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.

Mr. John W. Arendt was appointed to the Board in June 1995. He is the senior consultant and founder of John W. Arendt Associates, Inc., a registered professional engineer, and a certified nuclear materials manager.

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

Dr. Jared L. Cohon was appointed to the Board in June 1995. He is dean of the School of Forestry and Environmental Studies and professor of environmental systems analysis and mechanical engineering at Yale University.

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.

Dr. Jeffrey J. Wong was appointed to the Board in June 1995. He is the science advisor to the director of the Department of Toxic Substances Control, California Environmental Protection Agency.

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

***Term expired April 19, 1994. Served as a consultant until a replacement member was appointed on June 19, 1995.*

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

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:	Mr. John W. Arendt		
	Dr. John J. McKetta, Jr.		
	Dr. Ellis D. Verink, Jr.*		

4. Panel on Transportation & Systems

Chair:	Mr. John W. Arendt	Staff:	Dr. Sherwood C. Chu
Members:	Dr. Garry D. Brewer		
	Dr. Jared L. Cohon		
	Dr. John J. McKetta, Jr.		
	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.		
	Dr. Jeffrey J. Wong		

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. Jared L. Cohon		
	Dr. Donald Langmuir		
	Dr. Ellis D. Verink, Jr.*		
	Dr. Jeffrey J. Wong		

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 1995 – 1996*

January 9, 1995
Board Business Meeting *Beatty, NV*
Minutes available

January 10-11, 1995
Full Board Meeting *Beatty, NV*
Topics: Socioeconomic impacts, environmental issues, ESF update, DOE waste isolation strategy and program priorities

April 19-20, 1995
Full Board Meeting *Las Vegas, NV*
Topics: The emerging waste isolation strategy, thermal management strategy, and EBS design and research

April 21, 1995
Board Business Meeting *Las Vegas, NV*
Minutes available

May 9-10, 1995
Canada Trip *Winnipeg, Canada*
Topic: Visit to AECL's Whiteshell Laboratories and Underground Research Laboratory

May 23-24, 1995
Joint Meeting of the Panels on Risk and Performance Analysis and the Environment and Public Health *Las Vegas, NV*
Topics: Risk perceptions and socioeconomic impacts

June 6, 1995
Panel on the Engineered Barrier System
Idaho Falls, ID
Topic: INEL activities involving disposal of defense high-level waste and spent nuclear fuel

June 7, 1995
Tour: Panel on the Engineered Barrier System
Idaho Falls, ID
Topic: Tour of INEL

June 14, 1995
Panel on Transportation & Systems *Arlington, VA*
Topics: System safety, human factors and transportation issues

June 26-27, 1995
Panel on Hydrogeology & Geochemistry
Burlingame, CA
Topic: Fracture flow and transport in arid regions

July 11-12, 1995
Full Board Meeting *Salt Lake City, UT*
Topics: Exploratory studies facility update, repository operation and conceptual design, repository licensing

July 13, 1995
Board Business Meeting *Salt Lake City, UT*
Minutes available

October 16, 1995
Board Business Meeting *Arlington, VA*
Minutes available

October 17-18, 1995
Full Board Meeting *Arlington, VA*
Topics: Exploratory studies facility update, strategic concerns, legislative initiatives, total system performance assessment

January 9, 1996
Board Business Meeting *Las Vegas, NV*
Minutes available

January 10-11, 1996
Full Board Meeting *Las Vegas, NV*
Topics: Defense waste plan for Yucca Mountain, EPA / NRC response to NAS standards, technical basis report on surface processes, update on ESF and surface-based testing, expert judgment

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

January 12, 1996
Tour and Full Board Meeting *Las Vegas, NV*
Topic: Tour of Yucca Mountain / TBM operations

April 29, 1996
Board Business Meeting *Austin, TX*
Minutes will be available following the meeting

April 30 - May 1, 1996
Full Board Meeting *Austin, TX*
Tentative topics: Program integration: waste isolation strategy, total system performance assessment, repository design and operation, program and budget priorities
Transcripts will be available in June 1996

July 8, 1996
Board Business Meeting *Denver, CO*
Minutes will be available following the meeting

July 9-10, 1996
Full Board Meeting *Denver, CO*
Tentative topics: Update on environmental impact statement scoping, basic processes and model, climate change implications basic process and model
Transcripts will be available in August 1996

October 9-10, 1996
Full Board Meeting *Arlington, VA*
Tentative topics: EPA standards, core science requirements and priorities, updates on exploration and testing, tunnel boring machine, exploratory studies facility
Transcripts will be available in November 1996

Appendix D
NWTRB Statements Before Congress

As part of its interactions with the U.S. Congress, the NWTRB was asked to testify three times during 1995, on March 2, March 16, and June 30. Included here are copies of the testimony presented by Chairman John E. Cantlon. Also included are the answers to follow-up questions.

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

(Before the Committee on Energy and Natural Resources, United States Senate, March 2, 1995)

Chairman Murkowski and members of the Committee. Thank you for this opportunity to submit a statement for the record. I am John Cantlon, Chairman of the Nuclear Waste Technical Review Board.

As you are aware, in 1987, through the efforts of this Committee, the Congress established the Nuclear Waste Technical Review Board. The Board is charged with reporting to the Congress and the Secretary of Energy on the technical and scientific validity of the Federal government's program for the management of civilian spent nuclear fuel and some defense-related high-level radioactive wastes. Our scientific and technical conclusions are reflected in semi-annual and special reports to the Congress and the Secretary and letters to the Department. This testimony will summarize our most recent communications, but I request that a list of the current Board members and the text of our most recent communications appear in the record along with my testimony.

As noted, the Board's charter is to review the scientific and technical validity of the Federal government's civilian radioactive waste management activities. As it has reviewed the DOE's approach to site characterization and repository development, the Board has adhered to several basic scientific and technical principles that I would like to share with the Committee.

Our most recent efforts, Mr. Chairman, encompass those activities related to the DOE's new program approach to determining the suitability of the Yucca Mountain site for locating a permanent underground high-level waste repository. Our review also includes activities related to

- surface-based studies and underground site characterization and testing,
- interim storage and transportation, and
- waste package and repository design.

In many cases, however, we have found that before we could undertake a meaningful evaluation of the technical and scientific aspects of the program, we needed to acquire a general understanding of the related nontechnical factors, such as management, that were affecting the program.

As I will discuss later in my statement, among the critical institutional factors of concern are schedules and program funding as well as the question of when the DOE will be in the position to begin accepting spent nuclear fuel from nuclear utilities, and in what form it will be accepted.

Although outside the principal purview of the Board, these nontechnical factors have important implications for the scientific and technical integrity of the Federal program. The Board believes the Committee should be aware of their potential implications for the technical program, so I will discuss them in my closing remarks.

As the Committee is aware, beginning with the 1982 Nuclear Waste Policy Act, the Federal government's civilian radioactive waste program has been driven by overly optimistic schedules. Following enactment of the 1987 Amendments, the DOE's Office of Civilian Radioactive Waste Management (OCRWM) proposed a comprehensive set of site-characterization activities with an expectation of large budget increases. However, the DOE did not ask for, nor did the Congress appropriate, the necessary funds to accomplish the scope of tasks that the DOE had set out for itself, in part, out of general concern for the Federal deficit.

With each budget cycle, the backlog of inadequately addressed, but important, technical and scientific activities steadily increased. Furthermore, a large share of the appropriations that the program did receive went to fund overhead and infrastructure rather than direct project costs.

The Board is encouraged by the changes that the DOE has initiated over the last year and hopes that the program's managers will be successful in eliminating the duplication of effort among contractors that seems to have occurred over the years. However, we would observe that the number of contractor organizations remains quite large and staffing continues to grow. For example, in the first four months of this fiscal year, there was an increase 330 full-time equivalent contractor personnel at OCRWM — up to 2,946 FTE's — or a 12.6 percent increase.

On several occasions, our Board has criticized the DOE's own allocation of resources as fundamentally inconsistent with their optimistic work schedule. Among the Board's recommendations for completing DOE-scheduled activities were (a) establish priorities and intermediate goals based on a thorough understanding of the overall waste management system; (b) allocate more money to scientific studies and less to overhead and infrastructure costs; and (c) set realistic target dates for achieving important intermediate goals, such as beginning underground excavation and testing and determining site suitability.

The Board wishes to commend the current Department and OCRWM leadership for its recognition of these problems and its willingness to tackle a job made more difficult by unrealistic schedule deadlines and years of overly optimistic budget assumptions that did not materialize as actual budget requests. Since Dr. Dreyfus took over as director of the OCRWM last fall, significant progress has been made in dealing with this legacy. The December 1994 *Program Plan* is an earnest *first* attempt by the DOE to refocus its resources on what are perceived as those activities required for determining site suitability.

I repeat, for the *first* time the DOE has the elements of a mission statement for its civilian radioactive waste management program that are reflected in the current *Program Plan*. This plan is geared to three intermediate milestones. First, the DOE anticipates a decision in 1998 about the technical and scientific suitability of the Yucca Mountain site. Second, if the site is found suitable, in 2000, after evaluating environmental, transportation, and socioeconomic issues through the development of an environmental impact statement (EIS) for the proposed repository, the Secretary of Energy would recommend the site to the President for development as a repository. And, third, if approved, the DOE would then submit in 2001 an application to the Nuclear Regulatory Commission for a license to begin repository construction.

Currently, the Board is reviewing the December 1994 *Program Plan*. The results of our initial review will be addressed in the Board's 11th report which will be provided to you in about three weeks.

I would like to take the opportunity at this point in my testimony to provide the Committee with the Board's perspective on the improvements and progress that have been made in this program since Dr. Dreyfus assumed responsibility for it, and some concerns that still remain.

As we are all aware, the determination of site suitability is the first major milestone in repository development under the new approach. If the DOE finds the Yucca Mountain site suitable, the DOE's efforts to successfully *demonstrate* that it can construct a safe radioactive waste repository become critical. If the DOE does not present its case clearly and convincingly to the Nuclear Regulatory Commission (NRC), the DOE may be faced with costly and time-consuming delays during the licensing process.

From what we now know, it is our preliminary view that there are risks as well as opportunities associated with this new approach. Among the risks are the increased technical and scientific uncertainties that will be created because less data and analysis than previously planned will be provided *up front* for determining site suitability and for applying to the NRC for a license to construct a repository. Among the opportunities is the chance to refocus and streamline the program and to establish clear, near-term goals against which real progress can be demonstrated, although achievement of the objectives of the new approach will not be seen for many years. The Board is very concerned about the limited time available to collect and analyze the necessary data by the 1998, 2000 and 2001 scheduled dates.

As chairman of the Nuclear Waste Technical Review Board, I would like to highlight some of the recommendations that the Board will be making in its upcoming report. Some of them were made in past reports in some form but remain pertinent.

First, there is a need to look at the management of high-level radioactive waste as a system and set priorities accordingly.

Before this can be accomplished there is need for a clear and coherently articulated waste isolation strategy that takes into account the salient characteristics of the Yucca Mountain site and the ability and desirability of specific repository engineered barriers to enhance waste isolation. This is particularly important given the need to evaluate the DOE's tentative repository thermal management plans and the additional programmatic emphasis that is being placed on engineered barriers, extended retrievability, and postemplacement monitoring.

The waste isolation strategy also needs to be robust enough to accommodate possible changes in the basic criteria that will be used to assess the performance of the proposed repository and the standards and regulations that will be used to license the repository, which are currently undergoing review.

There also is need for a management and organizational commitment by the DOE to develop more systematic and effective ways of using iterative total system performance assessments to guide site characterization and to review priorities at Yucca Mountain. The use of performance assessments — based on a coherent waste isolation strategy — becomes even more critical now, if the program increases its reliance on postemplacement confirmatory testing — as opposed to providing comprehensive data and analysis to support a license to construct the proposed repository. The Board suggests that the Department examine closely the manner in which performance assessment was and is being used at the WIPP facility in New Mexico.

In the past, 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. A clear understanding of the waste management system and all its linkages is essential to developing a coherent and integrated program.

Second, the DOE should examine carefully the experience of others during the site- assessment process; particularly the influence of nonscientific and nontechnical factors.

In 1994, the Board decided to examine the experiences of others in assessing potential sites for critical or highly controversial facilities, such as low-level radioactive waste repositories, hazardous waste facilities, nuclear power plants, and other large engineering projects. Much can be learned from this experience.

Several commonalities emerged that are applicable to the Yucca Mountain project: (1) the importance of having clear strategies for site assessment, site-suitability determinations, and licensing; (2) the significance of uncertainty and the use of expert judgment; (3) the inevitable occurrence of surprises as site investigations proceed; (4) problems caused by technical and institutional overconfidence; and (5) the importance of independent technical review, quality control, and clear regulations.

But, equally important, political and process-oriented issues were found to be critical — *often overriding technical concerns.*

Third, the DOE needs to place greater emphasis on accelerating the underground exploration and testing program.

Getting underground to look at the site's complex geology is critical in determining whether the site is suitable for repository development. This recommendation, which was first made by the Board in 1991, remains pertinent. Therefore, in its December 6, 1994, letter to Dr. Dreyfus (which is attached), the Board indicated a need for substantially more underground excavation than currently is planned.

Fourth, unrealistic schedule deadlines that cannot be achieved also serve to increase frustration and erode confidence in the program. The DOE should establish realistic schedules for achieving its important intermediate milestones, and these should be reflected in current statutory deadlines.

We believe that schedules are vital if program momentum is to be maintained and progress measured. We also believe that important technical and scientific activities that were previously considered critical, not suddenly be truncated or eliminated under the combined pressure of arbitrary schedule deadlines and budgetary constraints. Without sufficient surface-based and underground data and accompanying analysis, the DOE will be forced to rely heavily on expert judgment and bounding assumptions, which may be less effective in winning public confidence. The existing schedule may not provide sufficient time to complete the necessary site exploration; for example, excavation across the block to explore known, and possibly unknown, faults at the repository level.

The Board thus continues to be concerned that, under the current schedule, important long-term, and perhaps more expensive, activities (e.g. an east-west excavation across the block at the repository level, initiation of in-situ thermal testing, and excavation below the repository in the Calico Hills formation) may be delayed or replaced by other, less efficacious, shorter duration activities.

An equally important concern of the Board is that the current schedules allow little time to accommodate the kinds of surprises that are often encountered worldwide in underground projects.

The Board recognizes the demands being placed on the program by overriding concern for meeting the 1998 and 2001 deadlines. Nevertheless, the Board is very concerned that important program decisions are being driven by unrealistic deadlines at some risk to the program.

Fifth, the DOE should allocate more of its resources to research and development of engineered barriers, and 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 that the DOE plans to increase funding for waste package development; we hope this happens; it is a move the Board strongly endorses.

Before closing, I would like to comment on the Board's perspective regarding legislation currently pending before the Committee. The Board views its role as one of providing technical and scientific information to policy makers, such as this Committee, as these bodies conduct their oversight of the Federal government's civilian radioactive waste management program and make their important policy recommendations as amendments to the Nuclear Waste Policy Act.

The Board itself has not taken a position on the need for legislative action. Of course, if the Committee so desires, the Board can, and is prepared to, evaluate the technical and scientific implications of legislative proposals under consideration by the Congress.

In this regard, in its October 1993 Special Report, the Board observed that the *urgent task of providing safe storage of spent fuel does not appear to present any substantial technical problems.*

Currently, there are approximately 25,000 metric tons of spent fuel stored at reactor sites around the country, and this amount increases at the rate of about 2,000 metric tons per year. By 2030, approximately 87,000 metric tons of spent fuel will have accumulated. Therefore, even if a repository is constructed according to the DOE's schedule, substantial amounts of spent fuel will remain in storage at reactor sites for decades. To date,

the implications of this extended interim storage have not been addressed by either the DOE or the utilities. In the next few months the Board will complete its technical review of the situation. The result of this technical review of the interim storage of spent fuel will be communicated to the committee and the Secretary when it is completed.

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 needs to be guaranteed during the full retrievability period both to complete the additional testing requirements and to cover the costs of retrieving the waste for any purpose, should that need arise. Given the DOE's new program approach, one important area that the Committee may wish to explore is the adequacy of funding over the very long term for the testing, monitoring, and possible spent fuel retrieval that is envisioned by the DOE for approximately 100 years once the waste has been emplaced in a repository.

In closing, I would like to observe that the Board believes that there is currently no convincing evidence that the Yucca Mountain site is not technically suitable for a well- designed repository. The Board also believes that the current Departmental leadership should be commended for recognizing the fundamental inconsistency among the schedule, the amount of work planned, and the funds made available to the program.

Immediate opportunities do exist to improve many aspects of the DOE's program. Among the opportunities listed in our December 6 letter are increased emphasis on site suitability, the clear articulation of a waste isolation strategy, the setting of priorities, and the allocation of funds to focus on the development of a long-lived waste package. This (mid-course correction) also provides an opportunity to improve the interface between the DOE and the NRC so as to capture the full potential of the DOE's programmatic changes.

As the specifics of the Department's new program approach evolve the Board will continue to assess their technical and scientific implications. The Board also will be taking a close look at the timetables for important site-characterization activities as they are continually being updated, including timetables for underground excavation and testing and the determination of site suitability.

The results of these ongoing reviews will be communicated to the Congress and the Secretary as they are completed. However, whatever the outcome of our scientific and technical evaluation, the Board wishes to emphasize how critical it is for the DOE to set priorities within the waste management system that are based on a coherent waste isolation strategy — not on how much testing can be accomplished within the constraints of the current schedule and available appropriations.

Thank you, Mr. Chairman, for this opportunity to convey the Board's appreciation to you and your Committee for its continuing leadership on this vital national program.

Attachment: December 6, 1994 letter to Dr. Daniel A. Dreyfus, Director, Office of Civilian Radioactive Waste Management, from Dr. John E. Cantlon, Chairman, Nuclear Waste Technical Review Board. (Editors note: This attachment can be found in the Board's *Report to The U.S. Congress and The Secretary of Energy, 1994 Findings and Recommendations* (March 1995), Appendix G.)

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

Subcommittee on Energy and Water Development, Committee on Appropriations, U.S. House of Representatives, March 16, 1995

Chairman Myers and members of the Subcommittee: Thank you for this opportunity to appear before you this morning. I am John Cantlon, Chairman of the Nuclear Waste Technical Review Board and former vice president for research and dean of the graduate school at Michigan State University. With me this morning is another member of the Board, Dr. Garry D. Brewer, who is dean of the School of Natural Resources and Environment at the University of Michigan. We are pleased to be here today to present the Board's appropriation request for fiscal year 1996.

I will begin, this morning, with a summary of our appropriation request followed by a brief review of the Board's charter and recent accomplishments as well as future activities. I also will highlight the Board's most recent recommendations concerning the Department of Energy's (DOE) civilian radioactive waste manage-

ment program. These were included in the Board's December 6, 1994 letter to the program and are in our upcoming 11th report to the Secretary of Energy and Congress. Mr. Chairman, I ask that my full statement and the attachments referred to be included in the record of these hearings.

The Board's appropriation request for fiscal year 1996 is $2,970,000 in new budget authority. When combined with an anticipated unobligated fiscal year 1995 balance of $523,000, the Board's aggregate funding requirement for fiscal year 1996 is $3,493,000. These funds will be utilized by the Board as it conducts its Congressionally mandated review of the DOE's civilian radioactive waste management program.

Overview

Finding the means to dispose of our nation's high-level radioactive waste is an issue of long-standing importance dating to the 1957 study by the National Academy of Sciences (NAS). There is a continuing worldwide scientific consensus that permanent isolation in mined geologic formations is the safest, long-term option for high-level radioactive waste disposal where risks to public health and safety extend for thousand of years. Mined geologic disposal is the primary approach being pursued in the United States and in other countries.

The DOE's Office of Civilian Radioactive Waste Management (OCRWM) is responsible for transporting and disposing of our nation's high-level nuclear waste — spent fuel from civilian nuclear plants, along with about 8,000 metric tons of high-level defense waste from reprocessing. As directed in the Nuclear Waste Policy Act Amendments of 1987 (NWPAA), the DOE is characterizing a site at Yucca Mountain, Nevada, to determine its potential suitability for construction of a permanent repository for nuclear waste.

The Congress created the Nuclear Waste Technical Review Board (Board) as an independent executive agency and assigned it the responsibility of providing an unbiased source of expert advice on the technical and scientific aspects of the DOE's work in this area. The Board's mission is simply stated in the NWPAA as follows:

The Board shall evaluate the technical and scientific validity of activities undertaken by the Secretary after the date of the enactment of the Nuclear Waste Policy Amendments Act of 1987, including (1) site characterization activities; and (2) activities relating to the packaging or transportation of high-level radioactive waste or spent nuclear fuel.

We believe the Board's mission is of significant national importance. The program for which the Board must provide peer review is politically highly controversial, is characterized by complex scientific uncertainties, and extends over several decades. The Board's oversight role is intended to provide essential scientific and technical credibility to a Federal program that has been plagued over the years by a lack of public trust and confidence.

Board Membership

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 nominated by the National Academy of Sciences. The first Board members were appointed on January 18, 1989. The terms of four members expired this past April, leaving only six members. The White House is currently acting on NAS nominations to fill the five vacant member positions. The six current members are listed below.

- Dr. John E. Cantlon replaced Dr. Don U. 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, East Lansing. 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, Ann Arbor.

- Dr. Edward J. Cording is professor of civil engineering at the University of Illinois at Urbana - Champaign, and a specialist in underground engineering.

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

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

The five Board vacancies are in the areas of hydrology, systems analysis, transportation, engineering / materials science, and radiobiology / health physics. The following three members whose terms expired last April have been retained as consultants until appointments to the vacant positions have been made by the White House.

- Dr. Patrick A. Domenico is the David B. Harris Professor of Geology at Texas A&M University, College Station, and a specialist in hydrology.

- Dr. Dennis L. Price is a professor in the Department of Industrial and Systems Engineering, and is director of the Human Factors Engineering Center at the Virginia Polytechnic Institute and State University in Blacksburg.

- 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, and a specialist in corrosion.

The Board is the *only* agency charged by Congress with providing an ongoing independent and unbiased review of all technical and scientific aspects of the DOE's efforts to dispose of spent fuel and high-level radioactive waste. During the six years since its formation, the Board has developed the knowledge and expertise envisioned by the Congress. The function being served by the Board cannot be accomplished by any other entity in existence, either within the Federal government or outside.

Board Activities

During the past five years, the Board and its panels have sponsored numerous meetings and technical exchanges with the DOE and its contractors, the Environmental Protection Agency (EPA), the Nuclear Regulatory Commission (NRC), the state of Nevada, Native Americans, 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, engineering, and ecological features in the area around the proposed repository site at Yucca Mountain.

Our most recent efforts, Mr. Chairman, encompass those activities related to the DOE's new program approach to civilian radioactive waste management that prioritizes determining the suitability of Yucca Mountain as the site for a underground high-level waste repository. Our review also includes activities related to

- surface-based studies and underground exploration and testing at Yucca Mountain,

- interim storage and transportation, and

- waste package and repository design.

In several instances, however, we have found that along with undertaking a meaningful evaluation of the technical and scientific aspects of the program, we needed to acquire a general understanding of the related nontechnical factors, such as management, that were affecting the program.

Among the critical institutional factors of concern are schedules and program funding as well as the question of when the DOE will be in the position to begin accepting spent nuclear fuel from nuclear utilities. Although outside the principal purview of the Board, these nontechnical factors have important implications for the scientific and technical integrity of the Federal program. The Board therefore has made the DOE aware of their potential implications for the technical program.

Ongoing Board Concerns

As the Subcommittee is aware, beginning with the 1982 Nuclear Waste Policy Act (NWPA) the Federal government's civilian radioactive waste program has been driven by overly optimistic schedules. Following enactment of the 1987 Amendments, the DOE's Office of Civilian Radioactive Waste Management proposed a comprehensive set of site-characterization activities with an expectation of subsequent large budget increases. However, partly out of general concern for the Federal deficit, the DOE did not ask for, nor did the Congress appropriate, the necessary funds to accomplish the scope of tasks that the OCRWM had set out for itself. Furthermore, a substantial share of the appropriations that the program did receive went to fund overhead and infrastructure rather than direct project costs.

On several occasions, our Board has criticized the DOE's allocation of resources as fundamentally inconsistent with the optimistic work schedule the DOE set for itself. Among the Board's recommendations for completing DOE-scheduled activities were

(a) establish priorities and intermediate goals based on a thorough understanding of the overall waste management system; (b) allocate more money to scientific studies and less to overhead and infrastructure costs; and (c) set realistic target dates for achieving important intermediate goals, such as beginning underground excavation and testing and determining site suitability.

New Program Approach

The Board is encouraged by the changes that the DOE has initiated over the last year and hopes that the program's managers will be successful in eliminating any duplication of effort among contractors that may have occurred over the years. The Board also wishes to commend the current DOE and OCRWM leadership for their recognition of the need for these changes and willingness to tackle a job made more difficult by unrealistic schedule deadlines and years of overly optimistic budget assumptions that did not materialize as actual budget requests.

Since Dr. Dreyfus took over as director of the OCRWM a year ago, significant progress has been made in dealing with this legacy. The December 1994 *Civilian Radioactive Waste Management Program Plan* is an attempt by the DOE to refocus its resources on important activities such as those required for determining site suitability. However, we would observe that the number of contractor organizations remains quite large and staffing continues to grow. For example, in the first four months of this fiscal year, there was an increase of 330 full-time equivalent contractor personnel at the OCRWM — up to 2,946 FTE's — or a 12.6 percent increase. However, an increasing number of contractor organizations now report through the M & O, which should begin to improve the overall management of the program.

For the *first* time, the DOE has the elements of a mission statement for its civilian radioactive waste management program that are reflected in the current *Program Plan*. This plan is geared to three intermediate milestones. First, the DOE anticipates making a decision in 1998 about the technical and scientific suitability of the Yucca Mountain site. Second, if the site is found technically suitable the Secretary of Energy, in the year 2000, would recommend the site to the President for development as a repository, after evaluating environmental, transportation, and socioeconomic issues through the development and review of an environmental impact statement (EIS) for the proposed repository. And, third, if the site is approved, the DOE would then submit in 2001 an application to the Nuclear Regulatory Commission for a license to construct a repository.

Currently, the Board is reviewing the December 1994 *Program Plan*. The results of our initial review will be addressed in the Board's 11th report, which will be provided to you in two weeks.

Recent Progress and Improvements

I would like to take the opportunity at this point in my testimony to provide the Subcommittee with the Board's perspective on the improvements and progress that have been made in this program since Dr. Dreyfus assumed responsibility for it, and some concerns of the Board that still remain.

It is our preliminary view, from what we now know, that there are risks as well as opportunities associated with DOE's new approach. Among the risks are the increased technical and scientific uncertainties that will be created because less data and analysis than previously planned will be available prior to determining site suitability and applying to the NRC for a license to construct a repository. Among the opportunities is the chance to refocus and streamline the program and to establish clear, near-term goals against which real progress can be demonstrated, although achievement of the long-term objectives of the new approach will not be seen for many years.

The determination of site suitability is the first major milestone in repository development under the new approach. If the DOE finds the Yucca Mountain site suitable and the President approves it for development as a repository, the DOE's efforts to successfully *demonstrate* that it can construct a safe radioactive waste repository become critical. If the DOE does not present its case clearly and convincingly to the Nuclear Regulatory Commission, the DOE may be faced with costly and time-consuming delays during the licensing process. Further, the review of the environmental impact statement provides another occasion for contesting the basis for the DOE's site-suitability determination.

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 needs to be guaranteed during the full retrievability period both to complete the additional testing requirements and to cover the costs of retrieving the waste for any purpose, should that need arise.

One important area that the Subcommittee may wish to explore is the adequacy of funding over the very long term for the testing, monitoring, and possible spent fuel retrieval that is envisioned by the DOE for approximately 100 years once the waste has been emplaced in a repository.

In response to these concerns, I would like to highlight some of the recommendations that the Board will be making in its upcoming report. Some of them were made in past reports in some form but remain pertinent.

Board Recommendations

First, there is a need to fully articulate a waste isolation strategy for the repository and to set priorities, accordingly.

Before priorities can be set there is need for a clear and coherently articulated waste isolation strategy that takes into account the salient characteristics of the Yucca Mountain site and the ability and desirability of specific repository engineered barriers to enhance waste isolation. This is particularly important given the need to evaluate the DOE's emerging repository thermal-management plans and the additional programmatic emphasis that is being placed on engineered barriers, extended retrievability, and post-emplacement monitoring.

The waste isolation strategy needs to be robust enough to accommodate possible changes in the basic criteria that will be used to assess the performance of the proposed repository and the standards and regulations that will be used to license the repository, which are currently undergoing review by the National Academy of Sciences in accordance with the 1992 Energy Policy Act.

There also is need for a management and organizational commitment by the DOE to develop more systematic and effective ways of using iterative total system performance assessments to guide site characterization and to review work priorities at Yucca Mountain. The use of performance assessments becomes even more critical now, if the program increases its reliance on confirmatory testing — as opposed to providing more comprehensive data and analysis prior to applying for a license to construct the proposed repository.

In the past, 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 packaging, storage, transport, and ultimate disposal. A clear understanding of the waste management system and all its linkages is essential to developing a coherent and integrated program.

Second, the DOE should examine carefully the experience of others during the site- assessment process; particularly the influence of nonscientific and nontechnical factors.

In April 1994, the Board examined the experiences of others in assessing potential sites for critical or highly controversial facilities, such as low-level radioactive waste repositories, hazardous waste facilities, nuclear power plants, and other large engineering projects. Much can be learned from these experiences.

Several commonalities emerged that are applicable to the Yucca Mountain project: (1) the importance of having clear strategies for site assessment, site-suitability determinations, and licensing; (2) the significance of uncertainty and the use of expert judgment; (3) the inevitable occurrence of surprises as site investigations proceed;

(4) problems caused by technical and institutional overconfidence; and (5) the importance of independent technical review, quality control, and clear regulations.

But, equally important, political and process-oriented issues were found to be critical, often overriding *technical concerns*.

Third, the DOE needs to place greater emphasis on accelerating the underground exploration and testing program.

Getting underground to look at the site's complex geology is critical in determining whether the site is suitable for repository development. This recommendation, which was first made by the Board in 1991, remains pertinent. Therefore, in its December 6, 1994, letter to Dr. Dreyfus (which is attached), the Board indicated a need for substantially more underground excavation than is planned by the current program.

Fourth, unrealistic schedule deadlines that cannot be achieved also serve to increase frustration and erode confidence in the program. The DOE should establish realistic schedules for achieving its important intermediate milestones, and these should be reflected in current statutory deadlines.

We believe that schedules are vital if program momentum is to be maintained and progress measured. We also believe that critical technical and scientific activities should not suddenly be truncated or eliminated under the combined pressure of arbitrary schedule deadlines and budgetary constraints. Without sufficient surface-based and underground data and accompanying analyses, the DOE will be forced to rely heavily on expert judgment and bounding assumptions, which may be less effective in winning both technical and public confidence. The existing schedule may not provide sufficient time to complete the necessary site exploration; for example, excavation across the repository block to explore known, and possibly unknown, geologic features at the repository level.

The Board thus continues to be concerned that, under the current schedule, important long-term, and perhaps more expensive, activities (e.g. an east-west excavation across the repository block at the repository level, initiation of in-situ thermal testing, and excavation below the repository in the Calico Hills rock formation) may be delayed or replaced by other, less efficacious, shorter-duration activities.

An equally important concern of the Board is that the current schedules allow little time to accommodate the kinds of surprises that are often encountered worldwide in underground projects.

The Board recognizes the demands being placed on the program by overriding concern for meeting the 1998 and 2001 deadlines. Nevertheless, the Board is very concerned that important program decisions are being driven by unrealistic deadlines at some risk to the program and the eventual licensing of the site for repository development.

Fifth, the DOE should continue to allocate more of its resources to research and development of engineered barriers, including 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 enhance the long-term safety of the repository system, and help reduce uncertainties. It appears that the DOE plans to increase funding for waste package development; we hope this happens; it is a move the Board strongly endorses.

Immediate Opportunities for Improvement

Immediate opportunities do exist to improve many aspects of the DOE's program. Among the opportunities listed in our December 6 letter are increased emphasis on site suitability, the clear articulation of a waste isolation strategy, the setting of priorities, and the allocation of funds to focus on the development of a long-lived waste package. This (mid-course correction) also provides an opportunity to improve the interface between the DOE and the NRC so as to capture the full potential of the DOE's programmatic changes.

As the specifics of the OCRWM's new program approach evolve, the Board will continue to assess their technical and scientific implications. The Board also will be taking a close look at the timetables for important site-characterization activities as they are continually being updated, including timetables for underground excavation and testing and the determination of site suitability.

The results of these ongoing reviews will be communicated to the Congress and the Secretary as they are completed. However, whatever the outcome of our scientific and technical evaluation, the Board wishes to emphasize how critical it is for the DOE to set priorities for site characterization that are based on a coherent waste isolation strategy — not on how much testing can be accomplished within the constraints of the current schedule and available appropriations.

Interim Storage

As the committee is aware, recent attention has centered on interim storage, on which I would like to comment briefly. In its October 1993 *Special Report*, the Board observed that the *task of providing safe storage of spent fuel does not appear to present any substantial technical problems.*

Currently, there are approximately 30,000 metric tons of spent fuel stored at 75 reactor sites around the country, and this amount increases at the rate of about 2,000 metric tons per year. By 2030, approximately 87,000 metric tons of spent fuel will have accumulated. Therefore, even if a repository is constructed according to the DOE's schedule, substantial amounts of spent fuel will remain in storage at reactor sites for decades. To date, the implications of this extended interim storage have not been addressed by either the DOE or the utilities.

In the next few months, the Board will complete its technical review of this situation. The result of this technical review of the interim storage of spent fuel will be communicated to the committee and the Secretary when it is completed.

Fiscal Year 1996 Appropriations Request

In order to continue the Board oversight of this critical national program, the Board's funding requirement for fiscal year 1996 is $3,493,000. This request assumes an 11-member Board operating with a targeted staffing level of 22. It is proposed that the funding needs be met by:

(1) an appropriation of $2,970,000 in new budget authority, and

(2) carryover of an anticipated fiscal year 1995 unobligated balance of $523,000.

The guiding objectives underlying this budget request are to

- support the efforts of the Board members who are heavily involved in a congressionally mandated review of DOE's technical and scientific activities;
- maintain a small professional and support staff of the highest caliber commensurate with the status, abilities, and responsibilities of the Presidentially appointed Board, which it supports; and
- provide the tools and the resources for the Board and staff to effectively pursue the mission with which Congress has charged the Board.

The mission of the Nuclear Waste Technical Review Board deserves and requires the talent and reputation of individuals whose judgment and recommendations will be respected throughout the scientific community and by the public. Appointed Board members fill these

needs. If these talents are to be effectively used, the Board requires a commensurate level of senior professional staff, consultants, and resource support.

Conclusion

In closing, I would like to observe that, with respect to the Yucca Mountain site, the Board has found no technical reason, from surface-based data collected so far, that would indicate that the site is unsuitable. However, *underground exploration and some testing at Yucca Mountain will be necessary for a site-suitability decision and a subsequent application for a construction authorization*.

The Board also believes that the current DOE and OCRWM leadership should be commended for recognizing the fundamental inconsistency among the schedule, the amount of work planned, and the funds made available to the program in the past.

I also would observe that the Board has made numerous assessments and recommendations to the DOE on the civilian radioactive waste management program in its past reports and letters.

One very important role the Board plays is that of catalyst for the technical community. By scheduling open, public meetings and asking detailed technical 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 iteratively set priorities and define the program's technical objectives. The Board also has been instrumental in increasing communication and coordination within the DOE and among DOE contractors and other organizations involved with or concerned about high-level nuclear 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 geology, geoengineering, hydrology, materials science, geochemistry, transportation, systems analysis, environmental science, risk and performance assessment, and public health and safety.

Continuing independence, objectivity, scientific competence, and freedom from conflicts of interest are critical to the Board's charge as a credible agency. Scientific and technical credibility is the foundation upon which the Board's activities and recommendations are based.

Thank you, Mr. Chairman, for this opportunity to appear before you this morning. Dr. Brewer and I would be pleased to answer your questions at this time.

Questions from the Subcommittee on Energy and Water, Development, Committee on Appropriations, U.S. House of Representatives, Hearing on NWTRB Fiscal Year 1996 Appropriation Request, March 16, 1995

Questions from Chairman Myers

Q#1. *As an independent Board charged by Congress to review scientific aspects of the Department's plans for disposal of high-level radioactive waste, the Nuclear Waste Technical Review Board is uniquely situated to comment upon the Yucca Mountain criticality debate. Has the Board undertaken an analysis of the criticality theories offered by Dr. Bowman at Los Alamos National Laboratory?*

A. Under certain conditions, the disposal in a geologic repository of radioactive material with high concentrations of uranium or plutonium could generate a self-sustaining nuclear reaction. This situation is called in-repository "criticality." In a well-designed repository for spent fuel from civilian reactors, criticality is a very remote possibility.

Criticality, if it were to occur in such a repository, would not necessarily lead to a nuclear explosion. Despite recent headlines, the potential for in-repository criticality has been recognized for years, if not decades. The Board has not reviewed Dr. Bowman's paper. However, we have addressed the issue of in-repository criticality at past meetings and are scheduled to do so again at our April 1995 meeting. At that time, the DOE has been

asked to discuss its current plans for analyzing in-repository criticality and to update the Board on the DOE's response to Dr. Bowman's theory.

In a paper drafted by Drs. Bowman and Venneri at Los Alamos National Laboratory (LANL), weapons-grade plutonium (dispersed in a borosilicate glass "log") is disposed of in an idealized repository. It is not yet known how relevant the assumptions in this paper might be to a repository at Yucca Mountain, which will be designed to hold utility spent fuel and some defense waste from reprocessing. (Weapons-grade plutonium is not currently slated for disposal in Yucca Mountain.) First, it is not clear whether the idealized conditions used in this paper are realistic. Second, it is more difficult to achieve criticality with the plutonium in commercial spent fuel than with weapons-grade plutonium. In any event, extrapolating calculations for glass logs containing weapons-grade plutonium to the more impure plutonium in utility spent fuel will be difficult.

The scientific debate about Dr. Bowman's theories has been confined thus far to LANL. However, it is our understanding that Dr. Bowman's paper and a rebuttal paper by those who do not agree with Dr. Bowman will be submitted to a peer-reviewed journal. We believe this is an appropriate process for beginning to resolve this issue. Making firm conclusions about Dr. Bowman's theories at this time would short-circuit the peer review process.

Q#2. *When do you expect the White House to make nominations to fill the five vacancies on the Board?*

A. The White House is currently screening technically qualified Board candidates nominated by the National Academy of Sciences. As in the past, the care given to identifying nominees who also must satisfy the rigorous conflict of interest requirements of the Nuclear Waste Policy Act has slowed the appointment process. This careful screening is necessary to assure that the Board retains its credibility, which is the foundation of its effectiveness. We understand that the White House is actively working to fill the five Board member vacancies. It is our hope that these appointments will be made soon.

In any case, one legislative change that could substantially facilitate the work of the Board would be to amend the Nuclear Waste Policy Act to provide for automatic extensions of the terms of Board members until such time as they have been reappointed or their replacements have been appointed. Because of the comprehensive nature of the program and the breadth of scientific and technical expertise required to adequately evaluate the program, the loss of a single Board member can make the Board's work more difficult. To operate at peak effectiveness, the Board should have its full complement of eleven members, which is something it has never had. Our budget request assumes that the five new members will be named to the Board during this fiscal year.

Q#3. *Do you have any comment on the recent decision of the Mescalero Apaches to pursue development of a monitored retrievable storage facility on tribal lands in cooperation with private utilities? Will the Board have any role in evaluating technical aspects of the plan?*

A. There are no real technical impediments to building or transporting spent fuel to such a facility. Under current law, both federal and private facilities for commercial spent fuel storage would be licensed by the Nuclear Regulatory Commission. The difficulties associated with developing a private storage facility, as with the development of any storage option, are primarily political and institutional and are mostly related to public concern over siting of the facility and the public's perception of risk related to transporting the waste. The Board is charged by Congress to review only those activities undertaken by the *Secretary of Energy* to manage commercial spent fuel and high-level waste. Therefore, unless the Board's mandate is changed, we will not be formally evaluating any specific plans for a private interim storage facility. However, we plan to issue a report in the next few months that will analyze the technical and nontechnical implications of the various options for extended storage of spent fuel.

Q#4. *Has the Board formulated any opinions on nuclear waste legislative proposals pending in Congress? In particular, do either the Johnston bill (S.167) or the Upton bill (H.R. 1020) significantly impact the scientific effort associated with the nation's current nuclear waste policy as articulated in the Nuclear Waste Policy Act?*

A. The Board has not taken a position on any of the legislative proposals that have been introduced. However, some proposals could shift the emphasis of national policy on spent fuel and high-level waste management, at least in the short term, from disposal to storage of utility spent fuel. It is important to recognize that the repository site-characterization program at Yucca Mountain is at a critical stage where actual underground excavation is currently underway. Maintaining the momentum of this very important work will require a consistent and predictable commitment of funds. The Board has some concern that, should a shift in policy toward storage occur, funds for site-characterization could be constrained. Diverting funds from the site-characterization program at this critical time could have an adverse effect on the development of a permanent repository at Yucca Mountain not only by reducing the amount of scientific and technical work that could be done but also through loss of the site-specific expertise of professionals who work on the program. Even if the decision is made to change national policy to emphasize storage of spent fuel, continuing a program of site investigations to confirm the feasibility of disposal will be important in helping alleviate concern that storage will be the final, not the interim, solution.

Q#5. *Please describe generally the status of the Department's efforts to design waste packages and develop multi-purpose canisters for spent nuclear fuel. Does much technical research and development remain in this area?*

A. The DOE has initiated a procurement process for a multipurpose canister that can be used to store and transport spent fuel. These new dual-purpose canisters can be designed and produced using existing technology. However, it is not clear at this point that the MPC will be compatible with waste packages that will be used for disposal of the commercial spent fuel in a repository. The Board has encouraged the DOE to take into consideration requirements for a disposal waste package as it develops its MPC concept.

The disposal waste package is a critical part of the engineered barrier system that will be used to isolate the radioactive waste in the repository from the accessible environment. Deciding which waste package design is most appropriate requires both a knowledge of what the repository environment (e.g., temperature) will be and extensive testing of materials degradation (corrosion) that will take up to ten years to complete. This testing began in earnest last year after several years of delay. It should be continued and adequately funded. The DOE also needs to carry out research on waste package fabrication, including welding, as well as developing methodology for nondestructive examination of metals and welds in the presence of ionizing radiation.

Q#6. *Your testimony notes that the Board has, on several occasions, criticized the Department's, "allocation of resources as fundamentally inconsistent with the optimistic work schedule the DOE set for itself." Does the Department's budget for science education activities perpetuate this inconsistency?*

A. In the past, the DOE has allocated a high proportion of its total program funds to overhead and infrastructure costs, thereby limiting the amounts available for critical scientific work. In addition, the DOE has established a very optimistic schedule for determining site suitability and applying to the NRC for a license to construct a repository, should the site prove suitable. The Board has expressed its concern that the OCRWM's allocation of such a high proportion of its funds to overhead and infrastructure costs makes it even more difficult to obtain the data necessary to make site suitability and licensing decisions in accordance with its ambitious schedule. The Board's primary concern has been that to meet this schedule, critical scientific work would have to be truncated. The costs of the DOE's science education activities, while they may be part of overhead costs, are so small relative to other overhead costs that eliminating them would not significantly enhance

the scientific program. Furthermore, continuing to inform the public is an essential requirement for this kind of undertaking.

Q#7 *It appears that the interstate transportation of nuclear waste is one of the more politically challenging aspects of nuclear waste storage. Could you please comment on the technical aspects of nuclear waste transportation? What scientific or technical hurdles, if any, must be overcome in order to plan and develop a nuclear waste transportation network?*

A. Numerous past studies and three decades of experience in this and other countries with these activities have shown that the health and safety risks associated with transporting spent fuel and high-level radioactive waste are small. The Office of Civilian Radioactive Waste Management has not yet started developing a transportation network on the scale that will be necessary to move large quantities of spent fuel from various locations in the country to a storage facility or a repository, should either begin operation. However, development of such a network and providing technically sound assessments of system safety do not appear to present any insurmountable technical challenges. The DOE will have to address a number of technical issues. Among these are (1) the weight of the MPC overpack, (2) safe handling of the spent fuel, (3) a system for tracking waste shipments, and (4) route-specific factors. As you point out, even though there are no insurmountable *technical* hurdles, transporting nuclear waste may be *politically* challenging.

Question from Mr. Bevill

Q#1. *In several instances in your testimony, you indicated that sometimes the most onerous problems in dealing with the storage of our radioactive waste may be political or process oriented. You cited a 1993 Special Report of the Board that observed that the task of providing safe storage of spent fuel does not appear to present any substantial technical problems. Could you please elaborate on what you mean by this.*

A. Safely storing spent fuel does not appear to present any serious technical problems. The Nuclear Regulatory Commission has found that spent fuel can be stored safely — in pools or in dry storage casks — for at least 100 years. The safety risks associated with transporting spent fuel also are quite small. Furthermore, constructing and operating an interim storage facility do not present any significant *technical* challenges. Even though from a technical point of view the risks associated with spent fuel storage are quite small, the public's *perception* of risk may be a very significant factor as decisions are made about interim storage options.

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

(Before the Subcommittee on Energy and Power, Committee on Commerce, U.S. House of Representatives, June 30, 1995)

Chairman Schaefer, and members of the subcommittee. I am John Cantlon, Chairman of the Nuclear Waste Technical Review Board. On behalf of the Board, I am pleased to be here today to provide the Board's perspective on the Department of Energy's program to develop a permanent repository for civilian spent fuel and high-level waste.

About the Board

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 all activities undertaken by the Department of Energy related to the management of spent nuclear fuel and some defense high-level radioactive waste. The Board's approach to this evaluation has been to look at these activities as a system that includes packaging, transporting, storing, and disposing of the waste. We also review the technical activities related to the DOE's site-characterization program at Yucca Mountain, Nevada, the goal of which is to determine if that site is suitable as a location for a permanent underground high-level waste repository.

Through its open public meetings, the Board serves as a catalyst for the technical community. The Board is thus 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 fostering communication within the DOE and among the DOE and its contractors, stakeholders, and others involved with high-level waste disposal issues.

Drawing on the significant expertise of its members, consultants, and professional staff, the Board has provided Congress and the Secretary of Energy with an ongoing evaluation of the technical aspects of the DOE's waste management program in many areas, including seismology, hydrology, geochemistry, risk and performance assessment, and public health and safety.

During its first six years of operation, the Board has made a number of important contributions to the DOE program in the form of technical recommendations that have resulted in improvements to the program. For example:

- In response to Board and NRC recommendations, several important changes have been made to the DOE's design for the exploratory studies facility. The new design is a substantial improvement over earlier versions.

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

- The Board has, since its inception, urged the DOE to begin underground exploration and testing to determine as soon as possible the suitability of the Yucca Mountain site for repository development. Tunneling at the site has been initiated, and the tunnel boring machine is scheduled to reach the repository horizon in 1996.

- The thermal-loading strategy selected by the DOE will directly affect the final repository design and will have important implications for 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 other engineered barriers and the geology at the site to provide long-term isolation of the radioactive waste from the accessible environment. The use of such waste packages can help improve confidence in the long-term performance of a repository and thus facilitate licensing of the facility. 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 comprehensive waste management system from generation of the waste through disposal to minimize as much as possible the number of times waste will be handled, especially when shielding from high radiation levels is required. For example, the use of a multipurpose canister system, in which the waste can be stored, transported, and disposed, could result in much less handling than called for in the DOE's earlier baseline plan. The DOE is developing such a system.

- The Board has urged the DOE to link key decisions, testing priorities, technical activities, budgets, and schedules to a waste isolation strategy. Although the program has not yet fully achieved this level of integration, the Board is encouraged that the program is moving in this direction.

Background

As you know, Mr. Chairman, the issue of safe disposal of the country's spent fuel and high-level waste is an issue of long-standing importance. In 1957, the Na-

tional Academy of Sciences first examined nuclear waste disposal and recommended permanent burial of the waste in underground repositories. The current policy of the United States, which is to proceed as expeditiously as possible to develop the capability to *dispose* of spent nuclear fuel in a geologic repository, was established in the Nuclear Waste Policy Act of 1982. The ultimate goal of this policy is to permit the radioactive material to be *permanently isolated* from the accessible environment. The decision to develop a disposal capability was premised on an overwhelming consensus among scientists and engineers in this country and abroad that there are no fundamental technical obstacles that would impede the development of such a repository. The Nuclear Waste Policy Act laid out a process and schedule for developing a permanent repository and charged the DOE with developing a program for the acceptance and eventual disposal of high-level radioactive waste. And in the 1987 amendments to that Act, Congress selected a site at Yucca Mountain, Nevada, as the sole site to be characterized as the potential location for a deep geologic repository.

Concerns about Change in Policy

The Board is concerned that some of the legislative proposals offered this year could — intentionally or inadvertently — change the focus of current national policy, from permanent disposal to long-term, centralized storage of the waste. I would like to comment briefly on the potential effects of this change in focus.

Storage of spent fuel is not a substitute for disposal. Eventually, high-level waste will have to be permanently disposed of. The Board recognizes and appreciates the important role storage plays in the management of commercial spent fuel. Indeed, the Board has long urged the DOE to address the implications of extended storage as part of a comprehensive waste management system that includes transportation, storage, and disposal. However, we are concerned that, as a result of efforts to find a solution for the nuclear utilities' concerns associated with spent fuel storage, the repository development program may be curtailed as funds are diverted for storage activities not originally envisioned. During a period of limited resources, increasing the emphasis on storage and decreasing the emphasis on disposal could adversely affect the viability of the repository program. Furthermore, a national policy that contains a major storage component may not be able to gain public acceptance unless it is accompanied by a credible repository development program that provides the confidence that disposal capability ultimately will become available.

Although the pace of the disposal program has been slower than many of us would like, the last two years have brought significant progress. More than one half mile of tunneling in the underground has been completed. In addition, mapping is being done, and hydrologic tests have been initiated. Furthermore, if excavation continues without further delays, the next few years will bring substantial amounts of information from the underground that will be crucial to the evaluation of the suitability of the Yucca Mountain site. In fact, the tunnel boring machine is scheduled to reach the repository horizon in 1996. The Board believes that a disruption of site characterization at this juncture would be a set back in achieving the important national goal of permanently disposing of spent fuel and high-level waste in a deep geologic repository.

The Repository Program

As I mentioned previously, during the past two years, significant progress has been made in the program. This is not to say, Mr. Chairman, that further improvements cannot be made. In the past, program plans and activities have not been as well integrated as they need to be, and integration remains a challenge for this large and complex program. In addition, the Board has long advocated that program managers allocate a greater proportion of whatever funds the program receives to scientific and technical work and a smaller portion to overhead and infrastructure costs. Although Dr. Dreyfus has initiated a trend in this direction, the number of people working on the program still seems to be increasing. As budgetary constraints are imposed, program managers will face even greater challenges in the future to ensure that the scientific work gets done. This will be especially true if the activities related to site characterization and repository development have to compete for limited funds with an ambitious storage program.

The United States has selected and is characterizing a specific site that could be used as the permanent repository. While the U.S. program is envied by other countries for its ability to study the actual site where nuclear waste could eventually be placed, the program also is facing a particularly complicated and difficult task. Scientific and technical work related to both characterizing the site and to designing and licensing a repository — should the site prove suitable — are being undertaken simultaneously. As a result, it is a challenge for program managers to sort out exactly what work is the most critical. This challenge is compounded by the complex organizational structure of the DOE program, which includes many contractors, laboratories, and federal agencies.

To assist the program in setting priorities for characterizing the Yucca Mountain site, the Board sent a letter to the DOE in December 1994 outlining exploration and testing activities the Board believes should be completed to ensure confidence in a site-suitability finding. (With your permission, Mr. Chairman, I would like to ask that the full text of this letter be entered in the record.) We anticipate that, if the program is streamlined and priorities are set effectively, even with reduced funding, the program can continue and real progress can be made in determining the suitability of the Yucca Mountain site. However, it seems clear that even if priorities are set effectively, with substantial reductions in funding, site characterization will take longer than is currently scheduled.

Storage Report

At this point, Mr. Chairman, I would like to summarize briefly the major points from a Board report on spent fuel storage that will be published later this summer. In it, we attempt to shed light on the wide range of issues that could influence the debate over how and where to store spent nuclear fuel.

In 1982 when the current nuclear waste policy was adopted, the decision was made to move quickly toward the permanent disposal of spent fuel in a deep geologic repository. At that time, the storage of this waste, either at reactors or off site, was considered a temporary measure to accommodate the 5- to 10-year interval between the removal of spent fuel from a nuclear reactor and the disposal of the spent fuel in a repository, which was expected to begin operating in 1998.

If these earlier expectations had been met, no more than 40,000 metric tons of spent fuel would have required storage at any one time. However, the challenge of developing a repository is taking longer than was envisioned in 1982. It is now clear that a repository will not begin operation until 2010, at the very earliest. Because the amount of utility spent fuel needing storage increases by approximately 2,000 tons every year, 60,000 metric tons of spent fuel will have been generated if the repository begins operating in 2010. Under a less optimistic scenario where repository operation is delayed until 2020, as much as 80,000 metric tons would have to be stored — somewhere. But even if a decision were made today to develop interim storage capacity, it probably would take 5-10 years to site, license, construct, and begin operations. Furthermore, it will take time to transport the accumulated stockpile from reactor sites to a centralized facility once it is ready. Therefore, it now makes more sense to speak in terms of *extended*, rather than interim, storage of this waste.

The Board's report contains a number of conclusions related to the question of how and where to store spent fuel for an extended period of time.

First, as mentioned before, storage of spent fuel — whether for a short time or for an extended period — is a temporary measure. It can postpone — but not eliminate — the need to dispose of spent fuel and high-level waste.

Second, the success of any approach to spent fuel storage will depend to a large extent on an understanding that a viable and credible repository development program is under way. Previous U.S. attempts to develop a centralized storage facility have met with opposition based on public concern that the facility would become a *de facto* repository. By the same token, public opposition to increasing storage capacity at any site is likely to grow if it appears there is little chance of later moving spent fuel off site. For example, in Minnesota this issue formed the basis of opposition to the utility's request to expand its dry storage capacity.

Third, there are no clear technical reasons for selecting one spent fuel storage option over another. Furthermore, the choice of an option is unlikely to make a significant difference in the low levels of health, safety, transportation, and environmental risks to which the general public and workers might be exposed. It is important to note, however, that extended storage of waste at utility reactors means that spent fuel may be stored there *after* the reactors cease generating electricity. Although safe, storing spent fuel at shut down reactors may be institutionally and economically cumbersome.

And fourth, under any realistic scenario, only token amounts of spent fuel could be removed from utility reactor sites by January 1998. No matter what policy is decided on for storing spent fuel, removal of the spent fuel from reactor sites will not occur quickly.

Under our current national policy, storage of spent fuel at reactor sites is the responsibility of the nuclear utilities. Should a decision be made to increase federal involvement in developing off-site storage capability, decision makers will face a number of options, several of which may pose real dilemmas. For example:

(1) If the objective is to ease the burden at reactor sites, a storage facility probably should be large enough to hold at least 30,000 metric tons of spent fuel, and, if repository operation is further delayed, this amount could increase to as much as 80,000 metric tons. However, constructing a large storage facility also could increase fears that the facility could become a *de facto* repository (siting several smaller facilities may help alleviate this concern but also could multiply the siting challenges).

(2) Collocating a storage facility at or near Yucca Mountain could reduce fuel handling and transportation, but only if that site proves suitable for repository development. On the negative side, locating a storage facility so close to the potential repository site before a suitability decision is made could generate institutional momentum to find the Yucca Mountain site suitable even if deficiencies are found in the site. This could compromise the credibility of the DOE program and undermine the national goal of finding a site that will safely isolate the waste for thousands of years.

Concluding Comments

Mr. Chairman, the Board believes that policy makers run the risk of being caught in a vicious circle. Safe disposal of nuclear waste in a deep geologic repository is an objective that is widely shared in the United States and abroad; it also appears to be technically feasible. Yet, the prevailing fiscal environment — coupled with pressure to begin removing spent fuel from reactor sites by 1998 — may well dictate that the repository program will operate at a lower funding level than anticipated, at least for the next few years. A program constrained by funding most likely will translate into major delays in repository start up. Delays in repository start up will in turn increase pressures to develop a large centralized storage facility. As storage activities increasingly compete with disposal activities for limited resources, a valued national goal — geologic disposal — will recede further and further into the future.

Yet, storage is not a panacea. In fact, very little, if any, storage capacity can be made available by 1998 and it could be 2005 or later before meaningful storage capacity becomes available. No matter what is decided about centralized storage, high-level radioactive waste ultimately will require permanent disposal.

Substantial progress is being made at Yucca Mountain. Barring delays in the tunneling schedule, significant information will soon be acquired about the suitability of the site. The Board believes it would be very unfortunate if the DOE's focus — and funding — were now seriously diverted from the disposal program just when we are about to reap the benefits of past expenditures.

As it debates what approach should be taken to address the relatively near-term problem of spent fuel storage, Congress may wish to keep in mind the implications of its actions for the long-term goal of disposal and of demonstrating the feasibility of deep geologic disposal at Yucca Mountain. In fact, lack of continuing progress toward a permanent disposal solution may only add credence to those who argue that any storage site ultimately will be come a *de facto* repository.

We have the technical know-how; we have assembled the human resources and implemented the program; and many continue to argue that we owe it to future generations to carry on this effort. It is the Board's view

that maintaining the major focus on site characterization at Yucca Mountain and on the continued development of a credible repository program may be the best way of reaching the national goal of safe disposal while helping ensure the success of any storage option.

Thank you.

Questions from the Subcommittee on Energy and Power, Committee on Commerce, U.S. House of Representatives, Hearing on High-level Nuclear Waste Policy, June 30, 1995

Questions from Representative Frank Pallone, Jr.

Q#1. *In your testimony, you commended DOE for improving its high-level nuclear waste repository program, and stressed the need for stability in terms of Congress's directives regarding this program.*

a. What impact do you think legislation directing DOE to develop interim storage by 1998 would have on its existing repository program? Assuming adequate funding, do you think the Department can handle both of these managerial responsibilities simultaneously?

A. Developing interim storage should not present a major technical challenge to the Office of Civilian Radioactive Waste Management (OCRWM). Sufficient technical and management experience exists in this area within other parts of the Department of Energy (DOE) from which the OCRWM can draw.

However, if in addition to the repository program, the OCRWM were directed to develop a storage facility for commercial spent fuel, the activities involved in carrying out this mandate could distract the OCRWM from its current focus on disposal, especially from characterizing the site at Yucca Mountain. Management structures — both within the OCRWM and within its contractor family — would have to be created to deal with spent fuel storage. The OCRWM has made slow progress during the last five years in instituting a focused and disciplined management team for the disposal program. Adding significant new responsibilities could undermine that progress.

Directing the DOE to develop a storage facility by 1998 — without a commensurate increase in funding for storage activities — will almost surely delay the repository program. Furthermore, because the costs associated with an ambitious storage program will increase as the DOE moves toward constructing and operating a facility and begins transporting the spent fuel, competition between storage and disposal activities for funding will become more intense. Congress could mitigate the competition for funding by choosing to provide the funding required for the development of both storage and disposal facilities.

b. Assuming adequate funding, do you think the 1998 deadline set by H.R. 1020 is a realistic date for DOE to open an interim storage facility?

A. Although the DOE could administratively begin *accepting* legal title to spent fuel in 1998, beginning to accept spent fuel at a storage facility by 1998 would present a very difficult challenge under current regulatory and statutory requirements. Under the best of circumstances, significant amounts of spent fuel could not realistically be moved from reactor sites to a storage facility until sometime around 2003 for the following reason.

None of the tasks associated with developing a storage facility pose insurmountable technical difficulties; however, time will be required to demonstrate compliance with existing safety and environmental protection standards. Before a storage facility can be placed in operation, the DOE would need to select a site and characterize its suitability (e.g., seismic hazards, etc.), construct the facility, and have it licensed by the Nuclear Regulatory Commission (NRC). The DOE also would need to develop a truck and rail infrastructure capable of transporting the spent fuel from reactor sites to the storage facility.

It is possible that this process could be expedited, for example, if an existing DOE defense site with an extensive database of site characteristics were selected as the site for a storage facility. The process also might be expedited if the NEPA process

were altered, for example, to eliminate consideration of alternative sites. The Board notes that a significant short-circuiting of existing laws and regulations, however, could have negative repercussions among stakeholders.

In the Board's judgment, before changing current policy, serious consideration should be given to the potential consequences that lowering the current priority on disposal would have for the credibility of the country's entire waste management program. The success of the program appears to be quite dependent on sustaining public trust and confidence. Balancing the desire to expedite this process to meet the desires of utilities to remove spent fuel from reactor sites, with the need to assure the public that safety will be maintained, is a delicate process.

Q. *Is it realistic to expect DOE to submit a multipurpose canister application to the Nuclear Regulatory Commission (NRC) by April 1996?*

A. As the Board understands the DOE's multipurpose canister program, the DOE initially will apply for a license for a canister designed for dual-purpose (transportation and storage) use. Later, the DOE proposes to apply for a disposal license as well. The initial licensing of the cask for dual-purpose use could be completed by the April 1996 date. Similarly, the private sector is responding to the utilities' immediate storage and transportation needs through development of (1) a dual-purpose cask and (2) a combination of transportation overpacks for commercially available storage canisters.

Q. *Is it realistic to expect DOE to submit an interim storage application to the NRC in six months of enactment?*

A. Probably not.

Q#2. *Critics of DOE's repository program have suggested that two primary problems which have plagued DOE's waste program over the years are at least partially Congress's fault: inadequate funding and unrealistic deadlines.*

a. Are these fair criticisms?

A. In the Board's view, these criticisms have some merit but, prior to fiscal year 1994, it also is true that the DOE consistently requested from the Congress substantially less funding for the program than it estimated it needed. It is ironic that just as the DOE is making real progress in exploring the underground at Yucca Mountain and we are about to reap the benefits of past expenditures, funding for the repository program may be substantially reduced.

The deadlines spelled out in the Nuclear Waste Policy Act have proven unrealistic given the complexity of site characterization and repository development in an arid region and the complex institutional requirements of the program. Consequently, the DOE has been forced to revise its schedule several times, and even the current schedule, which calls for the beginning of repository operation in 2010 is optimistic. However, the DOE feels intense pressure from Congress and others involved with the program to maintain its current schedules. The Board has on several occasions expressed its concern that in attempting to meet unrealistic deadlines the DOE could be forced to make important technical decisions before performing adequate technical and scientific analysis. This could ultimately undermine the technical validity of the program and delay program progress.

b. If so, are you concerned that Congress may make these mistakes again?

A. Yes. And, in the Board's view, the problems could be compounded if the DOE is required either to (a) halt repository development or (b) sustain both repository development and a very ambitious storage program, without realistic schedules or adequate funding.

Q#3. *I am concerned that if Congress is not careful, it will assign DOE interim storage responsibilities that overwhelm the repository program.*

a. Do you share my concern that there is a danger that interim storage is likely to become de facto permanent storage?

A. As explained in the answer to question 1, there always will be concern if the focus of national policy does not remain on finding a suitable site

for permanent geologic disposal. Directing the DOE to develop a storage facility by 1998 — without a commensurate increase in funding for storage activities — will almost surely delay the repository program. To be meaningful, a storage capacity of 30,000 metric tons or more of spent fuel (this does not include defense waste) needs to be established. If a facility of this size (or several facilities that in the aggregate have a capacity to hold a similar amount of waste) were constructed, the urgency of the utilities to find a permanent repository could be significantly reduced. As discussed below in the answer to question 4, storage is no substitute for disposal. The Board sees advantages to including centralized storage in an integrated waste management program — particularly to avoid potential and perceived problems associated with storing spent fuel at shutdown reactors. However, the Board believes that efforts to deal with spent fuel storage should not be pursued at the expense of the repository program. Furthermore, the Board believes a viable repository development program is a prerequisite for the success of any storage option — at reactors or off site.

b. What are the implications for defense waste disposal if the permanent repository program were delayed or abandoned? How important is it to keep up the repository program on a relatively fast track in order to deal responsibly with this defense material?

A. Defense high-level radioactive waste, including government-owned spent fuel, requires deep geologic disposal just as does civilian spent fuel. Indeed, current U.S. policy calls for the co-disposal of these materials — a policy that makes eminent sense from economic and safety perspectives. Technically, there are no reasons why defense waste and civilian spent fuel should not be disposed of in a common repository.

A delay in the current repository program will result in a commensurate delay in the disposal of defense wastes. Maintaining momentum in the repository program will allay the fears held by many states with defense high-level waste that their states will become de facto disposal sites for that waste.

Q#4. *With respect to funding limitations, if budget pressures forced Congress to choose between interim storage and the repository, which would you advise us to make the higher priority?*

A. Storage is no substitute for disposal. The Board believes that it would be very unfortunate if progress being made in the repository program were halted or significantly slowed, either intentionally or unintentionally.

There is an international consensus among scientists and engineers that no fundamental technical obstacles exist to safely disposing of high-level radioactive waste in a deep geologic repository constructed at a suitable site. The DOE's site-characterization program at Yucca Mountain is finally poised to obtain significant amounts of information that would allow a comprehensive evaluation of the site to determine whether it is suitable for a repository. The question is not whether to store spent fuel. It already is being stored at reactor sites and will continue to be stored somewhere for decades. The question is *where* the spent fuel should be stored. The Board sees advantages to including centralized storage in an integrated waste management program — particularly to avoid potential and perceived problems associated with storing spent fuel at shut-down reactors. However, the Board believes that efforts to deal with spent fuel storage should not be pursued at the expense of the repository program. Furthermore, the Board believes a viable disposal program is a prerequisite for the success of any storage option — at reactors or off site.

Q#5. *Many critics argue that it is impossible for anyone to speculate intelligently about building a repository that can safely isolate radioactivity for 10,000 years.*

a. In your opinion, is a 10,000 year standard a reasonable basis on which to ask the NRC to license the repository?

A. Selection of a repository site requires evaluation of its performance for time frames much longer than required for other activities. The long half-lives of potentially harmful radionuclides require that the public and the environment be protected from exposure to this material for thousands of

years. The fundamental premise behind geologic disposal is that many geologic formations have been relatively stable for millions of years and are very likely to remain stable for millions of years in the future. The advantage of geologic disposal is that deep geologic formations are virtually immune to many of the pestilences (fire, flood, tornado, hurricane) that affect the earth's surface.

The geologic record provides much evidence on the behavior of buried rock over many millions of years. However, expert judgment may be needed for guiding decisions on extending the applicability of some limited observations of natural processes and laboratory and in-situ experiments to the time periods needed to assess repository safety. Such judgment must rely on firm technical analyses of scientific data obtained from an examination of the repository's hydrogeologic environment and from appropriate underground tests and experiments. With such a firm technical base, it is not an unreasonable or impossible task to predict repository performance for several thousand years —- given adequate time and money to complete the necessary site characterization and testing. The Board also supports keeping the repository open for an extended period to provide an opportunity for continued evaluation of its operation.

On the other hand, predictions of the potential for human interference with, or intrusion into, a repository, over thousands of years are highly speculative. The National Academy of Sciences (NAS) currently is formulating its recommendations on how to consider human intrusion when setting safety standards for a repository. The NAS's report should help to resolve questions about the best approach for the treatment of the potential for human interference with, or intrusion into, a repository.

b. Should Congress consider changing the current method of establishing a safety standard for the repository? What is your opinion of proposals, such as that included in H.R. 1020, under which Congress would set a specific standard? Do you see any dangers in this approach? Do you have any alternate suggestions?

A. The Energy Policy Act of 1992 specifies the current method of establishing a safety standard, by directing the NAS to evaluate the technical bases for a Yucca Mountain standard. The Act also directs the Environmental Protection Agency (EPA) and the NRC to modify their regulations in accordance with the NAS recommendations. In the Board's judgment, the Congress might consider allowing this process to run its course, at least to the point of permitting the NAS to complete its evaluation of the technical bases for a Yucca Mountain standard.

Q#6. *H.R. 1020 permits DOE to begin constructing an interim storage facility before receiving final approval of its license application by the NRC. Do you see any drawbacks to providing DOE with this flexibility?*

A. The procedure proposed in H.R. 1020 represents a departure from the currently prevailing policy, which provides for a thorough airing, adjudication, and resolution of all technical questions before construction of a nuclear facility of any kind begins. In the Board's judgment, before changing this policy, serious consideration should be made of the potential consequences that such a change would have for the credibility of the country's entire waste management program — whose success is dependent on sustaining public trust and confidence.

All technical analyses undertaken to date suggest that the health, safety, and environmental risks associated with the construction and operation of a facility to store spent fuel in dry casks are quite low provided sufficient care has been taken in the siting, design, and construction of the facility. However, once construction begins and substantial funds are committed to a storage facility, it may be very difficult, if not impossible, to halt construction, even if serious health, safety or environmental questions should arise concerning the facility.

Questions from the Subcommittee on Energy and Power, Committee on Commerce, U.S. House of Representatives, Hearing on High-level Nuclear Waste Policy, June 30, 1995

From Representative Edward J. Markey

Q#1. *In a report submitted to Congress in March, the Nuclear Waste Technical Review Board expressed concern that the current schedule for Yucca Mountain may not allow sufficient time for certain necessary activities to be completed in time for a 1998 site-suitability decision.*

a. What specific activities do you fear might not be completed in time?

A. Some of our concerns were outlined in our December 6, 1994, letter to the DOE (which is enclosed and was attached to our June 30 testimony before the House Subcommittee on Energy and Power). In that letter, the Board expressed its view that the DOE would have to complete a number of basic activities before a site-suitability decision could be made with a reasonably high level of confidence. We are most concerned about maintaining progress on those activities related to exploratory tunneling, verifying geologic structures at depth, and initiating the necessary hydrogeologic and thermal tests.

The DOE's phased approach for exploring, testing and licensing the Yucca Mountain site includes a "technical" site-suitability decision in 1998. The DOE acknowledges that this approach will involve collecting less data and therefore carries a greater risk that, at some point in the future, something could be found to indicate that the site is in fact unsuitable for repository development. Consequently, the Board still is of the opinion that before a site-suitability decision can be made with confidence, the basic activities set forth in its December 6, 1994, letter need to be completed.

b. How would the Energy and Water Appropriations Bill's proposed budget cuts and its redirection of the program towards construction of an interim storage facility affect these activities?

A. Under the bill's approach, it will take the DOE even longer to complete site-characterization activities than is currently planned. However, some of the necessary tests will take several years to complete in any case. In fact, it is not clear to the Board how the necessary testing and data analysis can be completed to support a technically defensible site-suitability decision until sometime between 2000 and 2005, even if the program received its requested funding.

Q#2. *Page 9 of your prepared testimony states that even if a decision were made today to develop interim storage capacity, "it probably would take 5-10 years to site, license, construct, and begin operations."*

a. In light of your testimony regarding the time frame required to complete an interim facility, isn't it highly unlikely that the very tight deadlines set forth in the Upton bill (which require DOE to begin accepting waste at an interim facility by 1998) will be met?

b. Is there a risk that having to meet the artificial deadlines established in the bill would compromise public health, safety, and environmental protection?

A. Although the DOE could administratively begin *accepting* legal title to spent fuel at reactor sites in 1998, beginning to accept spent fuel at a storage facility by 1998 would present a very difficult challenge under current regulatory and statutory requirements. Under the best of circumstances, significant amounts of spent fuel could not realistically be moved from reactor sites to a storage facility until sometime around 2003.

None of the tasks associated with developing a storage facility pose insurmountable technical difficulties; however, time will be required to demonstrate compliance with existing safety and environmental protection standards. Before an interim storage facility can be placed in operation, the DOE would need to select a site and characterize its suitability (e.g., seismic hazards, etc.), construct the facility, and have it licensed by the Nuclear Regulatory Commission (NRC). The DOE also would need to develop a truck and rail infrastructure capable of transporting the spent fuel from reactor sites to the storage facility.

It is possible that this process could be expedited, for example, if an existing DOE defense site with an extensive database of site characteristics were selected as the site for a storage facility. The process also might be expedited if the NEPA process were altered, for example, to eliminate consideration of alternative sites. However, the Board notes that a significant short-circuiting of existing laws and regulations could have negative repercussions among stakeholders. Balancing the desire to expedite this process to meet the desires of utilities to remove spent fuel from reactor sites, with the need to assure the public that safety will be maintained, is a delicate process.

Q#3. *As you know, some in the Senate have been trying to revive reprocessing as an option for dealing with the waste issue by calling for spent fuel to be shipped over to Great Britain or France to be reprocessed.*

a. What are the risks involved in shipping nuclear fuel across the Atlantic for reprocessing in Great Britain and France?

A. The United States first began shipping highly enriched uranium fuel to foreign research reactors under the auspices of the "Atoms for Peace" program in the 1950s. We also have accepted return shipments of the spent fuel. Except for shipments from Canada, all of the spent fuel has been transported by sea — in casks. The historical safety record of these and other international ship transports of high-level waste has been good. The Board believes that with full compliance with transportation regulatory requirements and with proper care, the risks associated with the marine transport of spent fuel should be reasonably low.

b. How do these risks compare with the risks of rail or truck transport of waste to a geologic repository?

A. Truck and rail transport of spent fuel in the United States also has a long history. The safety record has been good, and quantitative risk analyses have corroborated low risk estimates. Although risks are low, there are some differences in the nature of the hazard in ocean transport, the principal risk being that of a ship sinking. If a ship were to sink in a coastal area, it is likely that its cargo of spent fuel casks could be recovered. If the ships were to sink in the deep ocean, the casks could only be recovered at great expense and with great difficulty.

Q#4. *How would we ultimately dispose of the reprocessed fuel and any wastes produced as a result of reprocessing? What would be the costs of reviving the reprocessing option compared to deep geologic disposal?*

A. Reprocessing is not a substitute for geologic disposal. Much reprocessing waste is high-level waste, which ultimately will require deep geologic disposal. Reprocessing may delay by a decade or two the need to dispose of the reprocessing wastes, but it does not postpone the need to permanently dispose of the high-level waste. Reprocessing may result in the need for a slightly smaller repository, but it is unclear whether this is of significance. In the end, the high cost of reprocessing would be in addition to, rather than in place of, expenditures for deep geologic disposal.

Q#5. *According to published reports, NRC chairman Ivan Selin has testified that it would cost the U.S. $82 billion to build and operate its own commercial reprocessing facilities and that the tab for sending the more than 22,000 metric tons of spent fuel piling up at U.S. reactors over to England or France for reprocessing would be about $62 billion.*

a. Are these estimates consistent with your cost estimates?

A. To date, the Board's activities have centered on evaluating the technical activities associated with the current national program on high-level radioactive waste management, which includes those activities related to the transportation, storage, and permanent disposal of high-level waste in a deep geologic repository. We have not estimated the costs associated with any other waste management alternative, such as reprocessing.

b. Isn't it true that the utility industry has shown little recent interest in reprocessing, due to its great cost?

A. Yes, reprocessing in this country has been uneconomical for more than a decade.

Q#6. *The 1992 Waste Policy Act directs the EPA to issue radiation release standards for a repository. However, H.R. 1020 states that the EPA "shall not promulgate...standards for protection of the public from releases of radioactive materials or radioactivity from the repository." Do you think it advisable to bar the expert regulatory agency in this area from fulfilling its function as a defender of public health and the environment?*

A. The Energy Policy Act of 1992 specifies the current method of establishing a safety standard, and directs the National Academy of Sciences (NAS) to evaluate the technical bases for a Yucca Mountain standard. The Act also directs the Environmental Protection Agency (EPA) and the NRC to modify their regulations in accordance with the NAS recommendations. In the Board's judgment, the Congress might consider permitting the NAS to complete its evaluation of the technical bases for a Yucca Mountain standard before revisiting the EPA's role in establishing radiation standards for a repository.

Q#7. *In his prepared testimony Dr. Makhijani criticizes the current radioactive waste categorization for sometimes labeling as "low-level," radioactive wastes that are actually several times more radioactive than other streams of waste. He notes that this has resulted in long-lived plutonium-239 being stored in a now closed low-level waste facility in Maxey Flats, Kentucky, where it leaked out into the environment and forced an expensive clean up effort. Should we follow his advice and move to a system similar to that in use in Sweden, in which disposal methods are determined by the longevity of the waste?*

A. There are a number of different, but equally good, ways to classify low-level radioactive wastes. The system used in this country for identifying Class A, B, and C low-level wastes is based on a combination of factors, including radionuclide longevity, radionuclide concentration, and radiotoxicity. Limiting waste classification only to radionuclide longevity does not account for concentration and toxicity, both very important parameters.

Q#8. *In his prepared testimony, Dr. Makhijani suggests that if we were to adopt the Swedish approach, we'd have approximately 225,000 cubic meters of waste that would have to go to the high-level repository, and that this would force the size of the repository to be increased by an additional 140 to 1,200 acres in addition to the 2,400 acres already needed for spent fuel and reprocessing wastes. Do you agree, and if so, what would this mean for Yucca Mountain's suitability as a repository?*

A. Since underground exploration at the Yucca Mountain site has not entered the proposed repository area, it is very difficult, at this time, to accurately estimate the overall capacity of the Yucca Mountain site. The physical size of the repository required for the disposal of spent fuel and high-level waste will depend on the amount of space required to dissipate the heat generated by those wastes that go into it (i.e., the thermal load) — not the physical volume of the wastes. This is not the case for low-level wastes, which generate essentially no heat. For any repository used for low-level waste disposal, the repository size would only need to correspond to the volume of the low-level waste.

Q#9. *H.R. 1020 establishes a radiation release standard of up to one third of the natural background radiation to an average member of the surrounding population. This exposure level is equivalent to 100 millirems and correlates to one cancer death in every 285 exposed individuals. In contrast, EPA regulations employ a stronger standard, limiting total body radiation exposures to 25 millirems. What are the public health and safety consequences of abandoning the EPA standard for the weaker standard proposed in the bill?*

A. The acceptability of any particular level of risk is a public policy judgment that is beyond this Board's purview. According to currently accepted theories of cancer risk from radiation exposure, an exposure to 100 millirem per year for a full 70-year human lifetime would increase the average cancer risk by about one chance in 285, as indicated in the question. Of course, if the standard were 25 millirem per year, rather than 100 millirem per year, the statistically predicted frequency of cancer incidence due to radiation expo-

sure would be lower by a factor of four. The public health consequences of either standard when applied to Yucca Mountain would be difficult to document due to the currently sparse population in the Yucca Mountain area.

Appendix E
Board Letter to the OCRWM on Yucca Mountain EIS

On December 5, 1995, the Board sent to the OCRWM the attached letter offering comments on the preparation of an environmental impact statement (EIS) for a repository at Yucca Mountain, Nevada, as solicited in a notice in the *Federal Register*. The letter covered the Board's thinking on (1) the alternatives to be evaluated, (2) the quantity of waste to be considered, (3) types of waste to be considered, (4) environmental issues to be examined, and (5) potential revisions to performance standards.

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

December 5, 1995

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

Dear Dr. Dreyfus:

On August 7, 1995, the U.S. Department of Energy (DOE) published in the *Federal Register* a notice of intent to prepare an environmental impact statement (EIS) for a repository at Yucca Mountain, Nevada. The U.S. Nuclear Waste Technical Review Board offers the following comments on the scope of the proposed EIS. These comments reflect concerns that the Board has voiced about the program over the last few years.

Alternatives to be evaluated. The notice of intent identifies three alternatives (in addition to the "no action" alternative) to be evaluated in the proposed EIS. These alternatives are characterized by the thermal loading of the repository (<40, 40-80, and >80 MTHM per acre). In the Board's view, the DOE also needs to identify alternatives to engineered aspects of the repository other than thermal loading including, but not limited to, repository layout and construction, waste disposal package materials and construction, spent fuel ageing, and the materials and emplacement methods to be used for backfilling and closing the repository. Alternatives for the major operational aspects of the repository also should be considered including human-operated alternatives to remote waste emplacement and monitoring. Design and operational features may have significant long-term effects on waste isolation in addition to short-term effects on natural resource consumption, emissions of pollutants during construction and waste package fabrication, and exposure of workers to ionizing radiation. The significance of these effects should be evaluated in the proposed EIS.

Quantity of waste to be considered. The DOE's notice of intent indicates that a maximum repository inventory of 70,000 tonnes of heavy metal in spent fuel and high-level waste will be considered, corresponding to the limit specified in the Nuclear Waste Policy Act. There is a reasonable likelihood, however, that this limit eventually will be revised upward if a repository is developed at Yucca Mountain. The Board recommends that the Yucca Mountain repository EIS also evaluate the environmental effects of

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disposal of the entire foreseeable inventory of both defense and commercial spent fuel (assuming no new orders or license extensions for nuclear power plants) and defense high-level waste in that repository.

Types of waste to be considered. The DOE's notice of intent indicates that only spent nuclear fuel and high-level radioactive wastes will be assumed to be emplaced in a Yucca Mountain repository. The Board recommends that the environmental effects of disposal of other wastes, such as "greater-than-Class C" wastes and surplus plutonium from the nation's nuclear weapons program (in forms analogous to spent fuel or high-level waste), also be evaluated. Although true that the DOE currently has no legal authority to place such wastes into a Yucca Mountain repository, it is reasonable to anticipate that the DOE's authority may be expanded in the future. Thus, one of the alternatives to be evaluated in the EIS should be disposal of a broader range of types of wastes than proposed in the notice of intent.

Environmental issues to be examined. It is unclear from the notice of intent whether the DOE intends to evaluate the significance of potential long-term environmental effects other than releases of radioactive materials from the repository. The Board has long been concerned that the DOE address possible changes to the overlying ecosystem caused by heat and refluxing water vapor and has recommended that the DOE initiate studies to develop the technical basis for projecting the nature, intensity, and scale of those changes. The Board continues to believe that the repository EIS should project the nature and duration of thermally induced ecosystem changes and evaluate their significance for each of the alternatives included in the EIS.

Potential revisions to performance standards. The notice of intent recognizes that the regulatory criteria of the U.S. Environmental Protection Agency and the U.S. Nuclear Regulatory Commission will influence the environmental effects of a Yucca Mountain repository. Those regulatory criteria are to be revised, perhaps substantially, in the coming years. The Yucca Mountain repository EIS needs to consider likely revisions to the regulatory criteria and the effects, if any, that those revisions might have on the environmental effects of repository site characterization, facility development and operation, and long-term performance.

Preparation of this EIS is a critical step in developing a repository at Yucca Mountain. To make an environmentally sound decision about the design and operation of a repository, it is important that an adequate range of alternatives be evaluated. The comments offered by the Board in this letter may tend to expand the scope of the EIS compared to the scope anticipated in the notice of intent. Although an expanded scope may make it more difficult to complete the EIS on schedule, the Board believes that the risk of later challenges to the adequacy of the EIS will be reduced, as will the risk of delay in developing a repository. The Board encourages the DOE to evaluate a broader range of alternatives to improve the decisions that will be based on the EIS and to reduce the risk of later delays in repository development.

The Board appreciates the opportunity to comment on the scope of the EIS for the proposed Yucca Mountain repository. As part of its congressionally mandated responsibilities, the Board plans to periodically review the DOE's progress in preparing this EIS with particular emphasis on the technical analysis upon which the document is based.

Sincerely,

John E Cantlon

John E. Cantlon
Chairman

cc:
Wesley Barnes
Ron Milner
Wendy Dixon

Appendix F

Board Letter to the EPA: Comments on NAS Report, *Technical Bases for Yucca Mountain Standards*

On December 13, 1995, the Board sent the attached letter to the Environmental Protection Agency (EPA) commenting on the National Academy of Sciences'(NAS) report that explored the technical rationale for setting new standards for radiological release from the potential repository site at Yucca Mountain, Nevada. The Board offered the EPA its technical perspective on the following issues: regulatory time period, acceptable level of risk, definition of "critical group", negligible incremental risk, and the definition of human intrusion scenario.

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

December 13, 1995

NAS Report Comments
Radioactive Waste Management Branch (66025)
Office of Radiation and Indoor Air
U.S. Environmental Protection Agency
401 M St. SW
Washington, DC 20460-0001

On behalf of the U.S. Nuclear Waste Technical Review Board, I welcome the opportunity to comment on the National Academy of Sciences' (NAS) report ***Technical Bases for Yucca Mountain Standards.*** This report was prepared to address the following issues which were raised in the Energy Policy Act of 1992:

- Whether a health-based standard based upon doses to individual members of the public from releases to the accessible environment . . . will provide a reasonable standard for the protection of the health and safety of the general public.

- Whether it is reasonable to assume that a system for post-closure oversight of the repository can be developed, based upon active institutional controls, that will prevent an unreasonable risk of breaching the repository's engineered barriers or increasing the exposure of individual members of the public to radiation beyond allowable limits.

- Whether it is possible to make scientifically supportable predictions of the probability that a repository's engineered or geologic barriers will be breached as a result of human intrusion over a period of 10,000 years.

In answering these questions, the NAS report recommends risk-based standards that emphasize protection of individual members of the public. The report recommends that institutional controls not be relied upon as the means to prevent unacceptable exposures to releases from a repository. The report also finds that there is no scientifically supportable way to predict the probability of human intrusion into a repository.

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

The Board believes that the NAS report raises a number of very relevant issues and provides a general direction for the EPA to follow in revising its standards for a Yucca Mountain repository. As the report itself notes, many important details related to the standards involve public policy choices among options. These include:

- defining the time period for which the standards are to be applied,

- defining an acceptable level of risk for the individuals who may be affected by releases from a repository,

- defining the "critical group" of individuals (those most at risk from repository releases) for whom the acceptable risk limit would apply and the "exposure scenario" by which the critical group might be exposed to releases,

- determining whether the risks associated with potential gaseous releases of carbon-14 from a Yucca Mountain repository would constitute a "negligible incremental risk" that need not be restricted by the standards, and,

- defining the human intrusion scenario, if any, to be used to evaluate the susceptibility of the repository to an intrusion event.

These (and possibly other) issues remain to be resolved by the EPA through the rulemaking process. In the following paragraphs, the Board offers its technical perspective on these issues.

Regulatory time period. The NAS report recommends that standards for the performance of a Yucca Mountain repository apply for a time limited only by "the long-term stability of the fundamental geologic regime — a time scale that is on the order of 10^6 years at Yucca Mountain." The report reaches this recommendation, in part, by noting that "potentially important exposures might not occur until after several hundred thousand years." The Board agrees that the fundamental geologic regime at Yucca Mountain should remain reasonably stable and predictable for a time on the order of a million years. However, predictions of repository performance over such long time periods involve considerations other than geologic stability, such as climate change and the performance of engineered barriers. The Board expects that the uncertainties in projected human health risks will increase the farther those projections are extended into the future. Therefore, ***if the EPA's standards for a Yucca Mountain repository are to apply for more than about 10,000 years, appropriate language should be included in the standards to accommodate the associated levels of uncertainty.***

Acceptable level of risk. The NAS report offers some useful perspectives on the levels of risk associated with the current regulation of radiological hazards by the U.S. Environmental Protection Agency and the U.S. Nuclear Regulatory Commission. The Board notes that *the stringency of the standards will depend as much on the definition of the critical group (and the associated exposure scenarios) as on the acceptable risk level prescribed in the standards.*

Definition of "critical group." The Board endorses the general concept of a probabilistic critical group suggested by the NAS panel. *The definition of a critical group suggested by the NAS panel on pages 53-54 of its report seems appropriate.* The Board believes that a probabilistic analysis is the only reasonable way to display both the variabilities in human characteristics and the uncertainties in the locations and lifestyles of members of the critical group. The alternative suggested in the NAS report — a subsistence-farmer critical group — seems overly conservative for a site like Yucca Mountain, which has a harsh climate and lacks arable land. Although there may be some probability that subsistence farming could occur in the general vicinity of Yucca Mountain, a reasonable analysis should consider alternative lifestyles by which individuals could be exposed to releases from a repository. By incorporating alternative lifestyles, a probabilistic approach is able to represent the risks of a repository more realistically than is a deterministic analysis based only on the subsistence-farmer critical group concept. The Board notes the increasing use of probabilistic analyses in other areas of regulation, including evaluation of Superfund sites. Perhaps the concepts used in other areas can be adapted for use with the Yucca Mountain standards.

Negligible incremental risk. The average individual risk associated with gaseous carbon-14 releases from a Yucca Mountain repository has been estimated to be on the order of 10^{-10} per year, assuming a linear relationship between radiation dose and risk. To the Board's knowledge, society rarely, if ever, attempts to regulate risks as small as this. The NAS report suggests that this level of risk should be considered negligible and should not be restricted by the EPA in its Yucca Mountain standards. The NAS report further notes that there may be no risk at all from such releases. The Board believes that *the incremental risk, if any, associated with gaseous carbon-I4 releases from a Yucca Mountain repository should be considered negligible and beyond regulatory concern.*

Definition of human intrusion scenario. The Board agrees that there is no scientific basis for predicting the probability of inadvertent human intrusion over the long times of interest for a Yucca Mountain repository. The NAS report recommends that a "stylized" calculation of the consequences (but *not* the probability) of a human intrusion scenario be carried out to provide assurance that the risk from such a scenario to the public would be no greater than the allowable level of risk for an undisturbed repository. The Board believes that the assumptions underlying even this limited analysis would be highly uncertain and that the results of the analysis would be met with great skepticism. Accordingly, *the Board believes that intrusion analyses should not be required by the EPA's*

standards and should not be used during licensing to determine the acceptability of the candidate repository. The regulations of the U.S. Nuclear Regulatory Commission already contain a number of criteria related to potential human intrusion. If additional analyses like those suggested by the NAS report are to be performed, they should be used only to develop insight into the way a repository might respond to an intrusion. An appropriate vehicle for public review of intrusion analyses might be an environmental assessment or environmental impact statement for the candidate repository.

Finally, the Board notes that the form of the standards may have significant implications for the design of the repository. A primary effect of some components of the geologic repository, including waste packages, some engineered barriers, and geologic strata (e.g., the Calico Hills formation beneath Yucca Mountain), is to delay releases through containment or retardation. If the repository standards are of unlimited duration, there may seem to be little merit in spending money to develop engineered barriers or to explore natural barriers that merely delay releases. Also, it may be difficult to capture the value of delayed releases in standards of the type suggested by the NAS. However, the Board believes that the longer the waste can be contained, or significant releases delayed, the better. Waste packages can probably be designed to provide thousands of years of containment; other engineered and natural barriers may add several thousand to hundreds of thousands of years of delay at a suitable repository site.

In summary, the NAS report provides a clarified scientific basis for the EPA to follow in revising its standards for a Yucca Mountain repository, while recognizing that certain matters of public policy must be considered by the EPA in a rulemaking process. The Board encourages the EPA to keep in mind the limits of scientific knowledge and the need to develop standards consistent with those limits. The Board particularly encourages the EPA to *keep it simple.* The complexity of the previous standards (40 CFR Part 191), including the cumulative release limits, led many observers to conclude that the standards were orders of magnitude more stringent than standards for regulation of other nuclear and non-nuclear activities. The Board believes standards can be developed that will be consistent with the suggestions of the NAS report and, at the same time, will be simple enough and consistent enough with regulations for other radioactive and non-radioactive hazardous wastes to avoid the controversy engendered by the previous standards.

The Board is encouraged by reports that the EPA plans to proceed quickly on a rulemaking that reflects consideration of the NAS recommendations. Doing so will rectify a long-standing area of regulatory uncertainty that the U.S. high-level waste program has had to face.

Sincerely,

John E Cantlon

John E. Cantlon
Chairman

cc:
Robert Fri, NAS

JEC189V3

Appendix G

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 NWTRB's Eleventh Report. Inclusion of DOE's responses does not imply Board concurrence.

Department of Energy
Washington, DC 20585

October 13, 1995

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 1994***, also referred to as the Board's ***Eleventh Report***, that was issued on March 31, 1995. Our response to the Board's recommendations may be found in the enclosure.

As noted in the Board's report, the Civilian Radioactive Waste Management Program has changed significantly with the implementation of the Program Approach. We believe that the modifications already initiated and the further refinements proposed by the Department represent improvements over previous plans. We look forward to receiving the Board's specific comments and recommendations regarding these actions.

We appreciate the Board's concern with our strategies to address complex technical issues such as the waste isolation strategy for a potential repository at Yucca Mountain. We believe that the program has matured to the point where credible strategies can be presented and competently investigated. These strategies, however, represent current thinking and may change as we gain further understanding of Yucca Mountain and other aspects of the waste management system. We have made the development of these technical strategies a high priority, and we look forward to presenting the results of the efforts at an upcoming Board meeting.

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, or if policy redirection is received from Congress, it will be necessary to revise the program.

The Department appreciates the Board's constructive review and insightful recommendations regarding our technical program. We are looking forward to receiving the Board's views on the implementation of our plans supporting the program's 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

DOE Response to the Recommendations of the Nuclear Waste Technical Review Board in its Eleventh Report to the U.S. Congress and the Secretary of Energy March 1995

RECOMMENDATIONS FOR STRUCTURAL GEOLOGY AND GEOENGINEERING

Recommendation 1:

The DOE must articulate a clear waste isolation strategy that provides an understandable technical rationale for prioritizing the studies to be completed under the new program approach.

Response:

The Department agrees that a clear waste isolation and containment strategy and a better definition of the requirements for evaluating the preclosure repository requirements for design and safety are needed. This information will also provide part of the basis for decisions about program priorities. Briefings to the Board in January and April 1995 by the Department and its Management and Operating Contractor provided preliminary thinking on the waste isolation strategy and related topics. These discussions addressed technical issues related to the components of the waste isolation strategy, approaches for resolving issues, and the relationship between the surface-based and underground exploratory studies facility-based investigations, waste isolation and related issues.

A formal description of the elements of the waste containment and isolation strategy is being developed by the Management and Operating Contractor and the U.S. Geological Survey. The description will include the elements of both the natural and the engineered barrier systems that are expected to contribute to safe performance of the site. The waste isolation strategy will consider the recently released recommendations of the National Academy of Sciences regarding environmental standards for the Yucca Mountain site. External distribution and review of this paper is expected in early Fiscal Year 1996.

Recommendation 2:

The Board recommends that the DOE carry out the minimum suite of underground exploration and associated testing outlined in its December 6, 1994, letter prior *to the site-suitability decision to ensure that no major surprises will be encountered during the completion of the deferred program.*

Response:

Although completion of underground exploration and associated testing is dependent upon adequate funding, no site suitability decisions will be made until the requisite scientific and engineering programs are completed. The Department's plans regarding the composition of the exploration and testing program were discussed in detail in our response to your letter of December 6, 1994, and sev-

eral subsequent presentations. These plans will evolve as information is obtained and analyzed. The resultant changes will be presented to the Board during routine meetings as they are developed and approved. If adequate funding for the requisite scientific and engineering programs is not forthcoming, the existing milestones will have to be modified or alternative milestones established.

Recommendation 3:

The DOE should develop a more efficient approach to managing the design and construction of the underground exploratory facility; this approach should include the creation of a geoengineering board of expert consultants and greater accountability and incentives for cost-effective and timely performance of the contractors.

Response:

As discussed at the July 1995 Full Board meeting in Salt Lake City, the Department plans to establish a geoengineering board of expert consultants as recommended by the Board. These consultants will provide experience in areas, such as, geotechnical engineering, construction management, project management, and tunnel boring machine design and modifications. The geoengineering board will review project design products, budgets and schedules and will provide recommendations to management.

The geoengineering board will consist of three members appointed by an executive steering group consisting of: the Yucca Mountain Site Characterization Office's Project Manager and Assistant Manager for Engineering and Field Operations; the Management and Operating Contractor's Assistant General Manager, Nevada, and the Site Construction and Operations Manager. The steering group will provide guidance to the geoengineering board, review recommendations, and direct the formation of *ad hoc* technical review groups.

With regard to greater accountability and incentives for contractors, the program is considering alternative contract structures on a case-by-case basis for each contract. Existing design and construction contracts provide incentives by linking the award fee directly to performance as measured against predetermined objectives, including timeliness and cost-effectiveness.

Recommendation 4:

The DOE should clarify the "low" thermal management strategy and its relation to the overall waste isolation strategy for the repository. Data needed to support this concept should be defined and the means of obtaining the data determined. For the program approach to be credible, the DOE also must clearly define actions that will be taken if a case cannot *be made for a high thermal loading during a license amendment prior to 2008.*

Response:

A thermal loading strategy is needed to focus design activities and as part of the scientific and engineering basis for evaluating compliance of the potential repository with the Department's siting guidelines and with the Nuclear Regulatory Commission's technical criteria. These compliance evaluations will rely on performance predictions for natural and engineered barrier systems under expected repository conditions. To date, computer modeling has been the primary source of information about

the effects of thermal loading on natural and engineered barrier performance. While laboratory tests and limited field tests have provided some data, measurements of repository-induced thermal effects at larger scales will initially be obtained from long-duration tests conducted in the Exploratory Studies Facility. Limited results from these long-duration tests will be available to support the 1998 technical site suitability evaluation and the license application. This situation leads to uncertainties in material performance requirements, design constraints, and overall repository performance. For example, an important uncertainty related to thermal loading is whether relatively high loadings will produce dry conditions around the waste packages and, if so, how long these dry conditions would persist. How moisture is redistributed in the environment surrounding the waste packages is key to predicting repository performance.

The proposed strategy is to focus current design activities on a reference design thermal load that will permit emplacement of at least the statutory maximum within the primary repository area and will produce dry conditions around the waste packages. This is a modification from the "low" thermal management strategy referred to in the Board's recommendation. The current working hypothesis is that an areal mass loading of 80-100 metric tons of uranium per acre will satisfy both repository loading and dry condition criteria. As a working hypothesis, the strategy will maintain prudent levels of flexibility by including alternative areal mass loadings through design options and variations in operational parameters. As laboratory and field test data become available and more refined analyses are performed, a preferred thermal load ultimately will be selected.

The evaluation of technical site suitability in 1998 will rely on assessments of preclosure and postclosure performance of the repository system for the reference design thermal load, and for alternative areal mass loadings. Similarly, the 2001 license application will present the design and performance assessment predictions for a repository system that will safely operate at the selected thermal load, as well as for the alternative loadings. For both of these milestones, the assessments will be based largely on theoretical model predictions consistent with the laboratory and field test data available at the time.

Risks associated with this strategy, such as unexpected and undesirable site responses, will be mitigated by maintaining the flexibility to accommodate a range of areal mass loadings and by pursuing a robust performance confirmation program. A lower loading may be appropriate if testing and modeling show that the negative impacts of heat dominate, such that performance of the natural system cannot be predicted with adequate confidence to meet the regulatory requirements with reasonable assurance.

The preferred thermal loading ultimately will be selected based upon evaluations of the reference design thermal load and alternative thermal loads. System studies will provide the technical basis for the thermal loading decision through evaluations that consider performance, cost, schedule, and operability. Contingency planning and risk assessment will be evaluated. The regulatory risks associated with this strategy will be managed through interactions with the Nuclear Regulatory Commission.

Recommendation 5:

Until contravening evidence becomes available, the DOE should continue to assume that the Ghost Dance Fault is "active" and capable of fault displacement within the repository block.

Response:

As described in the topical report, "Methodology to Assess Fault Displacement and Vibratory Ground Motion Hazards at Yucca Mountain" (YMP/TR-002-NP, DOE, 1994), the Department intends to assess fault displacement hazard, including the Ghost Dance Fault, using a probabilistic approach. Teams made up of experts in paleoseismology, tectonics, and seismology will use available data to develop interpretations of the activity of the Ghost Dance Fault and other faults in the controlled area and to specify the associated uncertainties. The available data will include the results of geologic mapping, paleoseismic studies, and geophysical surveys of these faults. The interpretations will include evaluations of the possibility of both primary displacement, and secondary displacement related to primary displacement on other faults in the site vicinity. The interpretations will be integrated to produce a hazard curve showing the annual probability that various levels of fault displacement will be exceeded along the faults. The results of the fault displacement hazard assessment will be used to develop seismic design inputs for the preclosure period and as input to postclosure performance assessment.

Recommendation 6:

The DOE should reevaluate its approach to seismic hazard estimation and place more emphasis on probabilistic hazard estimates and the insights they can provide to guiding the field investigations and resolution of important questions.

Response:

The Department is currently conducting a probabilistic seismic hazards assessment for a geologic repository at Yucca Mountain. DOE recognizes the potential benefit such an assessment provides by identifying important contributors to hazards and by explicitly including uncertainties. The Board's recommendation is consistent with the approach described in the topical report, "Methodology to Assess Fault Displacement and Vibratory Ground Motion Hazards at Yucca Mountain" (YMP/TR-002-NP, DOE, 1994). The topical report was prepared to document the evolution of DOE's approach to seismic hazard assessment since publication of the Site Characterization Plan (DOE, 1988). It also outlines DOE's integrated approach to seismic hazards assessment and seismic design, of which the hazard assessment methodology represents the first step.

The planning of field investigations takes into account many factors, including results of ongoing work and guidance provided by the Nuclear Regulatory Commission (e.g., NUREG-1451, NRC, 1992). For instance, results from a probabilistic assessment of ground motion hazard for the Exploratory Studies Facility have been factored into recent planning and data analyses. In particular, the major contribution of background seismicity to the hazard has highlighted the importance of the data (e.g., the seismicity catalog) that will be used to evaluate the recurrence of earthquakes for the background source.

RECOMMENDATIONS FOR HYDROGEOLOGY AND GEOCHEMISTRY

Recommendation 1:

The DOE working group on ground-water travel time should attempt to establish as early as possible the conceptual model of the unsaturated zone hydrology that it will use in the computation, so that the specific data requirements can be met at the earliest possible moment. In particular, the effort in isotopic data collection and analysis for ground-water age dating should be accelerated and expanded to increase the spatial resolution.

Response:

The Department agrees that a conceptual unsaturated-zone flow model of the site should be produced as soon as possible to focus data collection. The Department also believes that geochemical analyses and age dating will play an important role in confirming and/or calibrating the unsaturated zone model.

A three-dimensional conceptual site-scale model of the unsaturated zone is currently being calibrated using existing site data (i.e., stratigraphic, saturation, moisture tension, gas pressure, and temperature) from recent boreholes. Sensitivity analyses are being conducted that will aid in understanding the effects of geologic features and heterogeneity on unsaturated flow and will provide guidance to the site characterization program. The model is being used to make *a priori* predictions of the hydrostratigraphic conditions that are encountered in borehole UZ-7A. These predictions will be compared to the conditions encountered during drilling. The model is also being used to analyze the effects of excavation of the ramp on the pneumatic flow system.

At a more detailed level, in two dimensions, the effects of heterogeneity and the conceptual flow model are being investigated as part of the analysis of ground-water travel time. The two-dimensional cross sections through the mountain that are being modeled were selected based on results of the site-scale model (i.e., at locations expected to yield short ground-water travel times). Currently, results indicate that heterogeneity plays an important role in focusing flow into fractures and that the dual-permeability conceptual flow model may be a better representation for matrix/fracture interactions than the equivalent continuum model. In this case, the matrix/fracture interaction term remains as the largest unknown.

Data gathered during construction of the Exploratory Studies Facility (i.e., dripping fractures, moisture contents, and geochemistry of pore water and drips) will play an important role in defining the matrix/fracture interaction term for the more detailed dual-permeability flow model and in confirming and calibrating the site-scale unsaturated zone model. The geochemistry will be analyzed and isotopic age-dating analyses will be conducted on water samples from wet zones and on water extracted from core samples collected at intervals along the ramp during construction. Simulations conducted to replicate the occurrence and age of the water should aid in determining an appropriate fracture/matrix interaction term. To date, only one wet zone has been encountered. The occurrence of this wet zone, at the base of Tiva Canyon, was expected based on predictions using the site-scale model of the unsaturated zone.

Recommendation 2:

Because of the importance of the data that will be gained during underground excavation and because of the significant costs that would be incurred by further delays in construction, the Board recommends that construction of the exploratory facility not be delayed any further.

Response:

The Department agrees that important data regarding the suitability of the Yucca Mountain Site will be gained during underground excavation. The Department also recognizes the cost and schedule impacts of interrupting construction of the Exploratory Studies Facility. Under the Administration's budget proposal, underground excavation would be conducted concurrently with testing, design, and other activities. However, under reduced funding scenarios, the priority of underground excavation must be balanced against other program priorities.

RECOMMENDATIONS FOR THE ENGINEERED BARRIER SYSTEM

Recommendation 1:

In performing its "focused MGDS development" approach, the DOE must ensure that all assumptions about the repository system are clearly articulated, necessary, achievable and consistent with the current regulations.

Response:

The Board raises valid concerns regarding the inherent problems associated with making design assumptions which, as recognized by the Board, must nevertheless be made. The assumptions are revised periodically and become design requirements only after passing through an appropriate quality-controlled substantiation process. The Control Design Assumption document provides a detailed description of this process. To minimize the risks, a number of measures have been taken. These measures include requirements to justify the need and to state the rationale for the assumptions. Technical groups (e.g., Systems Engineering, Performance Assessment, Licensing, Design Engineering) review the assumptions prior to final approval.

The concerns expressed by the Board regarding a few specific assumptions will be reviewed carefully and will be considered in the course of conceptual design and assumption revisions. This review will be in the next revision of the Control Design Assumptions document, which is currently underway.

Recommendation 2:

To support waste package performance predictions, the DOE must develop a formal long-term corrosion research program plan and must support the program at an appropriate and consistent level. Failure to do so risks delaying the repository opening.

Response:

The Department has defined a long-term corrosion research program, which was described in the Scientific Investigation Plan for Metal Barrier Selection and Testing (SIP-CM-01) Rev. 2, January 31, 1995. The program was detailed in an Activity Plan for Long-Term Corrosion Studies (E-20-18(b)) Rev. 1, December 27, 1994. These detailed plans and the funding requirements were included in the program Plan. The Department recognizes the importance of this effort in supporting waste package design and performance prediction. Budgets and activities are assessed periodically to accommodate changes in program direction. The Department will evaluate the programmatic schedule impacts associated with potential funding decrements to the corrosion studies against the other program priorities.

Recommendation 3:

The Board believes that the DOE should address the issue of general repository requirements for both civilian and defense spent fuel; specific repository requirements applicable to DOE-owned spent fuel should be developed.

Response:

The Department agrees with this recommendation. The Department has taken the position that its spent nuclear fuel is authorized for geologic disposal under the Nuclear Waste Policy Act, as amended. Therefore, in June 1994 the DOE Spent Nuclear Fuel Steering Group was established. This group was formed to: recommend resolution of key issues regarding the disposal of the Department's spent nuclear fuel; support issue resolution by identifying activities required to provide the necessary data or analyses; and ensure integration between the activities of the Offices of Civilian Radioactive Waste Management and Environmental Management.

The Offices of Civilian Radioactive Waste Management and Environmental Management recognize the need to establish preliminary requirements applicable to the disposal of the Department's spent nuclear fuel in a repository. To this end, we are in the process of identifying key requirements potentially applicable to the acceptance, transportation, and disposal of this fuel. These requirements would be used by the Office of Environmental Management to assist in the near-term planning for the safe storage of this fuel at existing sites and the preparations for its ultimate disposal. Once requirements are incorporated into the program's technical requirements baseline, the program will evaluate the spent fuel as part of our design and development activities.

Recommendation 4:

The Board recommends that the DOE immediately initiate studies to determine what waste forms for Hanford's encapsulated strontium and cesium salts will be accepted for repository disposal.

Response:

The Office of Civilian Radioactive Waste Management, in collaboration with the Office of Environmental Management, is investigating the issues involved with potential disposal of encapsulated cesium (Cs) and strontium (Sr) salts in a geologic repository. The majority of the capsules are primarily Cs-137 and Sr-90 with half-lives of about 30 years. However, there are concerns about the solubility of

the residual radioactive material and its potential contribution to subsystem and total system performance in a repository that must be addressed. Various pre-processing options for Hanford's cesium and strontium capsules are being evaluated by the Office of Environmental Management. As these options mature and are more clearly defined, their impacts to repository and transportation conceptual designs and design requirements will be evaluated.

Recommendation 5:

The Board recommends that DOE's performance assessments address glass waste forms and other defense waste forms at a sufficient level of detail to assist the Office of Environmental Management as it makes decisions about waste forms and waste packages. The Board also recommends that the DOE not delay the completion of its revised total system life cycle cost estimate.

Response:

The Office of Civilian Radioactive Waste Management recognizes the need to assist the Office of Environmental Management in its decision-making process regarding the many DOE-owned fuels that may ultimately require disposal in an underground repository. The DOE Spent Nuclear Fuel Steering Group that has been established will address these waste forms, and studies have been identified to further define program needs.

The Department has performed a number of total system performance assessments. For example, Sandia National Laboratories issued "Performance Assessment of the Direct Disposal in Unsaturated Tuff of Spent Nuclear Fuel and High-Level Waste owned by the U.S. Department of Energy" (SAND 94-2563, March 1995, 3 vol) for the Office of Environmental Management. The latest formal assessment of Yucca Mountain (TSPA-1995) was completed this year. As modeling capability and material and system response information have increased, these assessments have become more detailed. Among other things, the 1995 assessment evaluates the system and subsystem compliance identified in 10 CFR Part 60 for waste packages containing spent nuclear fuel and high-level waste glass.

With regard to the status of the total system life-cycle cost estimate, the current exercise began in November 1994 and was completed in September 1995. In order to improve the level of assurance on the validity of the estimate, an Independent Cost Estimate review was performed. The final report has been sent to the Board.

RECOMMENDATIONS FOR RISK AND PERFORMANCE ANALYSIS

Recommendation 1:

The DOE needs to articulate a clear and coherent waste isolation strategy that takes into account the salient characteristics of the Yucca Mountain site, the ability and desirability of engineered barriers to enhance waste isolation, and postulated changes in the basic standard and regulations that will be used to assess the performance of the proposed repository.

Response:

As described in the response to the first recommendation in the section on Structural Geology and Geoengineering, the Department agrees that a clear waste isolation and containment strategy and a better definition of the requirements for evaluating the preclosure repository requirements for design and safety are needed. This information will also provide part of the basis for decisions about program priorities. Briefings to the Board in January and April 1995 by the Department and its Management and Operating Contractor provided preliminary thinking on the waste isolation strategy and related topics. Included in those discussions were technical issues related to the components of the waste isolation strategy, approaches for resolving issues, and the relationship between the surface-based and underground exploratory studies facility-based investigations and the waste isolation and related issues.

As explained in the previous response, a formal description of the elements of the waste containment and isolation strategy is being developed by the Management and Operating Contractor and the U.S. Geological Survey. The description will include the elements of both the natural and the engineered barrier systems that are expected to contribute to safe performance of the site. External distribution and review of this paper is expected in early Fiscal Year 1996.

The issue of how to plan for changes in the repository regulatory standard has been carefully considered. The most obvious impact on the site testing program is to focus attention on the adequacy of saturated zone testing to provide the basis for dilution factors that will be needed for dose calculations. Fiscal Year 1996 and out-year planning will carry this issue as a part of the planning basis that will be updated as new information and analysis become available.

Recommendation 2:

In light of the successful completion of the 1993 round of total system performance assessments (TSPA), the Board encourages the DOE to continue its program of iterative performance assessment.

Response:

The Department concurs with the Board's observation that the last TSPA iteration (TSPA-1993) was successfully completed. DOE has embarked on the next iteration (TSPA-1995), which is intended to be of limited scope and to focus primarily on utilizing more representative models for the waste package/engineered barrier system (EBS) components of the overall system. The goals and objectives of this next iteration (especially as they relate to the waste package/EBS) were presented to the Board during the Full Board meeting in April 1995. A substantial portion of the October 1995 Full Board meeting has been allocated to discuss the results and conclusions of this next TSPA iteration.

Recommendation 3:

The DOE needs to make a management and organizational commitment to develop more systematic and effective ways of using total system performance assessment to guide site characterization and to set priorities at Yucca Mountain. The Board suggests that the DOE learn from the manner in which performance was and is being used for the WIPP in New Mexico.

Response:

The Department uses many mechanisms to guide site characterization and to set testing and design priorities, including the results of total system performance assessment. Performance assessment has been used to assist in the development of the waste containment and isolation strategy. The uncertainties in the different process-level models have been used as a basis for setting general testing priorities, as described to the Board at the January 1995 meeting. Performance assessment has been used to define process model development and testing priorities in planning guidance given to site characterization and design elements of the program for the Fiscal Year 1996 annual planning process.

The program has conducted similar sensitivity / uncertainty analyses using performance assessment as reported to the Board by the Waste Isolation Pilot Plant (WIPP) Project in New Mexico. In these analyses, the most sensitive parameter is the aqueous percolation flux and the distribution of that flux in space due to heterogeneities. However, care must be taken in directly using performance assessment results to prioritize data collection because the results are predicated on the conceptual uncertainty associated with the process level models that are the foundation of the performance assessment analyses. If the conceptual understanding is not sufficient, then it is meaningless to address parameter uncertainty. If the priorities placed on site characterization activities at WIPP are examined carefully, it becomes evident that they were driven by conceptual issues (and external peer review organizations such as the National Academy of Sciences). A case in point at WIPP is the issue of gas production affecting fluid migration and salt creep. This process was not included in early performance assessment analyses and was added based on input from external reviewers.

The Department will continue to use performance assessment analyses as one input to the planning and prioritization process. However, DOE will also continue to address other aspects of site characterization that effect the prioritization process such as irretrievable data, scientific confidence, and baseline understanding.

Appendix H
Nuclear Waste Technical Review Board Publications

The following publications 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 sub-

jects: 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." Rec-

ommendations 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.

Report to the U.S. Congress and the Secretary of Energy: 1994 Findings and Recommendations, March 1995

This report summarizes Board activities during 1994. It covers aspects of the DOE's Program Approach, their emerging waste isolation strategy, and their transportation program. It also explores the Board's views on minimum exploratory requirements and thermal-loading issues. The report focuses a chapter on the lessons that have been learned in site assessment from projects around the world. Another chapter deals with volcanism and resolution of difficult issues. The Board also details its observations from its visit to Japan and the Japanese nuclear waste disposal program. Findings and recommendations in the report center around structural geology and geoengineering, hydrogeology and geochemistry, the engineered barrier system, and risk and performance analysis.

Disposal and Storage of Spent Nuclear Fuel — Finding the Right Balance, March 1996

This special report caps more than two years of study and analysis by the Board into the issues surrounding the need for interim storage of commercial spent nuclear fuel and the advisability and timing of the development of a federal centralized storage facility. The Board concludes in the report that the Department of Energy's efforts should remain focused on permanent geologic disposal and the site investigations at Yucca Mountain, Nevada; that planning for a federal centralized spent fuel storage facility and the required transportation infrastructure be begun now, but actural construction delayed until after a site-suitability decision is made about the Yucca Mountain site; that storage should be developed incrementally; that limited, emergency backup storage capacity be authorized at an existing nuclear facility; and that, if the Yucca Mountain site proves unacceptable for repository development, other potential sites for both centralized storage and disposal be considered.

Appendix I
Report by Letter to Congress and the Secretary of Energy

On December 13, 1995, the Board reported to Congress and the Secretary of Energy by letter, offering the Board's positive reaction to recent progress at the Yucca Mountain Project site. The letter contained an enclosure: a letter to Daniel Dreyfus, the director of the Office of Civilian Radioactive Waste Management, commenting on the progress and other specifics from the Board's October 1995 meeting in Arlington, Virginia.

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

December 13, 1995

The Honorable Hazel O'Leary
Secretary of Energy
U.S. Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585

Dear Secretary O'Leary:

At the Nuclear Waste Technical Review Board's October 1995 meeting, the DOE's Office of Civilian Radioactive Waste Management (OCRWM) reported on some important progress recently made in its Yucca Mountain site-characterization and repository development program. In accordance with our legislative responsibilities, we would like to bring this encouraging news to your attention. As you know, the OCRWM's program has received significant criticism — some warranted, some not — since its inception. Indeed, our Board has made many suggestions for its improvement. Recently, substantial funds were cut from the program's budget while the agenda was expanded conditionally to include the storage of commercial spent fuel.

Specifically, as discussed in the enclosed letter to OCRWM Director, Dr. Daniel Dreyfus, the Board was very pleased to hear about progress in excavating underground at Yucca Mountain; the tunnel boring machine is now advancing at very close to commercial rates. It has reached the level of the proposed repository, and the program is acquiring important data about the suitability of the site. Several of our members and staff returned recently from examining the tunnel. So far, the rock at the repository level looks very good, and no significant water has been found at the repository level. The Board also was very pleased to see recent progress in the development of the waste isolation strategy, which is becoming increasingly well defined and coherent. In combination with recent advances in performance assessment, this strategy should enable the OCRWM to undertake an aggressive delineation of program priorities and allocate available funds more efficiently among the various activities of the groups of scientists and engineers working at Yucca Mountain.

The Board is very encouraged about these developments and believes that real progress has been and continues to be made by the OCRWM both in the conduct and in the management of its investigations of the Yucca Mountain site. In the Board's

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judgment, the timely completion of these activities is critical to the future success of the DOE's entire high-level radioactive waste management program.

Thank you for your consideration.

Sincerely,

John E Cantlon

John E. Cantlon
Chairman

Enclosure

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

December 13, 1995

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

Dear Dr. Dreyfus:

Thank you for participating in the Nuclear Waste Technical Review Board's October meeting in Arlington, Virginia. The Board found this meeting to be extremely interesting and informative. The Board is impressed with the progress the Office of Civilian Radioactive Waste Management (OCRWM) has made both in analytic studies and in its underground exploration at Yucca Mountain. The information provided during the course of the two days stimulated a great deal of discussion among Board members during and after the meeting. The Board would like to take this opportunity to provide you with some preliminary feedback from the meeting and our discussions.

It appears that significant progress is being made in developing a clearly defined and coherent waste isolation strategy. As you know, the Board believes that this kind of strategy is needed to help establish and maintain program priorities. Now that program funding is being reduced, having such a strategy is more important than ever. Some critical assumptions underlying the draft waste isolation strategy do require further examination, especially the amount and character of future percolation flux, the duration of low relative humidity in the vicinity of the waste package, and the amount and duration of dilution in the saturated zone. Once completed, the results may dictate further modification of the strategy and of the program's priorities and study plans.

The latest round of total system performance assessment (TSPA-95) represents a major improvement over its 1993 iteration. The increased level of detail in modeling the near-field thermo-hydrological environment, waste package degradation, engineered barriers, and other aspects of repository performance provides new insights that should enable the OCRWM to decide what activities to emphasize during the coming months. The TSPA-95 also should be useful when explaining repository development issues and activities to stakeholder groups. The Board hopes the OCRWM uses the TSPA-95 aggressively to focus scarce resources on those activities that are of the highest priority.

The Board has long believed that engineered barriers are an important component of a multi-barrier repository system. The Board is pleased to see that

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engineered barriers are playing a more significant role in the draft waste isolation strategy and that TSPA-95 included preliminary evaluations of the performance of some potential engineered barriers, including backfill, cathodic protection of waste packages, and capillary (flow diversion) barriers. The Board generally believes that the longer the waste can be contained, or significant releases delayed, the better. Waste packages can probably be designed to provide thousands of years of containment; other engineered and natural barriers may add several thousand to hundreds of thousands of years of delay at a suitable repository site. Therefore, the DOE should encourage innovative thinking in the design and possible use of other engineered barriers, such as suitable waste package fillers.

The Board is pleased to hear that the performance of the tunnel boring machine (TBM) continues to improve, primarily due to favorable geology, a more realistic definition of what constitutes safe tunnel support, increased crew experience, and improved management. The TBM is now well into the proposed repository horizon, and, with continuing favorable geology and effective use of the board of expert consultants, TBM operations should continue at what are close to commercial rates. Underground excavation has already revealed features — some anticipated, others not — that contribute to our understanding of the Yucca Mountain geology. This level of understanding could not have been determined from surface-based investigations alone. The Board continues to believe that more underground exploration of the repository block is needed.

The Board recognizes that these are times of great apprehension for the program. Reduced funding and temporarily uncertain regulatory criteria dictate that the DOE carefully evaluate ongoing and proposed site-characterization activities at Yucca Mountain. The program must remain flexible yet focus on those activities that can be identified now as being high priority; contingency plans should be developed to address those activities that await regulatory clarification and congressional action. Finally, the program must continue to improve its organizational and managerial efficiency to carry out all of the above in a timely manner, thus strengthening the confidence of Congress and the stakeholders.

Once again, thank you for supporting an excellent meeting.

Sincerely,

John E Cantlon

John E. Cantlon
Chairman

References

AECL (Atomic Energy of Canada Limited). 1994. *Summary of the Environmental Impact Statement on the Concept for Disposal of Canada's Nuclear Fuel Waste*. AECL-10721. September 1994. Chalk River, Ontario: AECL Research.

Bartholomew, S. H., Chairman, Yucca Mountain Project Board of Consultants. 1995/96. *Report to the Project Control Group*. #1 11/95, #2 1/96. Chico, California: S.H. Bartholomew, Inc.

Buscheck, T. A., Nitao, J. J., and Ramspott, L. 1996. "Localized dry-out: An Approach for Managing the Thermo-hydrological Effects of Decay Heat at Yucca Mountain." in *Scientific Basis for Nuclear Waste Management XIX, Boston, Massachusetts, November 27-December 1, 1995*. 1996. Pittsburgh, Pennsylvania: Materials Research Society.

DOE (Department of Energy). Office of Civilian Radioactive Waste Management. 1988. *Section 175 report: Secretary of Energy's Report to the Congress Pursuant to Section 175 of the Nuclear Waste Policy Act, as Amended*. December 1988. DOE/RW-0205. Washington, D.C.

———. Office of Civilian Radioactive Waste Management. 1993. *Topical Report: Evaluation of the Potentially Adverse Condition "Evidence of Extreme Erosion During the Quaternary Period" at Yucca Mountain, Nevada*. YMP/92-41-TPR. March 1993. Las Vegas, Nevada.

———. High-Level Waste Division. 1994a. *High-Level Waste Borosilicate Glass: A Compendium of Corrosion Characteristics*. DOE-EM-0177 (Vols. 1-3). March 1994. Springfield, Virginia: National Technical Information Service.

———. Office of Civilian Radioactive Waste Management. 1994b. *Civilian Radioactive Waste Management Program Plan*. DOE/RW-0458 (Vols. 1-3). December 19, 1994. Washington, D.C.

———. Office of Civilian Radioactive Waste Management. 1995. *Technical Basis Report for Surface Characteristics, Preclosure Hydrology, and Erosion*. YMP/TBR-0001. 1995. Las Vegas, Nevada.

———. Office of Civilian Radioactive Waste Management. 1996. "Statement of Daniel A. Dreyfus, Director, Office of Civilian Radioactive Waste Management, before the House Appropriations Committee, Subcommittee on Energy and Water Resources, March 26, 1996." March 26, 1996. Washington, D.C.

EOP (Executive Office of the President). Office of Management and Budget. 1995. Letter from Alice M. Rivlin, Director, to Chairmen and Ranking Members of the House and Senate Appropriations Committees providing the Administration's views on H.R. 1905. October 13, 1995. Washington, D.C.

INTERA, Inc. 1994. *Total System Performance Assessment — 1993: An Evaluation of the Potential Yucca Mountain Repository*. March 1994. Las Vegas, Nevada.

NAS/NRC (National Research Council.) Committee on Technical Bases for Yucca Mountain Standards. 1995a. *Technical Bases for Yucca Mountain Standards*. 1995. Washington, D.C.: National Academy Press.

———. Committee on Yucca Mountain Peer Review. 1995b. *Review of U.S. Department of Energy Technical Basis Report for Surface Characteristics, Preclosure Hydrology, and Erosion*. 1995. Washington, D.C.: National Academy Press.

NRC (*Nuclear Regulatory Commission) v People Against Nuclear Energy*. 400 U.S. 766 (1983).

NWTRB (Nuclear Waste Technical Review Board). 1990. *First Report to the U.S. Congress and the U.S. Secretary of Energy.* March 1990. Washington, D.C.

——. 1992. *Sixth Report to the U.S. Congress and the U.S. Secretary of Energy.* December 1992. Arlington, Virginia.

——. 1993a. *NWTRB Special Report to Congress and The Secretary of Energy*. March 1993. Arlington, Virginia.

——. 1993b. *Underground Exploration and Testing at Yucca Mountain: A Report to Congress and the Secretary of Energy*. October 1993. Arlington, Virginia.

——. 1994a. *Full Board Meeting, Arlington, Virginia, January 12, 1994 (transcript of proceedings).* January 1994. Arlington, Virginia.

——. Panel on the Engineered Barrier System. 1994b. *Meeting on Current and Planned EBS Research, Pleasanton, California, March 10-11, 1994 (transcript of proceedings)*. March 1994. Arlington, Virginia.

——. 1994c. *Report to the U.S. Congress and the Secretary of Energy: January to December 1993.* May 1994. Arlington, Virginia.

——. 1994d. Letter from John E. Cantlon, Board Chairman, to Daniel A. Dreyfus, Director, Office of Civilian Radioactive Waste Management, "Comments on Exploration and Testing for Site Suitability Determination." December 6, 1994.

——. 1995a. *Winter Board Meeting, Beatty, Nevada, January 10-11, 1995 (transcript of proceedings).* January 1995. Arlington, Virginia.

——. 1995b. *Report to The U.S. Congress and The Secretary of Energy — January to December 1994 — Findings and Recommendations.* March 1995. Arlington, Virginia.

——. 1995c. *Spring Board Meeting, Las Vegas, Nevada, April 19-20, 1995 (transcript of proceedings).* April 1995. Arlington, Virginia.

——. Panel on Transportation & Systems. 1995d. *Meeting, Arlington, Virginia, June 14, 1995 (transcript of proceedings).* June 14, 1995. Arlington, Virginia.

——. Panel on Hydrogeology & Geochemistry. 1995e. *Meeting, Burlingame, California, June 26-27, 1995 (transcript of proceedings).* June 1995. Arlington, Virginia

——. 1995f. *Fall Board Meeting, Arlington, Virginia, October 17-18, 1995 (transcript of proceedings).* October 1995. Arlington, Virginia.

——. 1995g. Letter From John E. Cantlon, Board Chairman, to the Chairmen and Ranking Minority Members of the Appropriations and Authorization Committees of Congress and to the Secretary of Energy. December 13, 1995. Arlington, Virginia.

——. 1996a. *Winter Board Meeting, Las Vegas, Nevada, January 10-11, 1996, (transcript of proceedings).* January 1996. Arlington, Virginia.

——. 1996b. *Disposal and Storage of Spent Nuclear Fuel — Finding the Right Balance.* March 1996. Arlington, Virginia.

Pacific Northwest Laboratory. 1992. *Preliminary Total-System Analysis of a Potential High-Level Nuclear Waste Repository at Yucca Mountain*. March 1992. Richland, Washington.

Peterson Consulting Limited Partnership. 1995. *Independent Management and Financial Review: Yucca Mountain Project, Nevada.* Final Report. July 15, 1995. Denver, Colorado.

Sandia National Laboratory. 1992. *TSPA 1991: An Initial Total-System Performance Assessment*. SAND91-2795. July 1992. Albuquerque, New Mexico.

——. 1994. *Total-System Performance Assessment for Yucca Mountain — SNL Second Iteration (TSPA-93).* SAND93-2675 (Vols. 1&2). April 1994. Albuquerque, New Mexico.

TRW Environmental Safety Systems, Inc. (OCRWM Management & Operating Contractor). 1995a. *Systems Study of Options for Characterizing the Calico Hills Nonwelded Hydrogeologic Unit at Yucca Mountain, Nevada.* B00000000-01717- 5705-00021. June 30, 1995. Las Vegas, Nevada.

——. 1995b. *Strategy for Waste Containment and Isolation for the Yucca Mountain Site: Preliminary YMSCO Review Draft*. October 9, 1995. Las Vegas, Nevada.

——. 1995c. *Total-System Performance Assessment — 1995: An Evaluation of the Potential Yucca Mountain Repository*. B00000000-0717-2200-00099-Rev. 01. November 1995. Las Vegas, Nevada.

——. 1995d. *Controlled Design Assumption Document, Revision 2*. B00000000-0717- 4600-00032. December 19, 1995. Las Vegas, Nevada.

——. 1996a. *Mined Geologic Disposal System Advanced Conceptual Design (Revised) Report, Volume III: Engineered Barrier Segment Waste Package.* B00000000-0717- 5705-00027 Draft. January 1996. Las Vegas, Nevada.

——. 1996b. *Mined Geologic Disposal System Advanced Conceptual Design (Revised) Report.* B00000000-0717-5705-00027 Draft (Vols. I-IV). January 1996. Las Vegas, Nevada.

——. 1996c. *Strategy for Evaluating Waste Containment and Isolation for the Yucca Mountain Site*. Comment Resolution Draft. January 10, 1996. Las Vegas, Nevada.

Vermont Yankee Nuclear Power Corp. v Natural Resource Defense Council, Inc. 435 U.S. 519 (1978).

Laws, Legislation, and Hearings

Energy Act — U.S. Congress. 1992. *Energy Policy Act of 1992*, Public Law 102-486. 102nd Cong., 2nd Sess., 1992. Washington, D.C.: Government Printing Office.

H.R. 1020 — U.S. Congress. House. 1995. *H. R. 1020, to Amend the Nuclear Waste Policy Act of 1982.* 104th Cong., 1st Sess., February 23, 1995.

House 1995a — (U.S. Congress. House). Subcommittee on Energy and Water Development. 1995a. *Hearings before a Subcommittee of the Committee on Appropriations for Energy and Water Development Appropriations for 1996.* 104th Cong., 1st Sess., March 16, 1995. Washington, D.C.: Government Printing Office.

House 1995b — (U.S. Congress. House). Subcommittee on Energy and Power. 1995**.** *Hearings on High-Level Nuclear Waste Policy, June 28, June 30, and July 12, 1995.* 104th Cong., 1st Sess., June 30-July 12, 1995. H. Hrg. 104-24. Washington, D.C.: Government Printing Office.

NWPAA — U.S. Congress. 1987. *Nuclear Waste Policy Amendments Act of 1987.* 97th Cong., 2nd Sess., 1987. Washington, D.C.: Government Printing Office.

S. 167 — U.S. Congress. Senate. 1995. *S. 167, to Amend the Nuclear Waste Policy Act of 1982, and for other purposes*. 104th Cong., 1st Sess., January 5, 1995.

S. 1271 — U.S. Congress. Senate. 1995. *S. 1271, Nuclear Waste Policy Act of 1995.* 104th Cong., 1st Sess., September 25, 1995. Washington, D.C.: Government Printing Office.

Senate 1995a — (U.S. Congress. Senate.). Committee on Energy and Natural Resources. 1995. *Hearing on draft Legislation to Amend the Nuclear Waste Policy Act.* 104th Cong., 1st Sess. March 2, 1995. S. HRG. 104-56. Washington, D.C.: Government Printing Office.

Senate 1995b — (U.S. Congress. Senate.) Committee on Energy and Natural Resources. 1995. *Hearing on S. 1271, Nuclear Waste Policy Act of 1995.* 104th Cong., 1st Sess., December 14, 1995. S. HRG. 104-XX. Washington, D.C.: Government Printing Office.

Standards and Regulations

10 CFR 60 (*Code of Federal Regulations*). Title 10, *Energy*. Part 60. "Disposal of High- Level Radioactive Wastes in Geologic Repositories." Washington, D.C.: U.S. Government Printing Office.

10 CFR 960 (*Code of Federal Regulations*). Title 10, *Energy*. Part 960, "General Guidelines for the Recommendation of Sites for Nuclear Waste Repositories." Washington, D.C.: U.S. Government Printing Office.

40 CFR 1508.8 (*Code of Federal Regulations*). Title 40, *Protection of Environment*

Part 1508 "Terminology and Index." Section 1508.8 "Effects."

40 CFR 191 (*Code of Federal Regulations*). Title 40, *Protection of Environment.* Part 191, "Environmental Radiation and Protection Standards for Management and Disposal of High-Level and Transuranic Radioactive Wastes." Washington, D.C.: U.S. Government Printing Office.

Glossary

Accessible environment: As defined in TSPA-95, the rock more than five kilometers from the repository.

Advection: The transportation of solutes by the bulk mass of flowing fluid.

Areal mass loading: The concentration of emplaced spent fuel, averaged over the area of the repository and expressed in kilograms per square meter or in metric tons per acre.

Areal power density: The concentration of thermal energy *per unit of time* 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.

Assemblies: A group of mechanically linked rods or tubes that contain nuclear fuel.

Backfill: Materials placed into underground excavated areas.

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

Biota: The plant and animal life of a region.

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.

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.

Canister: The structure surrounding a waste form that facilitates handling, storage, transportation, and/or disposal. Before emplacement in a repository, the canister may be placed in a disposal container.

Capillary barrier: An engineered barrier consisting of two or more layers of sand or gravel. Pore sizes in the layers are tailored so that capillary forces will direct water away from waste packages.

Cathodic protection: When two different metals touch each other in the presence of an electrolyte (such as water containing dissolved salts) the more electropositive metal corrodes first, potentially inhibiting the corrosion of the other metal.

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

Corrosion-allowance: Materials that fail by generalized corrosion.

Corrosion-resistant: Materials that fail primarily by localized corrosion, and that tend to fail more slowly than corrosion-allowance materials.

Critical group: The group representative of those individuals in the population, who, based on cautious, but reasonable assumptions, have the highest risk from repository releases.

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

Defense high-level waste: Nuclear high-level waste generated by defense programs, as distinguished from waste generated by commercial and research facilities.

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 rate: The rate at which radioactive nuclides dissolve.

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

Engineered barrier system (EBS): The constructed, or engineered, components of a disposal system designed to retard or prevent the release of radionuclides from the underground facility or into the geohydrologic setting. It includes the waste forms, fillers, waste containers, shielding, material placed over and around such containers, and backfill materials.

Environmental impact statement: Analysis of the effect of a proposed facility on the surrounding environment, as required by Section 102 (2)(c) of the National Environmental Policy Act.

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 studies facility (ESF): The underground tunnels and alcoves at Yucca Mountain used for exploration and testing of the site's suitability to host a geologic repository.

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

Filler: Material used to occupy void spaces in a waste package.

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.

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 rod: A rod or tube, typically made out of zircaloy, into which fuel material, usually in the form of uranium oxide 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: See **repository**.

Greater-than-Class C waste: Waste that contains radionuclides in concentrations exceeding the limits for Class C wastes as defined in 10 CFR 61 and is generally not suitable for disposal in shallow land burial facilities.

Groundwater: Water that exists or flows in a zone of saturation beneath the land surface.

High-level waste: (1) Irradiated reactor fuel, if disposed of as a waste, (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.

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.

Hydrology: 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. Groundwater is considered to be a prime means by which radionuclides (atoms that are radioactive) could be transported from the repository to the accessible environment.

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.

Infiltration flux: The movement of water below soil depth per unit area per unit time.

Invert: Materials added to the bottom of a tunnel to form a level surface.

Matrix: The solid framework of a porous system.

Multipurpose canister: A canister used to accommodate spent nuclear fuel during handling, transportation, and storage operations.

Neutron absorber: Substance able to absorb neutrons (i.e. capture without fission).

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

Percolation flux: The movement of water through the repository horizon per unit area per unit time.

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.

Pitting factor: The ratio of pit depth to general corrosion depth.

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.

Pneumatic: Of or pertaining to air, especially the movement of air through Yucca Mountain.

Preclosure: That time prior to the closure of the repository.

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. Units of radioactivity are the curie (Ci) and the becquerel (Bq).

Radiolysis: The chemical decomposition of material by ionizing radiation.

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

Radionuclide transport: The movement of radionuclides, generally in liquid or gas forms, through a rock formation.

Refluxing: Flowing back, especially water that is vaporized near waste packages, migrates to cooler areas, condenses, then flows back toward the waste packages.

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.

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 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.

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.

Site assessment: The full range of activities needed to evaluate the suitability of the Yucca Mountain site including: site characterization; laboratory research; performance assessment; and design of the repository, waste packages, and engineered barriers.

Site characterization: See **characterization**.

Site suitability: The Yucca Mountain site will be suitable for construction of a repository if there is shown to be a high probability that the site, along with the appropriate engineered barriers, can provide long-term waste isolation.

Socioeconomic impacts: The impact on the economic and social behavior of a region.

Solubility limit: The maximum amount of any given radionuclide that will dissolve in a unit volume of water. It is a function of temperature and water chemistry.

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

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.

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.

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 the radioactive decay of wastes (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.

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

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 boring machine (TBM): A machine used to excavate a tunnel, it replaces tunneling by drill-and-blast methods.

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.

Waste form: The radioactive waste materials and any encapsulating or stabilizing matrix.

Waste isolation: Separation of waste from the environment so that amounts and concentrations of radioactive material reentering the environment will be kept within prescribed limits.

Waste package: The waste form, any fillers, 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.