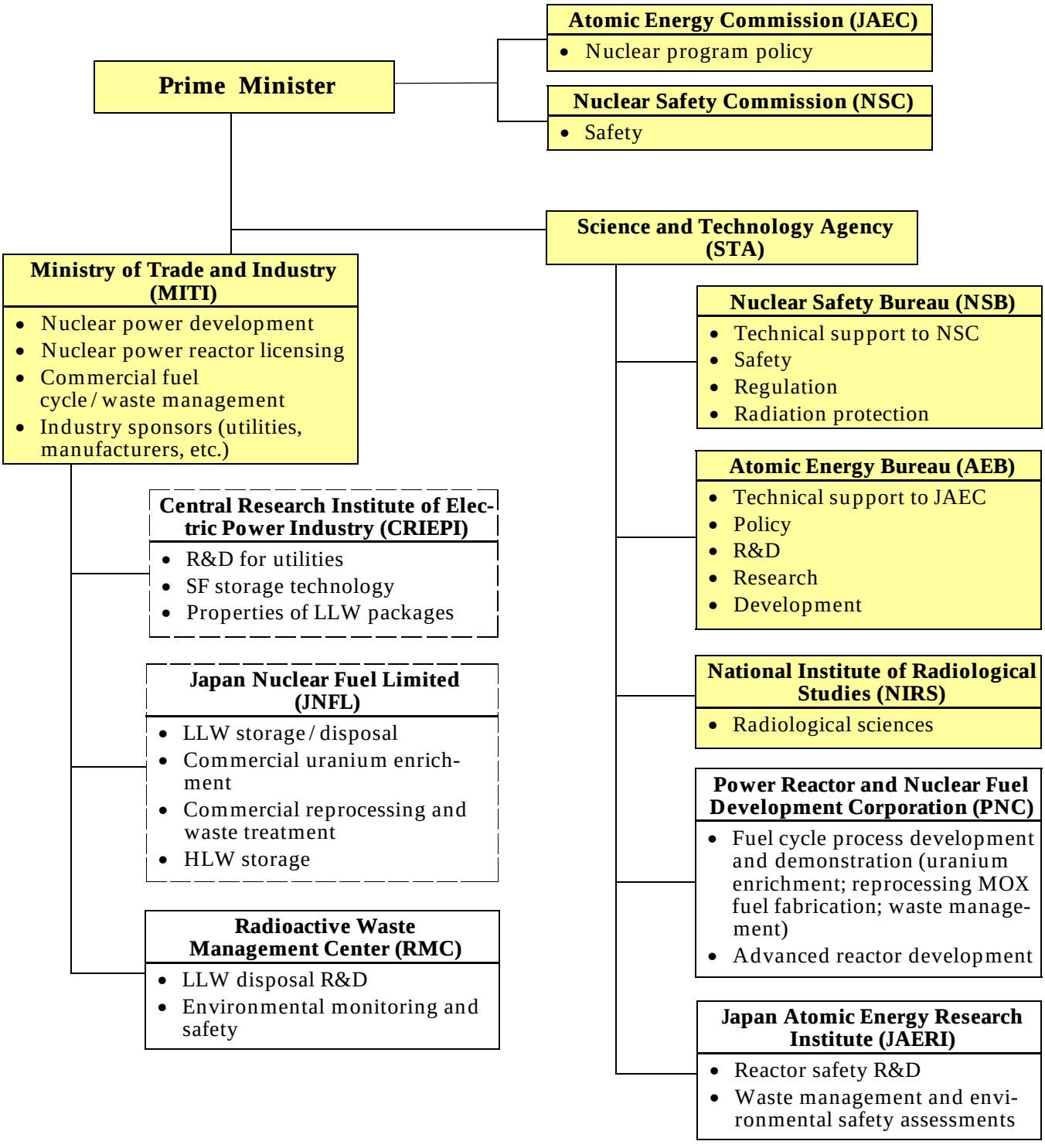
In addition, there are a number of quasi-governmental or government-run industries under the STA's official jurisdiction. Two key ones in nuclear waste are:

Power Reactor and Nuclear Fuel Development Corporation (PNC) — established in 1956 and reorganized under the name PNC in 1967 to promote the development and use of atomic energy. PNC, as the core organization, conducts extensive R&D on waste technologies through its subsidiaries. The installations owned and operated by PNC include Tono Geoscience Center (Tono Mine) and the Tokai Works. In addition, geoscientific studies are being carried out in Kamaishi Mine with the cooperation of the owner.

Japan Atomic Energy Research Institute (JAERI) — established in 1956. JAERI is a semi-governmental research organization implementing national long-term programs in nuclear energy. Among other facilities, the JAERI operates the Tokai and Oarai Research Establishments, where advanced research on waste management takes place.

Steering Committee on High-Level Radioactive Waste Project (SHP) — established in May 1993 to promote the preparation of the project to dispose of high-level radioactive waste. SHP reports to the Council for Promoting High-Level Waste Disposal, which was created in 1991. The goal of SHP is to promote better

Figure 2 — Japan's Nuclear Fuel Cycle/Waste Management Organization



Source: International Nuclear Waste Management Fact Book (PNL 1994)

public understanding and cooperation by conducting research and investigation on many issues pertinent to siting and then applying the results of that research. (However, SHP will not be the operational agency to be established around the year 2000.)

Ministry of Trade and Industry (MITI) — government agency responsible for nuclear power development and fuel and waste cycle activities. MITI has general responsibility for coordinating and promoting industrial activity in nuclear energy and the fuel cycle. A number of companies and research institutes work with MITI. For purposes of waste management, two worth noting include:

- *Central Research Institute of the Electric Power Industry (CRIEPI)* — CRIEPI provides waste management R&D on many aspects, including disposal, storage, and transportation, of low- and high-level waste and spent fuel.

- *Japan Nuclear Fuel Limited (JNFL)* — a private company is responsible for: (1) uranium enrichment; (2) reprocessing of spent nuclear fuel; (3) temporary storage of nuclear fuel materials and returned wastes; (4) disposal of low-level wastes; and (5) transportation of uranium, low-level wastes, spent fuel, etc.

V. Nuclear Waste Disposal Strategy

Low-level waste is currently being disposed of at the Rokkasho-mura site, after being reduced in volume and solidified. In 1994, approximately 30,000 drums were received from various power plant sites.

The basic high-level waste disposal strategy calls for the waste to be reprocessed and solidified in stable form. Then the waste will be cooled for 30 to 50 years in interim storage facilities. After that time, it will be permanently disposed of several hundred meters underground.

Consequently, Japan's Atomic Energy Commission enacted a new high-level waste disposal policy in August 1992, aimed at creating a new organizational structure that will foster better public understanding and cooperation. The purpose behind the effort to rethink and design a disposal strategy for high-level waste came from a desire to obtain understanding and cooperation from the general public through a clearer indication of procedures, schedules, and delineation of the roles and responsibilities of the organizations involved.

Under the new approach, the government is responsible for implementing and ensuring waste disposal. PNC currently is responsible for conducting R&D in support of geologic disposal. The electric utilities are required to pay for the disposal and to play a full role as generators of high-level waste even during the research and development stage. To promote cooperation, the Council for Promoting High-Level Waste Disposal, which was created in October 1991, was assigned the responsibility of promoting constructive measures and providing necessary coordination among the organizations involved. SHP was created under this council in May 1993. (See section on organizational structure.)

An operating agency of the government will be set up sometime around 2000. This agency will conduct preliminary site investigations, select a designated disposal site, and obtain the consent of the local communities prior to seeking approval by the government. This organization will also conduct site-characterization work and demonstrate disposal technologies at the proposed site. Tentatively, a repository is scheduled to begin operating around the 2030s or by 2045 at the latest.

VI. Reprocessing

Reprocessing of spent fuel and use of the recovered plutonium and uranium form the basis of Japan's waste management policy. Light water reactors are expected to generate 1,100 metric tons of spent fuel by the year 2000, 1,500 metric tons by the year 2010. Spent fuel generated to date has been reprocessed in PNC's Tokai plant and in foreign reprocessing facilities. To meet future demands and further develop domestic capabilities, construction of a reprocessing plant at Rokkasho-mura in the Aomori prefecture (county) began in April 1993. This facility is expected to reprocess 800 metric tons per year, beginning early in the 21st century. The facility's spent fuel storage pool, however, will be ready for use in 1996. Through reprocessing, the Japanese anticipate gaining at least

80 metric tons of plutonium through the year 2010 (50 MTs for the FBR, 55 MTs for LWRs, and 10 MTs for the HWR/ATR). Five MTs will come from the Tokai Works, 30 MTs will come from overseas facilities, and the rest will be processed at the Rokkasho-mura facility.

Also located at the Rokkasho-mura integrated fuel cycle center is a uranium enrichment plant, which commenced operation in 1991; a low-level waste facility which began operation at the end of 1992; and a storage facility for high-level waste returning from overseas.

The design of the Rokkasho-mura reprocessing facility was made with following objectives in mind.

- Use the best available proven technologies, and where new technologies are used, conduct mock-up tests.
- Investigate results and experiences of preceding plants and incorporate improvements into the designs.
- Build operational, inspection, maintenance, and replacement procedures into designs to accommodate the high-level of tectonic activity in the region.
- Design the treatment system for radioactive solid waste with final disposal in mind.
- Minimize effluent discharge according to the ALARA principle.
- Make confinement of radioactive materials the central focus of safety designs.
- Define in detail all safeguard measures.
- Strive for cost-effectiveness in design and during operation.

The facility will contain a spent fuel storage pool; facilities for head-end processing; facilities for separation, partitioning, and purification; facilities for "denitration;" facilities for acid recovery and solvent regeneration; a gaseous effluent treatment system; a liquid effluent treatment system; and a solid waste treatment facility.

With respect to the spent fuel storage pool at the site, fuel will have to cooled one year prior to shipment to the pool; then it will be cooled in the pool four years prior to reprocessing. The pool's storage capacity will be 3,000 MTUs, allowing approximately three years of annual throughput. Also, burnup credit will be taken into consideration prior to loading the fuel into the storage pool. As the spent fuel assemblies are shipped with PWR burnable poison rods and BWR channel boxes, these will be removed before the rods are sheared.

VII. Interim Storage

Low-level waste currently is being stored in warehouses at PNC's Tokai and Oarai works at the Japan Atomic Energy Research Institute, and at reactor sites. TRU wastes produced by MOX fuel fabrication facilities are being stored at the Plutonium Waste Storage Facility and the Low-Active Solid Waste Storage Facility until a long-term disposal option can be found. Zircaloy hulls from spent fuel elements and associated fuel assembly parts are being stored in pools at the Tokai reprocessing plant.

Very extensive conditioning procedures are in place for low- and intermediate-level waste, and much of this conditioning takes place at the Tokai site. Of note, combustible radioactive wastes, which comprise 60 percent of all generated radioactive solid wastes in Japan, are incinerated at the Fugen site (see Figure 1) in a solid waste incinerator. The incinerator has a capacity of 50 kg/hr and storage capacity for 250 cubic meters of waste resins.

Current plans call for high-level waste to be stored in dry, air-cooled vaults for 30-50 years before final emplacement in a repository. Such a storage facility was proposed for Honorobe on the island of Hokkaido for high-level waste from the Tokai reprocessing plant. In 1993, the government held an internationally attended waste forum in Aomori prefecture because of local concerns about the construction of an interim storage facility for high-level waste at the Rokkasho-mura site. (It had been under construction since 1992.) The public was concerned that the facility would become a de-facto repository. The opposition has since subsided, and the storage facility is being built.

VIII. Research and Development

Currently, PNC has primary responsibility for R&D pertaining to the disposal of high-level waste. (However other organizations, such as JAERI and CRIEPI, also conduct parts of the R&D work.) The JAEC's August 1992 policy on high-level waste disposal states that it is *extremely* important to obtain public understanding of the progress in R&D. The JAEC required the PNC to issue a summary report on progress, which has published in 1992. The report is several hundred pages long and describes the experiments and modeling work done in support of deep geologic disposal. PNC must prepare a second summary by the year 2000. The second summary will focus on the role of engineered barriers and the near field in waste disposal and on the methods and equipment needed for geologic surveys.

The government intends to establish a "committee for evaluation," which will assess the technological reliability of disposing of waste in geologic formations in Japan as well as safety assurance, technological knowledge, and the results of geologic surveys at that time.

In the same policy, PNC is also directed to establish multiple underground research facilities to gain "an accurate grasp of the characteristics to be considered as environmental conditions of deep geologic formations." These facilities are to be *clearly* distinguished as separate from a repository.

PNC has been conducting extensive, ongoing R&D work in the geosciences. Much of the work is taking place at the sites the Board visited. (See Figure 3 for a *brief* summary of work in progress.) The Shaft Excavation Effects (SEE) Project is part of the geosciences work under way at the Tono Geoscience Center. The project is designed to determine the effects of shaft excavation on surrounding rock mass stability and ground-water flow.

In addition, JAERI operates the Radioactive Waste Management Center (RMC), conducts safety experiments using a Large Scale Test Facility, and operates the Waste Safety Testing Facility (WASTF) at Tokai.

IX. Licensing

Anyone handling over 100 curies of radioactive material must seek a license. Overall licensing involves the public, MITI, the JAEC, and the NSC. After a site has been selected and the local government and public have given their approval, a construction plan will be submitted to the Electric Power Development Co-ordination Council of MITI.

After the construction plan has been approved, an installation permit would be submitted to the JAEC and the NSC, at which time a public hearing on safety would be held. A construction license would then be issued by MITI. After several interim inspections, an operating license would be issued. For a reactor, the entire process to this point takes 50 to 70 months.

X. Public Involvement

As has been the case in other countries, the Japanese government received a "rude awakening" in 1988 when the public began to express concern about nuclear activities and the disposal of high-level radioactive waste. Rather extensive analysis has been carried out and public opinion polls conducted by major Japanese newspapers on the nature of the public's concern and the difference between "old wave" (pre- and just post-Chernobyl) opposition and "new wave" opposition (more recent). It was observed that right after Chernobyl, public fears started to increase and were fed by large amounts of information in the media, which provides approximately 70 percent of the information that people base their opinions on. This increase in concern manifested itself in demonstrations and citizen actions beginning in 1988. Approximately 10,000 people protested at Ikata, on Shikoku Island (350 km southwest of Osaka) when a series of tests were conducted. Then in December 1988, the Aomori Prefectural Farmers Cooperative approved a resolution opposing the plan for facilities at the Rokkasho-mura site. While this opposition has since died down, the public outcry served to refocus much of the efforts on the government on improving communication and public understanding of work to date. This opposition in large part resulted in the new high-level waste policy of August 1992 and the subsequent creation of

Figure 3 — Summary of PNC Works in Progress

Disposal Measures for High-Level Radioactive Waste

(Radioactive Waste Management Project)

Japan's basic policy for the handling of high-level radioactive waste that has been separated from spent fuel at a reprocessing facility first calls for the waste to be vitrified (solidified) into a stable form and then placed in an interim storage facility for cooling. After 30 to 50 years, it is then disposed of in geological formations more than several hundred meters underground.

PNC is positioned as a leader in the implementation of R&D concerning the geological disposal of high-level radioactive waste.

Development of Vitrification and Storage Technologies for High-Level Liquid Waste

(Waste Technology Development Division, Tokai Works)

Development of technology for the vitrification of high-level liquid waste (HLLW) has included designing vitrification process equipment, testing the characterization of vitrified products on a full scale and performing vitrification and characterization tests using fully radioactive HLLW in the laboratory. Glass melting research has focused on controlling the quality of vitrified products, reducing entrainments (dust particles) that move from the melter to off-gas and securing the containment ability of the glass melter (to seal radioactive elements within the melter).

Equipment to inspect the inside of the melter and technology for dismantling the melter after its service life are also under development. Storage technology for vitrified products has been safety tested on the pits in a storage facility. Optimum glass composition was developed through testing the characterization of the glasses to understand the relationship between the properties and chemical composition of the glass.

Geosciences Research 1. An Overview of Geosciences Research

(Radioactive Waste Management Project)

One of the purposes of geoscientific research is to study the mechanisms of the geologic environment in Japan. Another purpose is to use the knowledge obtained through studies and observations of geologic features peculiar to Japan and various related phenomena to predict changes and to evaluate long-term stability in the geological environment. The research is to be done by conducting case studies in areas with representative geologic features and to further develop the required research techniques for these studies.

Geosciences Research 2. Geoscientific Studies at the Tono Geoscience Center

(Waste Isolation Research Section)

Geoscientific studies at the Tono Geoscience Center have been carried out in the four following areas:

(a) Rock Properties
The influences of the excavation of a shaft and a drift on the mechanical and hydraulic properties of the surrounding rock mass.

(b) Ground-water Flow
Hydrogeological models have been developed based upon relevant data from the literature and the field. A three-dimensional analysis of the ground-water flow was conducted using these models. Confirmation and further improvement of these models are under way.

(c) Hydrogeochemistry
In-situ measurements and laboratory analyses of the geochemical properties of the deep ground water have been continued. Geochemical evolution of the ground water has been studied from the viewpoint of the rock-water interaction.

Source: *PNC Review*, No. 25, Spring 1993, p. 8

Figure 3 — Summary of PNC Works in Progress (cont.)

(d) Isotope Chemistry of Ground Water
Migration and fixation of natural uranium series nuclides in the geological environment have been studied by observing the occurrence of uranium-series nuclides in the Tono uranium deposit as well as the laboratory experiments.

Geosciences Research
3. Kamaishi In-Situ Experiment

(Radioactive Waste Management Project)

The goals of the in-situ tests and research at the Kamaishi mine include acquiring data concerning the characteristics of the geological environment deep underground, gaining understanding of phenomena, developing and verifying analytical models of these phenomena, and developing and establishing research and testing techniques.

At the Kamaishi mine, testing has been conducted on crystalline rocks. The ground water in crystalline rock formations primarily flows through fractures in the rockbed. These fractures affect the water permeability of the rockbed and the chemical properties of the groundwater. When a cavity is excavated in the rock-bed, the rock stress is released, changing the fractures around the cavity and making the permeability of the host rock vulnerable to such change. Thus, the in-situ tests were conducted to obtain basic data on the crystalline rock formations in various fields, including research of ground-water flow, the geochemical characteristics of ground water, the dynamics of the rock-bed, engineered harriers and seismic activities.

4. Cooperation with Swedish Nuclear Fuel and Waste Management Co. (SKB)

(Waste Isolation Research Section, Tono Geoscience Center)

Since 1991, PNC has been participating in the research program of the Construction Phase of the Hard Rock Laboratory (HRL) project, an underground research project initiated by the Swedish Nuclear Fuel and Waste Management Company (SKB).

The main purpose of participating in the HRL project is to apply various methodologies, including site characterization of crystalline rocks and prediction and confirmation of the geological environment to an R&D program about geologic disposal in Japan. Results from the investigation of geologic structure of 0-700m section of the access tunnel has been compared to predictions based on a preliminary survey.

Geosciences Research
5. Studies of the Long-Term Stability of the Geological Environment

(Waste Isolation Research Section, Tono Geoscience Center)

Studies of the influences of various natural phenomena on the geological environment are necessary for a long-term stability assessment of geological environment in Japan. Important natural phenomena in Japan are: (1) fault movement and seismic activity; (2) uplift, depression and denudation; (3) volcanic activity; and (4) climatic variation and sea-level changes. The characteristics of these natural phenomena have been studied in terms of frequency and magnitude of occurrence, regularity of activity, and regional variation in Japan.

Geosciences Research
6. Development of Technologies and Instruments for Investigation of Geological Environments

(Waste Isolation Research Section, Tono Geoscience Center)

In order to understand the geological environment deep underground in Japan, new investigation techniques must be developed.

Figure 3 — Summary of PNC Works in Progress (cont.)

These include:

1. Investigation techniques for fracture characterization,

2. Nondestructive investigation techniques for detailed geological structures,

3. Instruments for investigating hydraulic characterization, and

4. Instruments for investigating hydrochemical characterization.

Results obtained so far are:

1. Fractures can be classified by their patterns,

2. The applicability and limitations of conventional geophysical methods were defined,

3. Instruments for measuring very low permeability were successfully developed; and

4. Instruments for sampling formation water without changing in-situ conditions were developed.

International Cooperation on the R&D Program

(Radioactive Waste Management Project)

Management of high-level radioactive waste is an issue common to all countries that promote the development and utilization of nuclear energy. It has been the subject of considerable research efforts. The PNC has actively pursued international cooperation and coordination in order to advance the progress of research and development projects and to promote public confidence in high-level radioactive waste management.

the SHP. One of the major criticisms of the government has been that *no clear rationale or policy for permanent high-level waste disposal exists* and that the government is not providing information in a form that the public can use to make informed choices.

In 1993, the government held an international waste forum in the Aomori prefecture to discuss public acceptance of a high-level waste repository. Representatives from key organizations in other countries were invited to attend. Many issues were explored in this symposium, but two major themes emerged: (1) The Japanese government needs to explain much more clearly what its waste policy is and how storage and R&D differ from disposal and (2) More general educational materials need to be made available to the public in a format they can understand and digest quickly.

Appendix J
Reports by the Nuclear Waste Technical Review Board

The following reports are available from the Nuclear Waste Technical Review Board.

First Report to the U.S. Congress and the U.S. Secretary of Energy March 1990

The first report sets the stage for the Board's evaluation of the Department of Energy's program to manage the disposal of the nation's spent fuel and high-level waste. The report outlines briefly the legislative history of the nation's spent fuel and high-level waste management program, including its legal and regulatory requirements. The Board's origin is described, along with its protocol, panel breakdown, and reporting requirements. The report identifies major issues and highlights five cross-cutting issues.

Second Report to the U.S. Congress and the U.S. Secretary of Energy November 1990

The Board's second report begins with the background and framework for repository development and then opens areas of inquiry, making 20 specific recommendations concerning tectonic features and processes, geoengineering considerations, the engineered barrier system, transportation and systems, environmental and public health issues, and risk and performance analysis. The report also offers concluding perspectives on DOE progress, the state of Nevada's role in site characterization at Yucca Mountain, the project's regulatory framework, the nuclear waste negotiator, other oversight agencies, and the Board's future plans.

Third Report to the U.S. Congress and the U.S. Secretary of Energy May 1991

The third report briefly describes recent Board activities and congressional testimony. Substantive chapters cover exploratory shaft facility alternatives, repository design, risk-benefit analysis, waste package plans and funding, spent fuel corrosion performance, transportation and systems, environmental program concerns, the DOE task force studies on risk and performance assessment, federal quality assurance requirements for the repository program, and the measurement, modeling, and application of radionuclide sorption data. Fifteen specific recommendations are made to the DOE. Background information on the German and Swedish nuclear waste disposal programs is included in Appendix D.

Fourth Report to the U.S. Congress and the U.S. Secretary of Energy December 1991

The fourth report provides an update on the Board's activities and explores in depth the following areas: ESF construction; test prioritization; rock mechanics; tectonic features and processes; volcanism; hydrogeology and geochemistry in the unsaturated zone; the engineered barrier system; regulations promulgated by the EPA, the NRC, and the DOE; the DOE performance assessment program; and quality assurance in the Yucca Mountain project. Ten recommendations are made across these diverse subject areas. Chapter 3 offers insights from the Board's visit with officials from the Canadian nuclear power and spent fuel disposal programs. Background on the Canadian program is in Appendix D.

Fifth Report to the U.S. Congress and the U.S. Secretary of Energy June 1992

The Board's fifth report focuses on the cross-cutting issue of thermal loading. It explores thermal-loading strategies (U.S. and others) and the technical issues and uncertainties related to thermal loading. It also details the Board's position on the implications of thermal loading for the U.S. radioactive waste management system. Included are updates on Board and panel activities during the reporting period. The report offers 15 recommendations to the DOE on the following subjects: ESF and repository design enhancements, repository sealing, seismic vulnerabilities (vibratory ground motion and fault displacement), the DOE approach to the engineered barrier system, and transportation and systems program status.

Sixth Report to the U.S. Congress and the U.S. Secretary of Energy December 1992

The sixth report begins with a summary of recent Board activities, congressional testimony, changes in Board makeup, and the Little Skull Mountain earthquake. Chapter 2 details panel activities and offers seven technical recommendations on the dangers of a schedule-driven program; the need for top-level systems studies; the impact of defense high-level waste; the use of high capacity, self-shielded waste package designs; and the need for prioritization among the numerous studies included in the site-characterization plans. In Chapter 3, the Board offers candid insights to the high-level waste management program in five countries, specifically those areas that might be applicable to the U.S. program, including its size and cost, the responsibility of the utilities, repository construction schedules, and alternative approaches to licensing. Appendix F provides background on the Finnish and Swiss programs.

Special Report to Congress and the Secretary of Energy March 1993

The Board's seventh report provides a nontechnical approach for those not familiar with the details of the DOE's high-level nuclear waste management program. It highlights three important broad-based issues: (1) the program is driven by unrealistic deadlines, (2) there is no integrated waste management plan, and (3) program management needs improvement. The Board makes three specific recommendations: amend the current schedule to include realistic intermediate milestones; develop a comprehensive, well-integrated plan for the overall management of all spent nuclear fuel and high-level defense waste from generation to disposal;

and implement an independent evaluation of the Office of Civilian Radioactive Waste Management's organization and management. These recommendations should be implemented without slowing the progress of site-characterization activities at Yucca Mountain.

Underground Exploration and Testing at Yucca Mountain — A Report to Congress and the Secretary of Energy October 1993

The eighth report focuses on the exploratory studies facility at Yucca Mountain, Nevada: the conceptual design, planned exploration and testing, and excavation plans and schedules. In addition to a number of detailed recommendations, the Board makes three general recommendations. First, the DOE should develop a comprehensive strategy that integrates exploration and testing priorities with the design and excavation approach for the exploratory facility. Second, underground thermal testing should be resumed as soon as possible. Third, the DOE should establish a geoengineering board with expertise in the engineering, construction, and management of large underground projects.

Letter Report to Congress and the Secretary of Energy February 1994

Issued in letter format contemporaneously with impending legislative hearings on the Department of Energy's fiscal year 1995 budget and new funding mechanism sought by the Secretary of Energy, this eight-page report (ninth in the NWTRB series) restates a recommendation made in the Board's *Special Report*, that an independent review of the Office of Civilian Radioactive Waste Management's management and organizational structure be initiated as soon as possible. The report adds two additional recommendations: ensure sufficient and reliable funding for site characterization and performance assessment, whether the program budget remains level or is increased, and build on the Secretary of Energy's new public involvement initiative by expanding current efforts to integrate the views of the various stakeholders during the decision-making process — not afterward.

Report to The U.S. Congress and The Secretary of Energy - January to December 1993 May 1994

This tenth report in the NWTRB series summarizes Board activities primarily during 1993. It reviews the nuclear waste disposal programs of Belgium, France, and the United Kingdom; elaborates on the Board's understanding of the radiation protection standards being reviewed by the National Academy of Sciences; and, using "future climates" as an example, examines the DOE's approach to "resolving difficult issues." Recommendations center on the use of a systems approach in all of OCRWM's programs, prioritization of site-suitability activities, appropriate use of total system performance assessment and expert judgment, and the dynamics of the Yucca Mountain ecosystem.

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Glossary

The following list of terms has been compiled to aid in the reading of the Board's reports. It is not meant to be a formal glossary, nor to have the completeness of a dictionary, but to help the reader understand some of the terms used regularly by the Board.

Accessible environment: The atmosphere, land surface, surface water, oceans, and portions of the earth's crust that are accessible to humans through air and water

Advection: The process whereby solutes are transported by the bulk mass of flowing fluid

Advective transport: In this report, movement of radionuclides by advection

ALARA: As low as reasonably achievable

Alluvium: Clay, silt, sand, gravel, or similar detrital material deposited by running water

Aluminosilicate: A compound in which silicon and aluminum atoms are joined by sharing linking oxygen atoms. Silicate compound in which some of the silicon atoms have been replaced by aluminum.

Analogue: A thing or part that is analogous. As used in this report, a naturally occurring phenomenon or something resulting from human activity that can provide information on or add understanding to aspects of repository performance. Analogues generally are broken into two categories: natural and anthropogenic. Natural analogues occur through natural phenomena. Anthropogenic analogues result from human activity. "Archaeological analogue" generally is used to refer to an analogue resulting from the activities of ancient cultures.

Anthropogenic: Caused by humans. (See **Analogue**.)

Anion: The dissolved negative ion of a salt

Apatite: A group of phosphate minerals with the general formula $X_5(YO_4)_3Z$, where X is usually Ca or Pb, Y is P or As and Z is F, Cl, or OH

Areal power density: The concentration of thermal energy produced by emplaced waste, which is averaged over the area of the repository and expressed in watts per square meter or in kilowatts per acre

Backfilling: The placement of materials, originally removed or new, into underground excavated areas, including waste-emplacement holes, drifts, tunnels, and shafts

Baseline: Defined and controlled element (e.g., configuration, schedule, data, values, criteria, or budget) against which changes are measured and compared

Basement rocks: Crust of the earth below sedimentary deposits (such as clays)

Biosphere: The zone of planet earth where life naturally occurs, extending from the deep crust to the lower atmosphere. Earth's living organisms.

Block: An undeformed mountain-sized section of rock that may be bounded by large faults and/or large-scale topographic features (e.g., river valleys); in this report, often refers to repository block

Borehole: An excavation, formed by drilling, that is essentially cylindrical and is used for exploratory purposes

Borehole emplacement: The DOE's baseline plan calls for the emplacement of canisters of spent fuel and high-level waste in boreholes excavated in the walls of tunnels in the proposed repository

Borings: Holes drilled into the earth

Borosilicate glass: A silicate glass containing boric acid and used to immobilize or encapsulate and stabilize commercial or defense high-level waste from reprocessing

Burnup: A measure of reactor fuel consumption expressed as the percentage of fuel atoms that have undergone fission, or the amount of energy produced per unit weight of fuel. Burnup history refers to the length of time spent fuel remains in the reactor. There is a direct correlation between burnup history and thermal output.

Burnup credit: To "receive burnup credit" related to licensing of multipurpose canisters (MPC), means that the NRC departs from its previous practice and allows the DOE to take into account in its MPC design the fact that the MPCs will be loaded with *spent* fuel, which is less reactive than fresh, unused fuel and is therefore less likely to "reach criticality" if a container should be breached during storage, transportation, or disposal.

Calcine: A solid that has been heated to a high temperature without melting, usually in the presence of oxygen

Canister: The structure surrounding a waste form (e.g., high-level waste immobilized in borosilicate glass) that facilitates handling, storage, transportation, and/or disposal. Before emplacement in a repository, the canister may be placed in a disposal container.

Cask: A container used to store and, perhaps, transport irradiated nuclear fuel or high-level nuclear waste. It provides physical and radiological protection and dissipates heat from the fuel. (See **Universal cask**.)

Characterization: The collecting of information necessary to evaluate suitability of a region or site for geologic disposal. Data from characterization also will be used during the licensing process.

Cinder cone: Conical hill formed by the accumulation of cinders and other particles ejected from a volcano

Colloid: A suspension of very fine-grained material

Colluvium: Rock detritus and soil accumulated at the foot of a slope

Container: A receptacle used to hold radioactive material (usually spent fuel)

Criticality: Being in a state sufficient to sustain a nuclear chain reaction

Curie (Ci): The unit used in measuring radioactivity. One curie equals 3.7×10^{10} spontaneous nuclear disintegrations per second; also the quantity of a material having the activity of one curie.

Dextrally offset Offset to the right

Diffusive transport In this report, migration or movement of radionuclides by diffusion, where the ionic or molecular constituents move under the influence of their kinetic activity in the direction of their concentration gradient

Dike: A tabular body of igneous rock that has been injected while molten into a fissure

Disposal: The isolation of radioactive materials from the accessible environment with no foreseeable intent of recovering them. Isolation occurs through a combination of constructed and natural barriers, rather than by human control. The Nuclear Waste Policy Act of 1982 specifies disposal in mined geologic repositories.

Dissolution kinetics: In this report, the study of the rates of chemical breakdown/disintegration/decay/separation into component parts of spent nuclear fuel pellets and other source term materials

Disturbed zone: That portion of the surrounding rock whose physical or chemical properties have changed as a result of construction or "as a result of heat generated by the emplaced radioactive waste such that the resultant change of properties may have a significant effect on the performance of the geologic repository" (10 CFR 60)

Drift: A near-horizontal, excavated passageway through the earth

EIS: Environmental impact statement

Engineered barrier system: The constructed, or engineered, components of a disposal system designed to prevent the release of radionuclides from the underground facility or into the geohydrologic setting. It includes the thermal-loading strategy, repository design, waste form, waste containers, material placed over and around such containers, and backfill materials.

Environmental issues: Issues covering the potential effects that site-characterization activities and development, operation, and closure of a repository could have on the environment, which includes air, water, soil, biologic, cultural, and socioeconomic resources at and downstream, in surface water or ground water, or downwind from the site for thousands of years. Environmental issues also include reclamation and restoration after, or mitigation of effects of, site characterization and repository construction, operation, and closure.

Evapotranspiration: The overall process of water vapor escaping into the atmosphere by evaporation from soil surfaces, by evaporation from open bodies of water, and by transpiration from the soil by plants

Exploratory facility: An underground opening and structure constructed for the purpose of site characterization

Exploratory shaft facility (ESF): An exploratory facility defined in the *Site Characterization Plan* consisting primarily of two adjacent shafts. Now called the exploratory studies facility.

Exploratory studies facility (ESF): New designation for the exploratory shaft facility

Fault: A plane in the earth along which differential slippage of the adjacent rocks has occurred

Fault displacement: Relative movement of two sides of a fault such as that which occurs during an earthquake

Fission product: A nuclide produced by the fission of a heavier element

Flux: The rate at which ground water flows across an area of porous or fractured media, which is at right angles to the direction of the flow

Fracture: Any break in a rock (i.e., a crack, joint, or fault) whether or not accompanied by displacement

Fracture flow: Flow through the fractures in a given medium

Frit: A mixture of calcified solids from which glass is made; its consistency is usually that of a sand or powder

Fuel ageing: Storage of radioactive materials, especially spent nuclear fuel, to allow the decay of radionuclides. Young spent fuel has a higher thermal output than aged spent fuel.

Fuel assembly: (See **Fuel rod**.)

Fuel rod: A rod or tube made out of zircaloy into which fuel material, usually in the form of uranium pellets, is placed for use in a reactor. Many rods or tubes, mechanically linked, form a fuel assembly or fuel bundle.

Geochemistry: Geochemistry at the Yucca Mountain site is concerned primarily with the potential migration of radionuclides to the accessible environment. Geochemists are studying the chemical and physical properties of the minerals, rocks, and waters that might affect the migration of radionuclides from a repository.

Geoengineering: Refers to the design, construction, and performance of the exploratory studies facility, surface drilling operations, and underground openings at the repository, taking into account the engineering properties of the geologic materials and their spatial variations

Geologic block: That portion of Yucca Mountain in which placement of the proposed repository site is being considered

Geologic repository: A system, requiring licensing by the NRC, that is intended to be used, or may be used, for the disposal of radioactive waste in an excavated geologic medium. A geologic repository includes (1) the geologic repository operations area and (2) the portion of the geologic setting that provides isolation of the radioactive waste and is located within the controlled area.

Ground water: Water that exists or flows in a zone of saturation between land surfaces

Ground-water table: The upper surface of the zone of water saturation in rocks, below which all connected interstices and voids are filled with water

Ground-water travel time: Ground-water travel time is defined as the time it takes ground water to travel from the edge of the disturbed zone (See **Disturbed zone**.) to the accessible environment.

Half-life: The time required for a radioactive substance to lose 50 percent of its activity by decay. Some radioactive materials decay rapidly. For example, the fission products strontium-90 and cesium-137 have half-lives of about 30 years. Others decay much more slowly: plutonium-239 has a half-life of about 25,000 years.

High-level waste: (1) Irradiated reactor fuel, (2) liquid wastes resulting from the operation of the first cycle solvent extraction system, or equivalent, and the concentrated wastes from subsequent extraction cycles, or equivalent, in a facility for reprocessing irradiated reactor fuel, and (3) solids into which such liquid wastes have been converted. (See **Reprocessing**.)

Holocene epoch: That period of geologic time extending from 11,000 years ago until the present

Host rock: The rock in which the radioactive waste will be emplaced; specifically, the geologic materials that will directly encompass and be in close proximity to the underground repository

Human factors engineering: A technical discipline that applies what is known about human psychological, physiological, and physical limitations to the design and operation of systems to enhance safety

Hydrogeology: Refers to the study of the geologic aspects of surface and subsurface waters. At the Yucca Mountain site, emphasis is placed on the study of fluid transport through the rock matrix and fractures. Ground water is considered to be a prime means by which radionuclides (atoms that are radioactive) could be transported from the repository to the accessible environment.

Hydrolysis: The chemical reaction between water and the ion of a weak acid or a weak base

Inclined dry-drilling: Drilling (at an angle) in which rock and cuttings are lifted out of a borehole by a current of air, rather than a drilling fluid

Infiltration: The flow of a fluid into a solid substance through pores or small openings; specifically, the movement of water into soil or porous rock

In-place disposal: Disposal of a waste material without moving it

Interim storage or storage: Temporary storage of spent fuel or high-level waste with the intention and expectation that the waste will be removed for subsequent treatment, transportation, and/or isolation

Isotope: A class of atomic species, of a given element, having differing atomic weights but identical atomic numbers and slightly differing chemical and physical properties

Jointed rock: Rock containing fractures or partings without displacement

Kinetics: Study of the rates of chemical reactions

Lava flow: A lateral, surficial outpouring of molten lava from a vent or a fissure: the solidified body of rock that is so formed

Leach: To partially or completely dissolve and remove chemical components of a solid usually by an aqueous solution. The rate at which this occurs is the leach rate.

Long-lived waste package: Generally used in this report to refer to a waste package that has the capability to contain wastes for at least many thousands of years

Low-level (radioactive) waste: Radioactive material that is neither high-level radioactive waste, spent nuclear fuel, transuranic waste, nor byproduct material as defined in Section 11a(2) of the Atomic Energy Act of 1954. An example is contaminated medical waste.

Magma: The molten rock material from which igneous rocks are formed

Matrix: The solid framework of a porous system

Metric ton: 1,000 kilograms; about 2,205 pounds

MGDS: Mined geologic disposal system (a repository)

Molecular diffusion: The process whereby solutes are transported at the microscopic level due to variations in the solute concentrations within the fluid phases

Monitored retrievable storage (MRS) facility: A facility to collect spent fuel in a central location, where it can be stored until the fuel can be accepted at a repository

MTHM: Metric tons of heavy metal (nuclear fuel)

MTU: Metric tons of uranium

Multipurpose container: A concept for a cask that can be used for more than one purpose, for example, to store and transport, and perhaps dispose of spent fuel

Natural analogue: (See **Analogue**.)

Nevada Test Site (NTS): A geographic area located in southern Nevada that is owned and operated by the U.S. Department of Energy and devoted primarily to the underground testing of nuclear devices

Nonvolatile: A material that changes from a solid or liquid state to a gaseous state insignificantly at a temperature of interest

Nonwelded tuff: A tuff that has not been consolidated and welded together by temperature, pressure, or a cementing mineral

Noble metals: Silver, mercury, gold, and the platinum metals (ruthenium, rhodium, palladium, osmium, iridium, and platinum)

Partitioning/transmutation A chemical solvent extraction or a dry process (partitioning) using fast neutron reactors or accelerators to obtain radionuclides with short half-lives in the waste packages (transmutation)

Perched water: Unconfined ground water separated from an underlying body of ground water by an unsaturated zone

Performance assessment: Any analysis that predicts the behavior of a system or a component of a system under a given set of constant or transient conditions. In this case, the system includes the repository and the geologic, hydrogeologic, and biologic environment.

Performance confirmation: The tests, experiments, and analyses that are conducted to evaluate the accuracy and adequacy of the information used to determine with reasonable assurance that the performance objectives for the period after permanent closure will be met

Plan view: An overhead or "aerial" view of a project, as opposed to a lateral or cross-sectional view

Plutonium: A radioactive element with an atomic number of 94. Its most important isotope is fissionable plutonium-239, produced by neutron irradiation of uranium-238.

Portal: Opening to the underground; the rock face at which a tunnel is started

Postclosure: The period of time after the closure of the repository

Preclosure: That time prior to the backfilling of the repository

Pressurized water reactor: A reactor system that uses pressurized water in the primary cooling system. Steam formed in a secondary cooling system is used to turn turbines to generate electricity.

Public health issue: An issue involving potential direct or indirect effects on, or risk to, human health during repository development, operation, and after closure. The possible public health and environmental consequences of the handling and transportation of high-level radioactive waste from points of origin to the repository are also of concern.

Quality assurance: The management process used to control and assure the quality of work performed

Quaternary period: The second part of the Cenozoic Era (after the Tertiary) beginning about 2 million years ago and extending to the present

Radioactivity: The spontaneous emission of radiation from the nucleus of an atom. Radioisotopes of elements lose particles and energy through this process of radioactive decay. Radioactivity is measured in terms of the number of nuclear disintegrations occurring in a unit of time. The common unit of radioactivity is the curie (Ci).

Radiolysis effects: Radiation-induced dissociation of molecules; radiation-induced dissolution of molecules

Radiometric age dating: The calculation of the age of a material by a method that is based on the decay of radionuclides that occur in the material

Radionuclide: A radioisotope that decays at a characteristic rate by the emission of particles or ionizing radiation(s)

Radionuclide migration: The movement of radionuclides, generally in liquids or gas forms, through a rock formation

Ramp: An inclined tunnel. Here, ramps would allow exploration and research of rock features and other phenomena critical to characterizing an underground repository site, while at the same time allowing for future use as an entrance to the underground repository should the site prove qualified.

Recharge: The process of addition of water to the saturated zone; also the water added

Repository: A site and associated facilities designed for the permanent isolation of high-level radioactive waste and spent nuclear fuel. It includes both surface and subsurface areas, where high-level radioactive waste and spent nuclear fuel-handling activities are conducted.

Repository horizon: A particular geologic sequence or layer where radioactive waste is intended for disposal. The Yucca Mountain repository horizon is 900 to 1,200 feet beneath the surface of the mountain.

Reprocessing: The process whereby fission products are removed from spent fuel, and fissionable parts are recovered for repeated use

Retrievability: The capability to remove waste packages from the repository

Risk: Possibility of suffering harm or loss due to some event. The magnitude of the risk depends on both the probability of occurrence of an event and the consequences should the event occur.

Risk and performance analysis: Here it refers to the assessment of the long-term performance of a waste repository. Such analysis provides a means for incorporating all scientific and technical aspects into an integrated description of the entire repository system. Iterative performance analysis also can be used to help determine which site-characterization studies need to be emphasized or moderated to provide information more focused on timely assessment of site suitability.

Saturated rock: Rock in which all of the connected interstices or voids are filled with water

Saturated environment: Part of the earth's crust in which all voids are filled with water under pressure greater than atmospheric

Seismicity: (i.e., seismic activity) The worldwide, regional, or local distribution of earthquakes in space and time; a general term for the number of earthquakes in a unit of time

Semivolatile: A material that changes from a solid or liquid state to a gaseous state slowly at a temperature of interest

Shaft: A near-vertical opening excavated in the earth's surface

Shear stress: That component of stress that acts tangentially to a plane through any given point in a body

Shotcrete: Fine aggregate concrete sprayed under high pressure onto the rock face between rock bolts, after wire netting has been attached between the rock bolt plates and the rock face. The resulting reinforcement produced by the wire netting and concrete, anchored by the rock bolts, forms a semi-smooth appearance and significantly reduces the formation and fall of stress slabs.

Silicate: A metal salt containing silicon and oxygen in the anion

Silica: Natural silicon dioxide

Site characterization: (See **characterization**.)

Slurry: A thin mixture of liquid and fine solids

Sorption: Retardation (of transport) through the binding of radionuclides by the surfaces of geologic materials along the flow path

Sorption characteristics: Characteristics describing the ability of rocks and minerals to bind, reversibly or irreversibly, radionuclides or other chemical species on their surfaces

Source term: The compositions and the kinds and amounts of radionuclides that make up the source of a potential release of radioactivity from the engineered barrier system to the host rock

Spent nuclear fuel: An irradiated fuel element not intended for further use in a nuclear reactor

Stochastic calculation: A numerical calculation based on probabilistic laws

Storage: (See **Interim Storage**)

Stratigraphic evidence: Evidence obtained through the analysis of the form, distribution, composition, and properties of layered rock

Stress slabs: Slabs of rock (of varying thickness) that "peel" off the exposed rock surfaces of an excavation. The slabs are caused by the forces being exerted on the rock surfaces by internal rock pressure and gravity after excavation provides a void into which the pressure can be released.

Strike-slip displacement: Fault movement that is parallel to the strike of a fault; horizontal displacement

Structural geology: Refers to the study of the deformational features of rocks induced by processes such as folding, faulting, and igneous activity. As used in this report, it also includes a study of the processes themselves.

Subsurface water: All water beneath the land surface and surface water

Systems safety: A technical discipline that provides a life-cycle application of safety engineering and management techniques to the design of system hardware, software, and operation

Talus: Slope formed by an accumulation of rock debris; rock debris at the base of a cliff

Tectonic features and processes: Those features (e.g., faults, folds) and processes (e.g., earthquakes, volcanism) that are related to the large-scale movement and deformation of the earth's crust

Thermal energy: Heat; in this case produced by the decay and transformation of radioactive waste over time

Thermal load: The amount of heat distributed and affecting the near field and overall repository material, including geophysical and engineered barriers, that is induced by waste emplacement (usually measured in kilowatts per acre)

Thermal-loading strategies: The determination of waste emplacement to cause specific effects on the repository by the heat generated by the waste. These strategies are based on such criteria as whether it is desirable to initially place the repository at a temperature below or above the boiling point of water, or what effect various temperature ranges will have on long-lived waste packages. Thermal-loading is usually measured in kilowatts per acre.

Thermal zone: That region of the repository where the temperature has been increased by the presence of high-level waste

Thermo-mechanical effects: Stresses or strains induced by temperature changes

Transportation and systems: As used here, it refers to a system for moving spent nuclear fuel from approximately 110 commercial nuclear reactors located at 70 sites throughout the nation and transporting the high-level radioactive waste from Department of Energy defense facilities to a disposal site. It is not merely the activities associated with packaging spent fuel in a shipping cask and shipping it by highway, rail, or water. Transportation and systems also includes all processes involved before and after the trip — removing spent fuel from its storage facility, loading it into the cask, loading and unloading it at the various handling sites, storing it, and finally emplacing it in a repository.

Transuranic: Containing elements or isotopes having atomic numbers higher than uranium (92).

Transuranic waste (TRU): Waste containing more than 100 nanocuries of alpha-emitting transuranic isotopes, per gram of waste with half-lives greater than 20 years — except for (1) high-level radioactive wastes, (2) wastes that the U.S. Department of Energy with the concurrence of the Environmental Protection Agency Administrator has determined do not need the degree of isolation required by 40 CFR 191, or (3) wastes that the U.S. Nuclear Regulatory Commission has approved for disposal on a case-by-case basis in accordance with 10 CFR 61. Research on disposal of TRU is under way at the Waste Isolation Pilot Project in Carlsbad, New Mexico, where waste consists primarily of clothing, equipment, machine parts, and some liquid waste contaminated during reprocessing at U.S. defense facilities. TRU wastes may take a long time to decay (i.e., have a long half-life).

Tuff: A rock composed of compacted volcanic ash. It is usually porous and often relatively soft.

Tunnel: An underground passage that is open to the surface at both ends

Unsaturated rock: A rock in which some or all of the connected interstices or voids are filled with air

Unsaturated zone: Rock/geologic formation that is located above the regional ground-water table

Uranium: A naturally radioactive element with the atomic number 92 and an atomic weight of approximately 238. The two principal naturally occurring isotopes are the fissionable U-235 (0.7% of natural uranium) and the fertile U-238 (99.3% of natural uranium). Uranium may be measured in metric tons of uranium (MTU).

Velocity dispersion: The spreading of a plume of radionuclides due to the nonhomogeneous nature of the flow field

Volatile: A material that changes from solid or liquid state to a gaseous state quickly at a temperature of interest

Volatilization: Conversion from a solid or liquid state to a gaseous state

Volcanism: The process by which molten rock and its associated gases rise from within the earth and are extruded on the earth's surface and into the atmosphere

Waste package: The waste form and any containers, shielding, packing, or other sorbent materials immediately surrounding an individual waste container

Welded tuff: A tuff that has been consolidated and welded together by heat, pressure, and possibly the introduction of cementing minerals

Zeolites (zeolite minerals): A large group of white, faintly colored, or colorless silicate minerals characterized by their easy and reversible loss of water of hydration and their high adsorption capacity for dissolved metal ions in water

$^{14}CO_2$: Carbon dioxide containing the radioactive isotope of carbon, ^{14}C