

January 1997

# NUCLEAR WASTE

## Impediments to Completing the Yucca Mountain Repository Project



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**Resources, Community, and  
Economic Development Division**

B-275449

January 17, 1997

The Honorable Frank Murkowski  
Chairman  
The Honorable Dale Bumpers  
Ranking Minority Member  
Committee on Energy and Natural Resources  
United States Senate

The Honorable Thomas J. Bliley, Jr.  
Chairman  
The Honorable John D. Dingell  
Ranking Minority Member  
Committee on Commerce  
House of Representatives

The Congress is expressing growing concern about the pace, direction, and cost of the Department of Energy's (DOE) program to permanently dispose of the highly radioactive waste produced by civilian nuclear power plants and DOE's nuclear weapons activities. The centerpiece of the disposal program is the scientific investigation of Yucca Mountain, Nevada, as a candidate site for disposing of the waste in a geologic repository. The Nuclear Waste Policy Act of 1982, as amended, requires the Secretary of Energy to determine, on the basis of the investigation, if the site is suitable for a repository and, if this determination is positive, recommend to the President that the site be selected for that purpose. If the site is formally selected, DOE must apply to the Nuclear Regulatory Commission (NRC) for authorization (a license) to construct a repository there. DOE's current objective is to begin disposing of waste in the repository in 2010, or 12 years later than had been originally expected.

The perceived lack of progress on the repository project has led to renewed debate on the need for a federal facility to store waste until the repository has been constructed and a reduced allotment of appropriations for the project in fiscal year 1996. The administration had requested \$472 million for the project, or almost \$100 million more than the project's previous appropriation allotment. However, the project was allocated \$250 million of the appropriations for the entire disposal

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program, or 53 percent of the amount originally requested.<sup>1</sup> Because of congressional concern about DOE's capability to maintain its schedule for the repository with reduced appropriations, we identified the (1) adjustments DOE made to the disposal program due to the reduced appropriations and (2) potential impediments to achieving DOE's objectives and schedule for the repository project. We addressed these issues under our responsibility, contained in the Nuclear Waste Policy Act of 1982, as amended, to audit the disposal program and to report the results of such audits to the Congress.

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## Results in Brief

Because DOE did not receive the amount of appropriations requested for fiscal year 1996, it revised the scope and objectives of the repository project with the goal of applying for a construction license in March 2002, about 5 months later than had been planned. Specifically, DOE

- curtailed most investigative activities at Yucca Mountain in favor of analyzing the information already collected to focus the remaining investigative activities on key uncertainties;
- decided to revise its guidelines for determining if the Yucca Mountain site is suitable for a repository by deleting those criteria that require compliance with specific technical conditions, such as those concerning the travel time for groundwater; and
- will issue, in September 1998, an assessment of the expected design, performance, and cost of a repository at Yucca Mountain. This report, called a viability assessment, is intended to support decisions on continuing the repository project and authorizing a waste storage facility near Yucca Mountain that may be made before the Department has determined if the site is suitable for a repository.

Several impediments must be resolved in DOE's favor if the Department is to achieve the project's revised objectives and schedule. First, it is uncertain when the Environmental Protection Agency (EPA) and NRC will issue the health standards and licensing regulations, respectively, that DOE needs to determine if Yucca Mountain is a suitable repository site. Also, the absence of applicable standards and regulations creates uncertainty about whether the scope of the Department's site investigation is adequate. Finally, limitations on (1) the information that DOE is collecting

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<sup>1</sup>The Energy and Water Development Appropriations Act of 1996 provided \$400 million for the disposal program. This included \$152 million from the civilian Nuclear Waste Fund appropriation account and \$248 million from the defense nuclear waste disposal account. The act reserved \$85 million of the appropriation from the latter account for the development of a facility for the interim storage of waste upon the enactment of statutory authority for such a facility. This effectively left DOE with \$315 million of available appropriations.

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in key areas, such as hydrology and the effects of heat generated by waste on the performance of the repository, and (2) NRC's preparations to review a license application add more uncertainty to the repository project.

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## Background

No country has yet developed a geologic repository for the permanent disposal of highly radioactive waste. Because this type of nuclear waste produces relatively intense levels of radiation for thousands of years, developing an acceptably safe repository is a complex task involving diverse scientific and technical challenges. For example, DOE must design a repository that is compatible with the site and will be safe to operate for several decades. In addition, the Department must demonstrate how the combination of geologic (natural) and engineered (man-made) barriers to the migration of waste from the repository will operate effectively. Inherent in this demonstration are numerous uncertainties related to understanding and predicting how a repository will perform over a very long period of time. Finally, safety standards for evaluating a proposed repository that recognize the inherent uncertainty in the repository's performance must be established.

In the Nuclear Waste Policy Act of 1982, the Congress found that federal efforts during the previous 30 years to devise a permanent solution to the problems of disposing of radioactive waste had not been adequate. The act established, among other things, federal policy and responsibility for the safe management and disposal of highly radioactive waste from civilian nuclear power plants.<sup>2</sup> The act charged DOE with selecting and investigating candidate sites for two repositories, recommending the selection of two sites for development, and constructing and operating one repository. DOE was required to establish guidelines for selecting and recommending repository sites that made specified geologic considerations the primary criteria. To ensure the safe management and disposal of waste for current and future generations, the act also required EPA to set environmental standards for the disposal of waste in repositories and NRC to establish regulations containing technical requirements and criteria for approving or disapproving of DOE's applications to construct and operate repositories.

Amendments to the act in 1987 directed DOE to investigate only the Yucca Mountain site. And the Energy Policy Act of 1992 required EPA to adopt specific public health and safety standards for that site on the basis of, and

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<sup>2</sup>As permitted by the act, the President also decided in 1985 that highly radioactive waste from DOE's nuclear weapons activities would also be disposed of in one or more civilian repositories.

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consistent with, a study of the scientific basis for such standards to be issued by the National Academy of Sciences, at EPA's request, by the end of 1993. The 1992 act also required that, within 1 year after EPA adopted its standards for Yucca Mountain, NRC had to make its licensing regulations consistent with the standards.

When the Congress passed the nuclear waste act, it expected that a repository could be operable by 1998. Subsequently, however, DOE extended the estimated date for a repository to 2003 and then to 2010. In the meantime, nuclear waste is accumulating and being stored at civilian nuclear power plants. The growing concern about the delay in beginning to remove nuclear waste from nuclear plant sites is reflected by a recent lawsuit and congressional consideration of legislation. In July 1996, the U.S. Court of Appeals for the District of Columbia Circuit ruled that the nuclear waste act creates an obligation for DOE to start disposing of utilities' waste no later than January 31, 1998, and remanded the case for further proceedings.<sup>3</sup> That same month, the Senate passed a bill (S. 1936) that, among other things, would have directed DOE to develop a facility for the interim storage of utilities' waste on DOE's Nevada Test Site.<sup>4</sup> (A portion of Yucca Mountain lies within the western boundary of the Nevada Test Site.) Similar legislation was under consideration in the House of Representatives when the 104th Congress adjourned.

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## Fiscal Year 1996 Adjustments to the Disposal Program

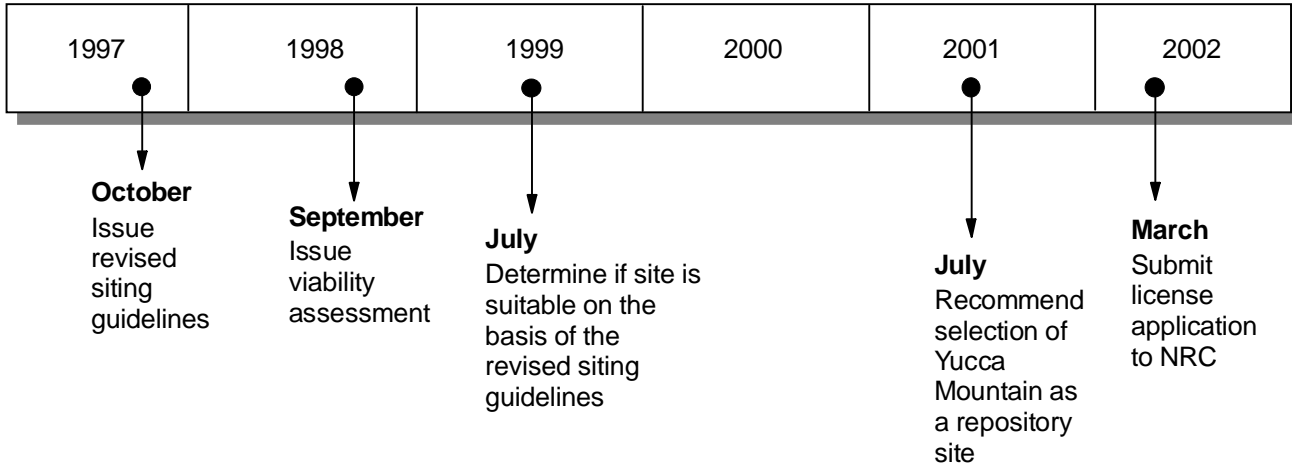
Following the appropriation for fiscal year 1996, DOE (1) curtailed most investigative activities at Yucca Mountain, (2) decided to revise its guidelines for determining if the site is suitable for a repository, and (3) announced that it would assess, in 1998, the "viability" of a repository at Yucca Mountain. DOE anticipates that these changes could enable it to submit a license application to NRC in March 2002 at an affordable cost. (See fig. 1.)

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<sup>3</sup>Indiana Michigan Power Co. v. Department of Energy, 88 F.3d 1272 (D.C. Cir., 1996). The administration has decided not to appeal the decision.

<sup>4</sup>The site would be used for a storage facility unless the President, after determining that Yucca Mountain is not a suitable site for a repository, designated another site for the facility.

Figure 1: DOE's Schedule Leading to License Application



DOE Curtailed the Investigation of Yucca Mountain

During fiscal year 1996, DOE curtailed, for the second consecutive year, the scope of its investigation of Yucca Mountain. In January 1992, DOE had estimated that it would cost \$6.3 billion through 2001 to investigate the site and prepare a license application. As we reported in 1993, however, the budget requests and allotments of appropriations for the repository project from fiscal years 1991 through 1993 were less than the estimated funding requirements.<sup>5</sup> (See table 1.) Therefore, in December 1994, DOE announced a plan to reorganize the investigation around tests to determine if the site is suitable for a repository, tests to support a license application, and tests that could be deferred until after the application had been submitted to NRC.

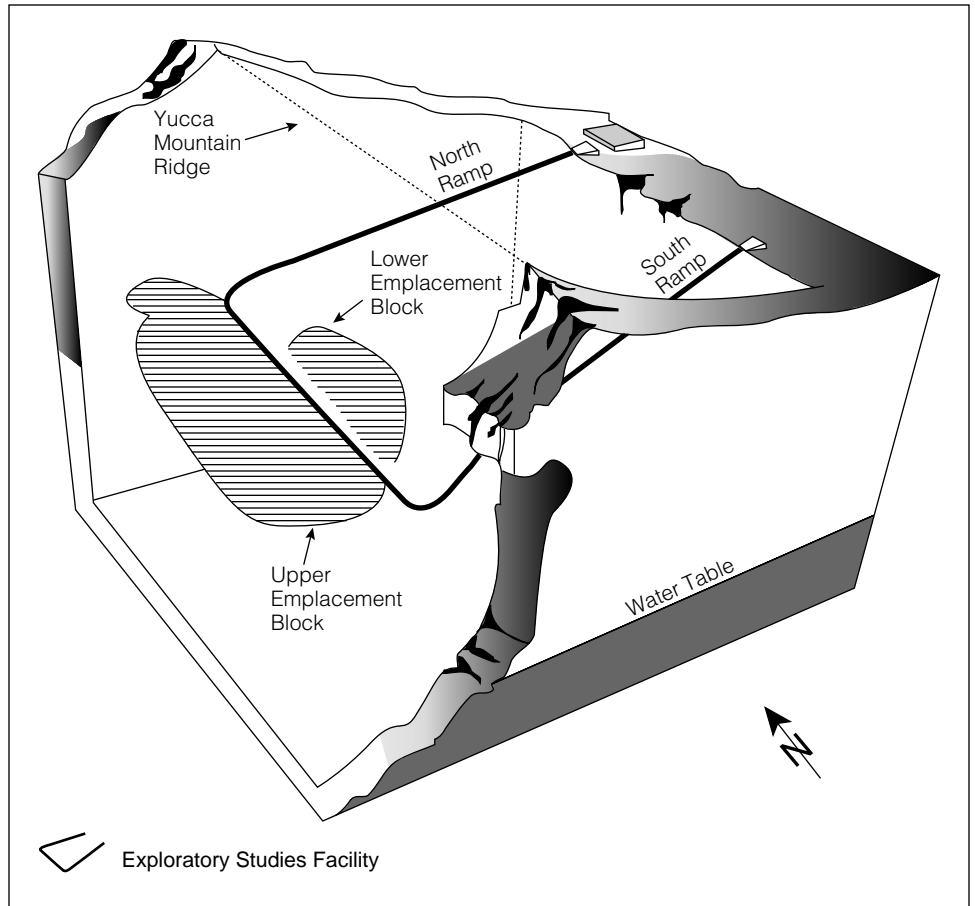
Table 1: Estimated Funding Required, Requested, and Appropriated for the Repository Project

Dollars in millions			
Fiscal year	Funds required	Funds requested	Funds appropriated
1991	\$ 194	\$193	\$155
1992	340	172	166
1993	625	248	259
<b>Total</b>	<b>\$1,159</b>	<b>\$613</b>	<b>\$580</b>

<sup>5</sup>Nuclear Waste: Yucca Mountain Project Behind Schedule and Facing Major Scientific Uncertainties (GAO/RCED-93-124, May 21, 1993).

According to DOE, the plan identified an aggressive field program, including drilling about 25 to 30 deep boreholes, and tests to be conducted from the surface of the site, in laboratories, and in the underground exploratory studies facility. This facility, which DOE expects to complete in 1997, is a U-shaped, 5-mile underground tunnel through Yucca Mountain. (See fig. 2.) DOE estimated that the reorganized investigation would cost about \$2.9 billion for the 6 fiscal years from 1995 through 2000.

**Figure 2: Artist's Conception of a Repository at Yucca Mountain**



Source: DOE.

Shortly after DOE received its appropriations for fiscal year 1996, it further reduced the scope of the investigation and eliminated about 875 positions



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for contract employees in the repository project. In addition, DOE reduced funding for waste storage, transportation, and program management activities by \$82 million and eliminated more than 200 related positions for contract employees. The revised investigation is now focused on completing the viability assessment and, according to DOE, was developed using the following priorities, in descending order of importance: (1) synthesis and modeling of available information to focus testing programs on key uncertainties, (2) testing in the exploratory studies facility, and (3) surface testing, such as using existing and new wells from holes drilled into the groundwater underneath the site to test the characteristics of the groundwater. DOE estimated the cost of the revised investigation at about \$2.1 billion for the 7 fiscal years from 1996 through 2002.

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## DOE Decided to Revise Its Suitability Guidelines

Fundamental to the success of DOE's revised approach for the repository project is its decision to revise its guidelines for determining if Yucca Mountain is a suitable site for a repository.<sup>6</sup> DOE's existing siting guidelines address the operation of a repository before it is permanently closed (preclosure guidelines) and the long-term behavior of the repository after it is closed (postclosure guidelines). For both areas, the guidelines are divided into "system" and "technical" guidelines. For example, the postclosure system guideline requires a demonstration that a proposed repository site and design would likely comply with EPA's disposal standards and NRC's licensing regulations. The technical guidelines establish specific conditions that are important to meeting the system guidelines. For example, the postclosure technical guidelines contain nine conditions that must be present at a site (qualifying conditions) and six conditions that must be absent from a site (disqualifying conditions) for DOE to find that the site is suitable for permanent waste disposal.

Instead of comparing the Yucca Mountain site's features to the technical conditions in DOE's existing guidelines, the Department now plans to compare how a repository at Yucca Mountain would be expected to perform to EPA's disposal standards and NRC's licensing regulations. This approach, DOE says, will lead to a more efficient process for determining the site's suitability by enabling the Department to focus investigative activities on issues that are most important to the performance of a repository at the site. The Department's proposed changes to the guidelines were published for public comment on December 16, 1996 (61 Federal Register 66157).

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<sup>6</sup>The nuclear waste act gave the Secretary of Energy the authority to amend the siting guidelines.

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## DOE Will Assess the Viability of a Repository at Yucca Mountain

The principal objective of DOE's new approach for the repository project is to issue a "viability assessment" in September 1998. The assessment will be a statement of the (1) tentative design and expected performance of the repository system, (2) necessary investigation activities and associated costs to submit a license application, and (3) estimated cost to construct and operate the repository. The assessment, in DOE's view, will represent an improved appraisal of the prospects for disposing of nuclear waste at Yucca Mountain.

According to the director of the disposal program, the assessment is intended to guide the completion of the work required for a site recommendation and to provide policymakers with a better estimate of the "viability" of a repository in the time frame required for decision-making.

If the repository appears to be "viable," then DOE intends to complete the work necessary to determine the suitability of the site, recommend that the site be selected for a repository, and, if the site is formally selected, apply for a construction license. The Department has not defined what constitutes a "viable" repository project; however, the assessment is not intended to demonstrate either that the Yucca Mountain site is suitable for or can be licensed as a repository.

DOE also intends that the assessment be used to "inform" a possible decision in 1999 by the administration and the Congress to develop a facility near Yucca Mountain for storing nuclear waste until a repository is operational. An affirmative decision would trigger the beginning of the construction and operation of the storage facility and the transport of waste from nuclear power plants to the facility. As shown in figure 1, however, DOE does not expect to make a determination of the site's suitability until July 1999 or to recommend a site until July 2001. Therefore, an earlier decision to develop a storage facility near Yucca Mountain could be viewed as a firm commitment to disposing of waste at Yucca Mountain.

For example, the administration opposed S. 1936 because the bill would have designated a location on DOE's Nevada Test Site as a site for a storage facility before DOE had completed the viability assessment. Such a designation, in the administration's view, would have destroyed the credibility of the disposal program by prejudicing a future decision on a permanent repository at Yucca Mountain. According to the disposal program's director, making a decision to develop a storage facility near Yucca Mountain after the viability assessment, although before DOE

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determines if the Yucca Mountain site is suitable for a repository, would provide for a more informed decision.

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## Potential Impediments to Achieving the Objectives and Schedule for DOE's Repository Project

Several uncertainties must be resolved in DOE's favor if the Department is to achieve the project's revised objectives and schedule. First, it is uncertain when EPA and NRC will issue the health standards and licensing regulations, respectively, that DOE will use to determine if Yucca Mountain is a suitable repository site. Also, the lack of applicable standards and regulations creates uncertainty about whether the scope of the Department's site investigation has been adequate. Finally, limitations on the information that DOE is collecting in key areas and on NRC's preparations to review a license application add more uncertainty to the repository project.

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## Timing of Standards and Regulations Could Affect DOE's Objectives and Schedule

The time it will take for EPA to issue its new disposal standards for Yucca Mountain and for NRC to conform its licensing regulations to those standards could affect DOE's ability to make a decision on the site's suitability and a recommendation on its current schedule. When EPA and NRC will issue their respective standards and licensing regulations is uncertain, but it could take 2 years or longer.

Because NRC is required to conform its licensing regulations to EPA's disposal standards, the standards must be issued first. In February 1993, EPA contracted with the National Academy of Sciences for the study, mandated by the Energy Policy Act of 1992, of the scientific basis for standards applicable to the Yucca Mountain site. In August 1995, the Academy issued its report. As of January 15, 1997, however, EPA had not issued proposed standards for public comment. EPA anticipates that it may be able to issue final standards within 1 year of proposing the standards for comment. According to officials of NRC's waste management division, NRC expects to begin the process of revising its licensing regulations after EPA proposes its standards. For example, when NRC's staff provides the Commission with comments on EPA's proposed standards for the Commission's consideration, the staff also plans to provide the Commission with a strategy for revising NRC's licensing regulations.

The two regulatory agencies' previous experiences with earlier standards and licensing regulations have shown that it could take 2 years or longer to issue the new standards and revised licensing regulations. For example, EPA took almost 3 years from December 1982, when it proposed its original

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standards for nuclear waste repositories, to issue the final standards.<sup>7</sup> After the standards were successfully challenged in court in 1987, EPA issued revised standards for public comment in February 1993 and final standards in December 1993. In June 1981, NRC proposed technical regulations for repositories. Subsequently, it took about 2 years for NRC to adopt the final technical regulations.

Thus, it is unlikely that EPA's standards and NRC's revised licensing regulations will be in place by September 1998, when DOE expects to issue its viability assessment of the Yucca Mountain project. According to DOE, however, it is not important to have the standards and licensing regulations in place for the viability assessment because the Department does not intend to compare, in the assessment, the expected performance of the repository to the standards and regulations.<sup>8</sup>

The timing of EPA's standards and NRC's revised licensing regulations could, however, affect DOE's schedule for completing a report that would provide the technical basis for determining if the Yucca Mountain site complies with the Department's siting guidelines and for making the site selection recommendation. As discussed earlier, the Department intends to make compliance with the standards and licensing regulations its criteria for determining if Yucca Mountain is a suitable site for a repository. According to DOE, it needs to have the standards and licensing regulations in place at least 1 year before it makes the determination. In July 1999, DOE plans to complete an "interim evaluation" of the site's suitability (see fig. 1) by issuing a technical report addressing the site's compliance with the siting guidelines. To adhere to the Department's schedule for completing the report, DOE needs to have the standards and licensing regulations in place by July 1998.

Moreover, a recommendation by the Secretary to the President that the Yucca Mountain site be selected for a repository must, according to the nuclear waste act, be based on a comprehensive statement of the basis for the recommendation. Among other things, the comprehensive statement must contain NRC's preliminary comments on the sufficiency of DOE's investigation of Yucca Mountain for inclusion in a license application and

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<sup>7</sup>At that time, these standards would have applied at the Yucca Mountain site; however, the Energy Policy Act of 1992 required EPA to develop specific standards for a repository at that site.

<sup>8</sup>The Department's fiscal year 1997 appropriations act directed DOE to issue the viability assessment to the President and the Congress. The act also instructed DOE to include in the assessment a comparison of the probable behavior of the repository to the "overall system performance standards." This language is essentially identical to language in S.1936, which would have established an overall system performance standard of 100 millirems of radiation exposure to the affected population per year.

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the proposed form of the waste. In April 1999, DOE plans to issue a report to NRC documenting the investigation's results. This report, DOE says, will provide information describing and modeling the site's characteristics, the designs of the repository and waste packages, and the expected performance of the overall repository system. DOE intends to use this integrated discussion of its case for a safe repository at Yucca Mountain as the basis for NRC to provide its preliminary comments to DOE by January 2000. The Department will not be able to issue a meaningful report and NRC will not be in a position to provide the Department with its formal comments on the sufficiency of DOE's site investigation until the standards and regulations have been issued.

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### Substance of Standards and Regulations Could Affect DOE's Objectives and Schedule

Until the substantive requirements of EPA's disposal standards and NRC's revised licensing regulations are known, DOE will not know if its scientific investigation of Yucca Mountain has adequately addressed all of the technical issues that are important to a credible determination of the site's suitability and an acceptable license application.

Although EPA has not yet proposed its standards, the National Academy of Sciences' report to EPA on the technical basis for Yucca Mountain standards and DOE's comments on that report show that there are significant differences of opinion about what the substantive requirements of the standards should be. The Academy recommended, among other things, standards that (1) limit the health risk, rather than the radiation dose, to individuals from the radioactive materials released from the repository; (2) require the measurement of compliance out to the time of peak risk, which is expected to occur tens or hundreds of thousands of years after the repository has been closed; and (3) define a critical group that would be at risk.

Subsequently, DOE expressed three key concerns with the Academy's recommendations and made recommendations to EPA on how the standards should be written. First, DOE recommended limiting compliance calculations to a 10,000-year period on the basis that the uncertainties in calculations over a longer period of time would limit the usefulness and validity of the calculations in a licensing proceeding. Second, DOE recommended using a less conservative level of risk than the Academy had recommended as a starting point for rulemaking. Third, DOE recommended a less complex and conservative approach to calculating risk to the critical group than the two options discussed in the Academy's report. (See app. I for a more detailed discussion of the Academy's report, DOE's comments,

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and other issues related to the development of EPA's standards and NRC's licensing regulations.)

The extent to which NRC revises its licensing regulations in making the regulations consistent with EPA's standards could also affect the adequacy of DOE's scientific investigation. Currently, NRC's regulations require DOE to demonstrate compliance with EPA's "generally applicable environmental standards." However, these standards have been revised to pertain to repositories at sites other than Yucca Mountain. In addition, to provide sufficient confidence that a repository would perform as predicted, NRC's regulations require DOE to demonstrate that the repository would comply with three more specific requirements. These requirements, called subsystem performance requirements, establish a minimum lifetime for packages containing waste, limits on the rate at which radioactive materials can be released from engineered (man-made) barriers within the repository, and the minimum time that water might take to travel from the repository to the accessible environment. NRC included these additional requirements because of the inherent uncertainty in an assessment of the performance of a repository over a long period of time.

In its August 1995 report, the Academy concluded that NRC's subsystem performance requirements could adversely affect the performance of a repository at Yucca Mountain by limiting DOE's design flexibility. DOE agreed and recommended that NRC reconsider the use of these requirements. There are, however, arguments favoring these requirements. As recognized by NRC in the early 1980s, the subsystem performance requirements provide "defense in depth" by increasing confidence in assessments of compliance with EPA's standards. Also, NRC pointed out that its regulations provide considerable design flexibility by permitting NRC to change the subsystem performance requirements, if warranted, during a licensing proceeding.

According to the deputy director of NRC's Division of Waste Management, NRC's staff is considering whether or not the regulatory agency should retain these subsystem performance requirements in its licensing regulations and will address this issue when it provides the Commission with a proposed strategy for revising the agency's licensing regulations. The outcome of this issue, as well as other issues that may arise as NRC revises its licensing regulations, could affect the scope and depth of the scientific investigation that DOE must perform to determine if Yucca Mountain is a suitable site for a repository.

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## DOE May Not Have Adequately Investigated Key Areas

Regardless of the timing and substance of the final repository regulations, limitations on the information that DOE is collecting and on NRC's preparations to review a license application increase uncertainty about the sufficiency of the Department's investigation of Yucca Mountain.

According to DOE, among the most important attributes of a repository at Yucca Mountain are the rate at which water seeps into the repository, the period of time that the packages containing waste will prevent the release of radioactive materials from them, and the manner in which radioactive materials that eventually reach the water table beneath the repository will be diluted by groundwater. Also, heat generated by the waste in the repository will affect the movement of water through the repository and the durability of the waste packages. There are indications of shortcomings in DOE's investigation of all of these areas.

For example, DOE may not have done enough to investigate the groundwater beneath and beyond Yucca Mountain, including where and how fast water moves and the rate at which water contaminated with waste materials would be diluted and dispersed as it enters the groundwater. According to the U.S. Geological Survey, which performs groundwater research for DOE, new questions about the importance of groundwater to the scientific investigation are beginning to arise; in the last decade, however, no new boreholes to address these uncertainties have been drilled, and only limited testing of the groundwater has occurred. One such issue is the unexplained cause of the large drop in the elevation of the water table at the northern end of Yucca Mountain. Geological Survey scientists say that this feature, which was discovered in 1981, is the most striking hydrologic feature in the area. According to the scientists, until they can explain the cause of the drop in the water table, they would find it difficult to claim that they understand the hydrology of the site.

DOE agrees that the drop in the water table has not been fully evaluated. According to the Department, however, preliminary observations of a recently completed pumping test in an existing well indicate that this feature of the site has no effect on the flow of groundwater in the aquifer beneath Yucca Mountain.

According to a 1996 report by DOE on the quality of the Geological Survey's hydrologic investigations, major uncertainties, such as the unexplained drop in the groundwater level, at this stage of the scientific investigation limit understanding of how radioactive materials would move in

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groundwater. In the opinion of the report's authors, the Geological Survey's research has been severely handicapped by, among other things, the elimination of most borehole drilling from the investigation. (App. II discusses this limitation and others on DOE's investigations of the hydrology at Yucca Mountain, as well as limitations on its investigations of the effects of heat on the repository's performance and the testing of candidate materials for waste packages.)

Under the existing legislative framework, NRC, not DOE, will ultimately decide if the Department's investigation of Yucca Mountain has been adequate. Over the years, NRC has reviewed DOE's repository project to identify and resolve technical issues, to prepare to review a license application, and to develop criteria for an acceptable license application. The criteria would provide guidance to DOE on NRC's expectations for a license application that would adequately address the requirements of NRC's licensing regulations.

In 1995, NRC modified its approach to reviewing DOE's repository project. Instead of trying to review all aspects of the project, NRC decided to identify and emphasize the 10 most important technical issues. According to NRC, however, in fiscal years 1996 and 1997 it eliminated its contractor support for independently evaluating 3 of these 10 issues because its nuclear waste appropriations for each year were only half of its \$22 million appropriation for 1995. In the absence of funding, NRC will not conduct any more independent studies of the three issues. Instead, NRC's staff will monitor DOE's related activities and will bound related regulatory issues using conservative assumptions. Moreover, NRC said, if the recent budget trend continues, the agency would have to discontinue its contractor's work on two more key technical issues and would not be able to complete its review of a DOE license application in the 3-year period required by the nuclear waste act.

Thus, an additional uncertainty confronting DOE's repository project is NRC's position on the contents of an acceptable license application. NRC's review of and comments on DOE's 1998 viability assessment will provide the first insights into NRC's formal position. (DOE does not intend to request comments on its viability assessment; however, NRC believes that its evaluation of the assessment would provide vital input to future decisions on the repository project.) For those key technical issues that NRC has reviewed, it intends to identify potential licensing weaknesses and major concerns with DOE's designs or testing plans that could affect DOE's estimate of the cost of the repository. For technical issues for which NRC



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has eliminated technical work by its contractor, the agency's reviews of DOE's designs and technical basis for performance assessments and cost estimates in the viability assessment will be limited and based on conservative assumptions and available knowledge.

The viability assessment, however, is not a step required by the nuclear waste act. The first formal opportunity that the act provides NRC to comment on the sufficiency for a license application of DOE's investigation of Yucca Mountain will occur when DOE seeks NRC's preliminary comments on the sufficiency of the investigation. DOE expects to seek NRC's comments in April 1999 and to receive the comments in January 2000. NRC's next formal opportunity will be its initial review of DOE's license application in 2002 to determine if the application is acceptable to begin the licensing proceeding. To the extent that NRC is unable to review important issues to gain confidence in DOE's investigation and develop acceptance criteria, the agency intends to adopt conservative regulatory positions. Conservative positions could have the consequence of either requiring DOE to obtain and provide NRC with more information or, alternatively, to make modifications to the design of the repository system that could increase the system's cost.

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## Observations

DOE's viability assessment may provide important insights into the expected design, performance, and cost of a repository at the Yucca Mountain site. However, the assessment's utility as the basis for a decision in 1999 to develop a waste storage facility near the site is limited because the assessment will not demonstrate compliance with applicable siting guidelines, standards, and licensing regulations. Therefore, making such a decision on the basis of the viability assessment could be perceived as a firm commitment to eventually disposing of nuclear waste at the site. For essentially this reason, the administration opposed the provisions of S. 1936 that would have designated a site near Yucca Mountain for a storage facility before DOE had completed its viability assessment. The administration argued that such a designation would have destroyed the credibility of the disposal program by prejudicing a future decision on a permanent repository at Yucca Mountain. In our view, the logic of the administration's position would also apply to such a designation made after the assessment has been completed but in advance of the decision on the site's suitability, a recommendation that the site be selected for a repository, and the decision on licensing that must be made on the basis of compliance with the guidelines, standards, and regulations.

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## Agency Comments and Our Evaluation

We provided a draft of our report to DOE, EPA, and NRC for their review and comment. DOE and NRC provided written comments on this report, which appear in appendixes III and IV, respectively. EPA declined to comment on the report.

DOE said that our report recommends that decisions involving the construction of a repository be suspended until the Secretary has recommended to the President that Yucca Mountain be selected for a repository. We did not propose such a recommendation. We merely observed that deciding to develop a waste storage facility near Yucca Mountain before the Department has determined that the proposed repository site complies with applicable siting guidelines, standards, and licensing regulations could be perceived as a firm commitment to eventually disposing of nuclear waste at the site. We revised our observation section to make clear that we were not proposing any recommendation.

DOE also said that we appear to be misinformed about its plans to continue addressing the uncertainties related to hydrology, the effects of heat from waste on the performance of the repository, and waste package materials. The Department intends to make every reasonable effort to reduce uncertainties and, in a license application, will identify and discuss any remaining major uncertainties and the steps planned to reduce them. It is important to note, DOE added, that it is not required to demonstrate the performance of the repository system or components of this system until it submits a license application. We disagree that we are misinformed about DOE's plans for addressing key technical issues. Our report states that, on the basis of the limited information that DOE has collected and concerns raised by technical experts, resolving existing uncertainties about these issues could affect the Department's ability to achieve its objectives and schedule for the repository project. Whether or not DOE's current plans to address key uncertainties are adequate can be definitively answered only after the Department has submitted an application to construct a repository.

DOE provided other specific clarifying comments that we incorporated as appropriate.

NRC pointed out that its previous and ongoing reviews of DOE's site investigation project and interactions with the Department have documented feedback to DOE on what is needed for licensing. Therefore, NRC's comments on the viability assessment's discussion of DOE's plans for

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the license application will reflect whatever significant differences remain between NRC's staff and the Department. Moreover, NRC said, interactions between the two agencies focused on resolving licensing issues will continue, and should differences of opinion persist, they will be documented in the Commission's preliminary sufficiency comments to be included in DOE's site recommendation report. NRC provided other specific clarifying comments that we incorporated as appropriate.

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We performed our review at DOE's headquarters in Washington, D.C., and at DOE's Yucca Mountain Site Characterization Project Office in Las Vegas, Nevada. We also performed our review at the headquarters of NRC in Rockville, Maryland, and EPA in Washington, D.C. We visited the Yucca Mountain site in southern Nevada and met with representatives of the state of Nevada and Clark County, Nevada. We conducted our review from February 1996 through January 1997 in accordance with generally accepted government auditing standards. (See app. V for details of our scope and methodology.) A list of related GAO products appears at the end of this report.

We are sending copies of this report to the Secretary of Energy; the Chairman, NRC; the Administrator of EPA; and the Director, Office of Management and Budget. We will also make copies available to others on request.

Please call me at (202) 512-3841 if you or your staff have any questions. Major contributors to this report are listed in appendix VI.



Victor S. Rezendes  
Director, Energy, Resources, and  
Science Issues

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**Abbreviations**

DOE	Department of Energy
EPA	Environmental Protection Agency
NRC	Nuclear Regulatory Commission

# Uncertainties About Regulatory Requirements Could Affect the Objectives and Schedule for DOE's Repository Project

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The Department of Energy's (DOE) efforts to determine if a safe repository can be developed at Yucca Mountain are made more difficult because the site investigation is proceeding in parallel with fundamental changes to the regulations governing the project. If the site is eventually selected for a repository, DOE must demonstrate, in a licensing proceeding conducted by the Nuclear Regulatory Commission (NRC), that the proposed repository would comply with health standards issued by the Environmental Protection Agency (EPA) and NRC's licensing regulations. However, EPA is just beginning the process of issuing health standards for the Yucca Mountain site that must be consistent with the findings and recommendations of a study by the National Academy of Sciences. And after EPA issues its standards, NRC must, if necessary, revise its licensing regulations to make the regulations consistent with the standards.

The Academy has recommended that EPA take a different approach to setting standards for Yucca Mountain than the agency took a decade ago in setting its original standards for all nuclear waste repositories, including Yucca Mountain. DOE, however, has disagreed with several of the Academy's findings and recommendations because, in part, of the perceived difficulty in implementing the recommended standards in a licensing proceeding on a repository at Yucca Mountain.

Moreover, whether DOE's scientific investigation of Yucca Mountain will be adequate to support a determination of the site's suitability, a recommendation to select the site, and an acceptable license application on the Department's current schedule will, to some extent, depend on when the final standards and licensing regulations are issued and their substantive requirements. Finally, DOE is in the process of basing its guidelines for determining the suitability of Yucca Mountain for a repository on EPA's standards and NRC's licensing regulations. Thus, the timing and content of the standards, licensing regulations, and siting guidelines that will be used for determining if the site is suitable for a repository, recommending that the site be selected for a repository, and applying for a license are currently unknown.

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## Background

The Nuclear Waste Policy Act of 1982 charged EPA with setting generally applicable environmental standards for the disposal of nuclear waste in repositories and NRC with setting criteria and technical requirements for licensing and regulating repositories. In December 1982, EPA proposed, and in September 1985 issued, its original disposal standards (40 C.F.R. part 191). The primary standard was based on containing waste materials

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within a repository.<sup>9</sup> Specifically, the standard limited the cumulative releases of radioactive materials from the boundary of the repository to the accessible environment (the biosphere) for 10,000 years after closing a repository. In issuing this standard, EPA expected that the assessments of the long-term performance of a repository would be based on mathematical predictions of the anticipated behavior of both the natural and engineered (man-made) barriers making up the repository system and the likelihood of unanticipated events and processes, such as earthquakes and human intrusion, that could disrupt the repository.<sup>10</sup>

Subsequently, the Energy Policy Act of 1992 directed EPA to set specific disposal standards for the Yucca Mountain site that would prescribe the maximum annual effective dose to individual members of the public from the release of radioactive materials (disposed of in the repository) to the accessible environment. The act also required EPA to (1) arrange for an analysis by the National Academy of Sciences of the scientific basis for a standard to be applied at Yucca Mountain and (2) adopt health and safety standards on the basis of, and consistent with, the Academy's findings and recommendations. Finally, the act required NRC to make its licensing regulations for a repository at Yucca Mountain consistent with EPA's standards.

In February 1993, EPA contracted with the Academy to study the technical basis for disposal standards for a repository at Yucca Mountain. The Academy issued its report to EPA in August 1995.<sup>11</sup> Among other things, the Academy recommended that EPA

- limit the risk to individuals of adverse health effects from releases of radioactive materials from the repository rather than limiting the radiation dose to individuals or the cumulative releases of radioactive materials from the repository;<sup>12</sup>

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<sup>9</sup>EPA also established standards for protecting (1) individuals in areas surrounding a repository from receiving harmful radiation doses and (2) groundwater from radioactive contamination for 1,000 years. The standards also contained qualitative assurance requirements to increase confidence that the long-term containment requirements would be met.

<sup>10</sup>The exception to the release standards includes expected or accidental events that, while conceivable, are expected to have less than 1 chance in 10,000 of occurring over 10,000 years.

<sup>11</sup>Technical Bases for Yucca Mountain Standards, National Research Council, National Academy of Sciences, Aug. 1995.

<sup>12</sup>The Academy recognized that the dose-based and risk-based standards are closely related. The risk-based standard would be based on a statistical distribution of health effects (i.e., premature fatal cancers), which are derived from a distribution of dose and the expected consequences (i.e., health effects) per unit dose.

- measure compliance with the standard out to the point of peak risk to individuals, which is expected to occur tens or hundreds of thousands of years in the future, rather than the 10,000-year period in EPA's original standards;
- define the "critical group" that would be at risk, rather than basing compliance on exposures of collective or worldwide populations to radiation;<sup>13</sup> and
- separately evaluate the risk and consequences of intrusion into the repository by future humans and focus this evaluation on the repository's capability to withstand such intrusion.

As of January 15, 1997, EPA had not proposed standards for a repository at Yucca Mountain; however, according to the agency's director of the Radiation Protection Division, Office of Radiation and Indoor Air, the agency may be able to issue final standards within 1 year of proposing the standards.

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## **EPA's Standards Could Affect DOE's Repository Project**

EPA's disposal standards for Yucca Mountain must be based on and consistent with the Academy's findings and recommendations. DOE, however, expressed several concerns about the Academy's recommendations. Depending on the substantive requirements of the standards that EPA eventually adopts, DOE may have to modify its scientific investigation of Yucca Mountain.

In a November 2, 1995, letter to EPA, DOE expressed three key concerns about the Academy's recommendations for a Yucca Mountain standard. First, the Department is concerned that uncertainties in the results of quantitative calculations made for a period that is greater than 10,000 years would limit the usefulness and validity of the calculations in a licensing proceeding. Therefore, DOE recommended that compliance calculations be limited to a period of 10,000 years. In DOE's view, reasonably reliable calculations of a repository's expected performance can be made for the shorter period of time.

Second, DOE is concerned that the level of permissible risk to the designated critical population group that the Academy recommended as a starting point for developing the standards is unnecessarily conservative. The recommended level of risk would limit annual fatal cancers from the

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<sup>13</sup>The critical group has been defined by the International Commission on Radiological Protection as a relatively homogeneous group of people whose location and habits are such that they are representative of those individuals expected to receive the highest doses as a result of the discharges of radioactive materials.



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operation and closure of the repository to an increase of from 1 in 1 million to 1 in 100,000 in the affected population. According to DOE, none of the other federal and international regulations the Academy examined in its study require such a stringent limit over a period of hundreds of thousands of years. Moreover, DOE said, because of the overwhelming conservatism in the Academy's study related to the calculations of risk levels, EPA should relax the starting point by a factor of 10; that is, the permissible level of risk should be a range of 1 in 100,000 to 1 in 10,000 increased fatal cancers per year.<sup>14</sup>

Third, DOE is concerned that the two options the Academy presented for calculating risk to the critical group and establishing a future reference biosphere are either too complex or too conservative. The majority of the Academy's panel had recommended that EPA use theoretical statistical and analytical techniques to identify the observed characteristics of people currently living in the vicinity of the repository and to calculate the risk to this group. One panel member had recommended that EPA derive the average risk calculation from the radiation dose likely to be received by a "subsistence farmer." This farmer was defined as the person likely to become the most contaminated because of his use of water extracted from a well near the repository to drink and to grow all of his food. DOE commented that the first of these two options is unprecedented and, among other things, would be very complicated to implement. The second option, according to DOE, appears to be simpler and easier to implement but would result in a very conservative level of risk. DOE suggested that a better option for calculating risk would be to base the calculations on the characteristics of a current population group perceived to be most at risk to radiation exposure from drinking contaminated groundwater and using it to irrigate the crops they would consume. In this option, DOE said, specific factors, such as the diversity of occupations and lifestyles and the relative consumption of local and imported foods, would be considered.

The eventual content of EPA's standard for Yucca Mountain is likely to influence the extent of the work that DOE must complete to determine if Yucca Mountain is a suitable site for a repository, recommend that the site be selected for that purpose, and submit an acceptable license application to NRC. For example, the substantive requirements of the standards could affect the scope of the investigation of groundwater around Yucca Mountain that is necessary to demonstrate compliance with the standards. According to DOE's current strategy for containing and isolating waste in a

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<sup>14</sup>One example DOE mentioned was the Academy's assumption that future humans can and will use groundwater contaminated as a result of a repository losing its integrity over time and that they will not test and treat their water supply.

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repository at Yucca Mountain, the use of a dose-based or risk-based standard—instead of the release-based standard in EPA's original standards for all repositories—would place additional emphasis on how radioactive materials would move through the rock layers in the saturated zone (the area containing groundwater) beneath and around Yucca Mountain. A goal of DOE's containment strategy is to prove that the radioactive materials escaping into the saturated zone will be dispersed and diluted before they reach the accessible environment and therefore will result in acceptably low doses to humans over thousands of years.

Hydrologists at the U.S. Geological Survey, who are investigating the hydrology of Yucca Mountain for DOE, told us that they are measuring the movement of injected tracer materials among three wells developed in close proximity to one another to model the flow of groundwater. In conjunction, DOE's Los Alamos National Laboratory is modeling how the groundwater would transport radioactive materials. A limitation of the tests, however, is that they measure the transport of radioactive materials at only one point in time and space. For this reason, the tests are not likely to answer questions about the total flow of the groundwater system. A Geological Survey official stated that the project's study plans provide for drilling another series of holes at a different location in 1998 and 1999, but the specifics of the study plans are uncertain. Thus, DOE may need to undertake additional work to help explain the flow of groundwater in the saturated zone and transport characteristics to verify theories that dispersion and dilution of radioactive materials will keep radiation doses low for thousands of years.

Similarly, the period of regulatory compliance that EPA adopts in the final standard could affect the relative importance of hydrologic studies to a compliance determination. Geological Survey scientists told us that a period of compliance that is much longer than 10,000 years would place more emphasis on the behavior of the saturated zone. Currently, these scientists believe that very little water would move from Yucca Mountain down into the saturated zone in 10,000 years. Over a much longer time period, however, more water may reach the saturated zone. This possibility raises questions about how radioactive materials escaping the repository over the longer time period would be diluted in the groundwater to limit potential human exposure. As discussed above and in appendix II, however, groundwater flow and transport properties in the saturated zone are not well understood.

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## **NRC's Revised Licensing Regulations Could Affect DOE's Repository Project**

The revisions that NRC may make to its licensing regulations could affect DOE's ability to meet the objectives and schedule for its repository project. As required by the 1992 energy act, NRC is to make its licensing regulations consistent with EPA's disposal standards for Yucca Mountain. Because EPA has not yet issued its standards, there are outstanding questions about how DOE will implement both the standards and NRC's revised licensing regulations. One key unanswered question, for example, is whether NRC will retain certain requirements for repository performance that are contained in its existing licensing regulations.

NRC's existing licensing regulations require DOE to demonstrate compliance with EPA's disposal standards. However, when NRC developed its regulations in the early 1980s, it recognized that the assessment of the performance of a repository over a long period of time entails considerable uncertainty. Therefore, to provide sufficient confidence that a proposed repository would perform as predicted, NRC's regulations also require DOE to demonstrate that a repository would comply with three more specific requirements. These requirements, called subsystem performance requirements, establish (1) a minimum lifetime for packages containing waste, (2) limits on the rate at which radioactive materials may be released from engineered barriers within the repository, and (3) a minimum period of time that groundwater may take to travel from the repository to the accessible environment.

In its report to EPA, the National Academy of Sciences concluded that the retention of the subsystem performance requirements in NRC's licensing regulations could result in a less than optimal design and level of performance for the repository. For example, according to the Academy, DOE might find it necessary to move the repository site within Yucca Mountain to meet the subsystem performance requirement for groundwater travel time. In doing so, the Academy suggested, DOE might also increase the risk of human exposure to radioactive gases moving from the repository to the surface. Accordingly, the panel recommended precluding the subsystem performance requirements from foreclosing design options that ensure the best long-term performance of the repository. DOE, in commenting on the Academy's report, agreed and recommended that NRC reconsider the use of subsystem performance requirements. In a previous report on seven foreign countries' programs for disposing of nuclear waste, we noted that regulators in most of these countries are concerned only that proposed repositories meet overall

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safety goals (standards). These regulators said they expect to leave the design details to the repository developers.<sup>15</sup>

On the other hand, there are arguments in favor of retaining subsystem performance requirements. For example, in response to public comments on NRC's proposed technical regulations for repositories, issued in June 1981, NRC stated that there is significant uncertainty in making assessments of the overall performance of a repository for a period covering thousands of years. NRC added that subsystem performance requirements provide "defense-in-depth" by increasing confidence in the assessments of compliance with EPA's standards. NRC also pointed out that the subsystem performance requirements are not absolute—the final regulations, issued in June 1983, permit NRC to change them, if warranted, during a repository licensing proceeding. Thus, in NRC's view at that time, its licensing regulations provided DOE with considerable flexibility to design an optimal repository system at a specific site. Furthermore, NRC noted, the subsystem performance requirements may be necessary to ensure that a repository will meet the numerical criteria in EPA's (original) containment standard for unanticipated processes and events (such as earthquakes, flooding, or disruption of the repository by humans). Finally, NRC noted that its task is not only one of mathematically modeling a system and assigning values for particular barriers represented in the model to arrive at a "bottom line" for overall system performance. NRC is also concerned, it said, that its final judgments be made with a high degree of confidence. Accordingly, NRC stated, it can and will expect the performance of barriers to be enhanced so as to provide greater confidence in its licensing judgments, wherever practicable to do so.

According to the deputy director of NRC's Division of Waste Management, NRC's staff expects to review its technical requirements for repositories and its licensing criteria and will re-evaluate, as part of this review, the need for subsystem performance requirements. However, NRC is waiting for EPA to issue its proposed standards for Yucca Mountain before proposing any changes to its licensing regulations.

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<sup>15</sup>Nuclear Waste: Foreign Countries' Approaches to High-Level Waste Storage and Disposal (GAO/RCED-94-172, Aug. 4, 1994).

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## **DOE's Siting Guidelines Are to Be Based on EPA's Standards and NRC's Licensing Regulations**

Fundamental to the success of DOE's revised approach to completing the repository project is its decision to revise its criteria for determining if Yucca Mountain is a suitable site for a repository. The Nuclear Waste Policy Act required DOE to establish general guidelines for the recommendation of sites for nuclear waste repositories. These siting guidelines must specify detailed geologic considerations that shall be the primary criteria for the selection of sites in various geologic media. After obtaining public comment, including NRC's concurrence with the guidelines, DOE issued them as a regulation in December 1984. The siting guidelines require that DOE evaluate individual sites and compare them on the basis of criteria that address (1) the operation of a repository before it is permanently closed (preclosure guidelines) and (2) the long-term behavior of the repository after it is closed (postclosure guidelines).

Both the preclosure and postclosure guidelines are divided into system and technical guidelines. Three preclosure system guidelines establish performance objectives that must be taken into account during a repository's operations in the areas of radiation safety; environment, socioeconomics and transportation; and ease and cost of siting, construction, operation, and closure. The postclosure system guideline establishes broad performance objectives for protecting public health and safety that are based on compliance with EPA's disposal standards and NRC's licensing regulations. These requirements must be met by the repository system, which must contain both natural and engineered barriers. The engineered barriers are to be designed to complement the natural barriers, which are to provide the primary means for waste isolation.

The preclosure and postclosure guidelines also contain technical guidelines which establish specific conditions that are important to meeting the system guidelines.<sup>16</sup> For example, the postclosure technical guidelines contain nine conditions that must be present at (qualifying conditions) and six conditions that must be absent from (disqualifying conditions) a site for DOE to find that the site is suitable for permanent waste disposal. For each such technical guideline, DOE is to make an evaluation of qualification or disqualification.

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<sup>16</sup>For the postclosure guidelines, the conditions address site characteristics, processes, and events that may influence the performance of a repository system after closure of the repository. They include hydrological and chemical characteristics of the site; changes in climate, erosion, rock quality, movement of tectonic plates comprising the earth's crust; and human interference with the repository system.

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Until recently, DOE had intended to use these siting guidelines as the basis for determining if Yucca Mountain is a suitable site for a repository. To this end, DOE had planned to complete, at an estimated cost of \$634 million, sufficient scientific investigations and related technical reports to make preliminary technical findings in 1998 on whether Yucca Mountain meets the criteria contained in the guidelines. DOE has now decided, however, to amend the siting guidelines by adding new guidelines that would pertain only to the Yucca Mountain site.

The proposed guidelines, which were published for public comment on December 16, 1996, would base the determination of the suitability of Yucca Mountain as a site for a repository on a comparison of the overall performance of a repository system at that site to EPA's new disposal standards and NRC's revised licensing regulations. DOE does not, as required by the original guidelines, intend to determine the presence or absence of each qualifying and disqualifying condition contained in the technical guidelines. An overall system performance approach, DOE says, will lead to a more efficient process for evaluating the suitability of the Yucca Mountain site.

DOE believes that the overall approach to a repository system's performance is the appropriate method to consider all relevant site features because the approach identifies, in an integrated manner, those attributes of the site and engineered components that are most important to the protection of health and safety. According to DOE, the information gained from the site investigations and the preliminary assessments of how a repository would perform at the site show that the significance of selected site characteristics should not be judged in isolation from one another or from a specific design concept for the repository.<sup>17</sup> For example, a geological structural feature may seem to be a detriment because it provides a fast pathway for groundwater flow through the mountain when considered alone, but in consideration with a specific repository design, the feature may act beneficially by channeling groundwater flow away from the waste, thereby reducing the chances that the groundwater will contact the waste packages and cause them to fail.

According to DOE, its amendments to the siting guidelines will be developed concurrently with the development of a site-specific radiological protection standard for Yucca Mountain by EPA and conformance of the licensing regulations to this new standard by NRC.

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<sup>17</sup>Consistent with the provisions in the original EPA standards, DOE is using an analytical method known as "performance assessment," which uses computer models to simulate and predict the behavior of the Yucca Mountain site and repository over thousands of years.

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Moreover, as DOE agreed when it issued the original guidelines, the Department intends to obtain NRC's concurrence with the amended guidelines.

After the completion of a public comment period, DOE expects to issue the revised guidelines in 1997. A key uncertainty, however, is the timing of the issuance of EPA's standards and NRC's revised licensing regulations. According to DOE's manager for site suitability and licensing, DOE needs NRC to complete revisions to its licensing regulations 1 year before DOE makes its determination of site suitability (now scheduled for July 1999) and 2 years beforehand if NRC makes major changes to the regulations. He added that DOE's determination of the suitability of Yucca Mountain will be based on comparing an up-to-date assessment of the repository's performance to EPA's standard and NRC's licensing regulations.

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# Limitations of DOE's Activities Could Affect the Objectives and Schedule for DOE's Repository Project

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To preserve the repository project at Yucca Mountain following the unexpectedly low appropriations for fiscal year 1996, DOE redirected the project to address the major unresolved technical issues so that, in 1998, the Department can assess the viability of a repository at the site. DOE is developing a strategy for containing and isolating waste in the repository to guide the preparation of this assessment. The draft strategy specifies the natural and engineered (man-made) barriers that DOE will rely on to isolate waste from the accessible environment and provide the technical basis for setting priorities for designing the repository and completing the scientific investigation of Yucca Mountain. Following the viability assessment, DOE would complete the work it believes is necessary to (1) determine if Yucca Mountain is a suitable site for a repository, (2) recommend selection of the site for that purpose, and (3) submit a license application to NRC.

However, the limited information that DOE will have in several areas that are important to its strategy for containing and isolating waste could affect its ability to achieve its objectives for the repository project on its current schedule. These key areas include the hydrology of Yucca Mountain and the surrounding area, the effects of heat on the repository's performance, and the testing of candidate materials for waste packages.

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## Waste Containment and Isolation Strategy

In 1994, the Nuclear Waste Technical Review Board concluded that DOE had not established exploration and testing priorities for determining if Yucca Mountain is a suitable site for a repository.<sup>18</sup> To that end, the Board recommended that DOE articulate a clear waste isolation strategy that provides an understandable technical rationale for assigning priorities to studies of the site. DOE agreed and began developing the elements of such a strategy.

In July 1996, DOE published a draft of its evolving strategy for containing and isolating waste in a repository at Yucca Mountain. The strategy, which represents DOE's approach to addressing and resolving issues related to the long-term performance of the repository, is based on the observation that there is very little water in the rocks in and around the repository area to dissolve and transport radioactive materials to the environment. The goals of the strategy are to contain nearly all radioactive materials within waste packages for several thousands of years and ensure that doses to the public living near the site will be acceptably low.

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<sup>18</sup>The Nuclear Waste Policy Amendments Act of 1987 created the Nuclear Waste Technical Review Board as a source of independent review of the scientific and technical activities undertaken by DOE in managing highly radioactive wastes.



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The strategy relies primarily on emplacing waste packages in an area in Yucca Mountain above the water table to delay and minimize releases of radioactive materials to the environment when the waste packages finally begin to fail. Secondary lines of defense to enhance containment and isolation lie in potential engineered (man-made) barriers adjacent to the waste packages and in the natural system that are expected to delay the movement of radioactive materials released from waste packages.<sup>19</sup> The strategy defines the following key attributes for predicting the performance of engineered and natural barriers:

- The rate at which water seeps into the repository. Assessments of the repository's performance have shown that water seeping into the emplacement areas is the most important attribute of the ability of the site to contain and isolate waste. This process affects all aspects of performance, from the life of the waste packages to the movement of radioactive materials.
- The integrity of waste packages (containment). As long as waste packages remain intact, the waste will be completely contained and prevented from any contact with the surrounding rock or the groundwater. According to DOE, containment times exceeding 1,000 years are feasible.
- The rate of release of radioactive materials from failed waste packages. Performance assessments have shown that the release rate is one of the key factors in determining the peak doses of radiation that the affected public would be exposed to each year.
- The transport of radioactive materials through barriers. The potential radiation dose depends directly on the concentration of radioactive materials in water. These concentrations change as the materials move in water through engineered and natural barriers to points where people can use the water.
- The dilution in the groundwater. Dilution is an important factor that can reduce concentrations of radioactive materials and limit doses of radiation to humans. If the amount of water seeping into the repository and contacting the waste is small, the concentration of radioactive materials will be reduced when the contaminated water is added to the groundwater.

The strategy also hypothesizes that some cross-cutting issues, such as the effects on the repository's performance of the heat generated by the waste, can be dealt with successfully as the repository is designed and that other issues, such as the potential effects of climate changes, human

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<sup>19</sup>DOE is evaluating whether a backfill of crushed rock around the waste packages will be used to limit water contact with the packages to delay corrosion and, following corrosion, to limit the dissolution and transport of radioactive materials.

interference, and volcanoes, will not significantly reduce the repository's performance. The strategy outlines tests and analyses to be pursued to try to substantiate the five key attributes and to address cross-cutting issues.

According to DOE, the waste containment and isolation strategy will guide its plans for a viability assessment in 1998. DOE would use the strategy to guide the scientific and engineering studies necessary to confirm or revise the models that are used to predict the performance of the repository and to provide the technical basis for a license application.

In a report on its activities for 1995, the Nuclear Waste Technical Review Board concluded that DOE was making considerable progress in developing its waste strategy and made several recommendations for improving it. First, the Board said the strategy relies heavily on the presumed dryness of the Yucca Mountain site and recommended that the strategy identify ways to compensate for an unexpectedly high movement of water between the repository and the water table. Second, the Board criticized the qualitative descriptions of the waste attributes and recommended that DOE designate a numeric limit for radiation doses to individuals and specify conditions under which exposures to releases of radioactive materials would be assumed to occur.

Also, the Board said, DOE's strategy does not contain criteria for validating or rejecting the five attributes; therefore, a clearer understanding is needed of the degree of proof that is being sought for each attribute. Finally, after pointing out that all five attributes address favorable conditions, the Board said the strategy would be strengthened if DOE placed more emphasis on identifying potential mechanisms for the repository system to fail and on formulating testable hypotheses about the importance of these mechanisms.

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## **Limitations in DOE's Hydrology Program**

Knowing how water moves through and under Yucca Mountain is critical to the repository project. DOE is studying the hydrology of both the groundwater beneath the site and the area above the water table because the movement of water through the mountain to the groundwater is considered the primary means by which radioactive materials could move from the repository to the environment. Recently, the U.S. Geological Survey identified a number of issues concerning studies of the saturated (groundwater) and unsaturated (above the water table) zones at Yucca Mountain.

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In April 1996, Geological Survey scientists wrote a memorandum that updated their understanding of the key inputs for the models of the flow of water in the saturated zone. They noted that as new issues about the importance of uncertainties about the saturated zone have been raised, the level of understanding of many issues has not increased. They attributed this situation to the lack of new boreholes drilled to the saturated zone since the mid-1980s and the limited testing of the saturated zone since then. One key issue the scientists raised is the resolution of a large drop in the elevation of the groundwater (hydraulic gradient) at the northern end of Yucca Mountain that was discovered in 1981.<sup>20</sup> Estimates of the direction and rate that water moves beneath the site and how radioactive materials would be diluted in the groundwater may differ considerably, depending on different explanations of the cause of the gradient. The gradient remains a concern because the scientists cannot account for its origin. It would be difficult, they said, to claim that they understood the hydrology of the site if they could not explain the cause of the most striking feature in the area. Earlier, in 1992, the technical project officer for the Geological Survey wrote that the large hydraulic gradient must be understood to understand the hydrology of the saturated zone and that it would be “folly” to determine the suitability of the site without a reasonable understanding of this feature and its durability.

In commenting on a draft of our report, DOE pointed out that one existing well is being used to test hypotheses about the origin of the large hydraulic gradient and that the Geological Survey is currently interpreting the test information. The test information, DOE said, may either tell it what it needs to know or indicate how to approach the problem by, for example, drilling another hole or identifying another type of necessary test. Also, NRC commented that studies to date have not shown a significant negative effect on performance as the result of the gradient.

The Geological Survey also identified what it considers important<sup>21</sup> hydrological issues concerning the (1) scarcity of transport data and (2) flow of water directly from the Amargosa Desert near Yucca Mountain to Death Valley to the west. The first issue reflects a severe lack of information to support transport models, which in turn support performance assessment models. According to the Geological Survey

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<sup>20</sup>A key issue is one that is central to having sufficient understanding of the saturated zone's flow system to make a meaningful evaluation of the contributions that the saturated zone can make in meeting regulatory requirements.

<sup>21</sup>An important issue is one that warrants careful consideration but may not be resolvable or may be so difficult or costly to resolve that the Yucca Mountain Project may choose not to resolve it.

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scientists, transport data are scarce because measurements are being made at only one site and may be made at only one additional site in the future. The second issue reflects a potential change in the conceptual model of the flow of groundwater in the region. Little information is available to choose among competing models, and what information is available is subject to different interpretations. Acquiring additional, unambiguous information, however, would be very expensive and may not be warranted.

In June 1996, DOE issued a report on the Geological Survey's program to ensure the quality of its research on the repository project. Although the report's authors concluded that the quality assurance program was adequate, they also expressed concern about persistent, major, unquantified uncertainties at this stage in the project. The report's authors also concluded that the project was severely handicapped by the absence of high-quality hydrochemical data from the site and the elimination of most borehole drilling from DOE's site investigation plans. Specifically, they noted that (1) boreholes to resolve the cause of the large hydraulic gradient north of the site and to test an aquifer at a second location have not been drilled, (2) existing boreholes in the Amargosa Desert have not been sampled or instrumented and drilling in the Southern Funeral Mountains (southwest of Yucca Mountain, in the direction of Death Valley) has not occurred, and (3) instrumentation to measure water levels in numerous boreholes has been removed and mothballed. These actions are inconsistent, they continued, with what is expected of a useful model for the flow of water in the saturated zone, particularly insofar as such a model would be used to support evaluations of the transport of radioactive materials. The issues appear to have been caused by unrealistic expectations for "bounding" system performance in the absence of data that would allow uncertainties to be quantified.

According to the Geological Survey scientists, an important aspect of understanding how water would flow through the unsaturated zone at Yucca Mountain is to study the rate at which water infiltrates the mountain from the surface. Using a network of shallow boreholes across the site, scientists are monitoring changes in moisture content in the upper 50 feet of ground where these changes occur each year. This monitoring program is necessary to develop an adequate record of moisture changes in what is one of the driest areas of the country. The Geological Survey has developed a model of soil moisture and produced a preliminary map of the rates at which water infiltrates the unsaturated zone across the mountain. According to the scientists, the model is fairly rigorous, but certain

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assumptions must be made while using it. However, the infiltration program has ended sooner than had been planned and no new work is planned to study uncertainties in the model. The scientists are concerned about whether there is a sufficient level of confidence in the supporting assumptions used in its model of soil moisture and whether the data and assumptions supporting the model can withstand external scrutiny. They stated that drilling and instrumenting more boreholes would provide more information, but project officials are considering an alternative approach of compensating for uncertainty in this area by backfilling the repository with a material that would keep water away from waste longer.

Geological Survey scientists are also concerned about the adequacy of the studies of water moving through the repository horizon (i.e., percolation). According to these scientists, such studies have been reduced substantially from original plans. The project had planned to drill 17 boreholes to the water table at various locations around the site. Monitoring of pneumatic pressure, temperature, and water potential was to be performed in each borehole for a minimum of 3 to 5 years. According to the Geological Survey, however, while 15 boreholes have been drilled, 4 of them were drilled in different locations than planned. Of the 15 boreholes, 8 do not reach the repository horizon, and no borehole has been drilled deep enough to characterize the Ghost Dance Fault in the Calico Hills Formation. In addition, only seven of the boreholes have been instrumented to monitor pneumatic pressure, temperature, and water potential. Finally, other tests have been reduced or deleted from the testing program altogether.

In commenting on a draft of our report, DOE recognized that more information on the saturated zone is needed and stated that its long-range site investigation plan includes additional tests in the saturated zone. DOE added, however, that its primary focus remains on the unsaturated zone because of the importance of this area to its strategy for containing and isolating waste. After DOE has acquired a better understanding of the overall performance of the proposed repository system, the Department said, it may decide that it can get better performance from the repository system by changing waste package materials rather than by more precisely defining some aspect of water flow. Finally, DOE stated that the concept of backfilling waste storage rooms in the repository with a selected material is one option for improving the repository's performance but that this concept is unrelated to the potential need to reduce hydrological uncertainties.

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One other issue has recently emerged that affects DOE's understanding of the hydrology of the unsaturated zone at Yucca Mountain. DOE has detected the presence of the isotope chlorine-36, produced from atmospheric tests of nuclear weapons about 50 years ago, at the level of the proposed repository. DOE has been testing for the presence of this and other elements to provide information on the age of the water at various locations in the mountain and on the travel time of water through preferential paths, such as faults and fractures, in the rock. DOE found elevated levels of chlorine-36 in samples from five locations within the exploratory studies facility. According to the disposal program's director, the findings need not be, but could be, a critical problem. In DOE's current view, the findings appear to indicate rapid flow of water along preferential pathways. DOE is collecting and analyzing additional samples to confirm results and to provide new information on new areas of the exploratory tunnel. In addition, DOE will perform more modeling studies to evaluate the chlorine-36 data as they relate to the understanding of the hydrologic processes of Yucca Mountain and DOE's conclusions about the repository's performance.

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**Limited Information**  
**Will Be Available on**  
**the Effects of Heat**  
**From Waste**

According to DOE, a key issue that it must address in its investigation of Yucca Mountain is the uncertainty about the interaction of the heat generated by waste in the repository with the surrounding rock, the water contained in Yucca Mountain, and the packages containing waste. To provide information on this issue, DOE planned a series of experiments in the exploratory studies facility and at the surface near Yucca Mountain that began in 1996 and will continue until about 2000. DOE's general testing strategy is to perform simpler, smaller-scale tests first and then move to a more complex, larger test. However, a peer review team, the Nuclear Waste Technical Review Board, and DOE's Lawrence Livermore National Laboratory have raised concerns about the testing program. In general, these concerns are that DOE is not doing large enough tests for long enough periods of time.

Because of the decay of radioactive materials in nuclear waste, it will continue to produce heat for thousands of years after its disposal in a repository. The Nuclear Waste Technical Review Board described this issue—called thermal loading—as one that would largely determine the level of uncertainty about the repository's long-term performance. As early as 1990, the Board stated that the strategy selected to control the temperatures in a repository is a fundamental decision because the selected strategy will affect most components of the waste management

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system, including methods for storing and transporting waste, the design of waste packages, and the design, size, performance, and cost of the repository.

The thermal load of the repository has the potential to significantly redistribute moisture within Yucca Mountain, resulting in extended periods of dryness in the repository or channeling of moisture toward waste packages. Therefore, it is necessary to understand the effects of the thermal load on the temperature of the surrounding rock as well as the movement of water and gases in the vicinity of the repository to have confidence in predictions of containment and long-term waste isolation. The distribution of temperature, liquid saturation, and humidity within the repository will influence the corrosion of metals, alteration of minerals, and geochemistry. These factors are important in predicting the containment time within the waste package and transport times through both the engineered and natural barrier systems.

DOE's thermal test strategy described several sequential tests, in general order of scale and complexity, in the exploratory studies facility. Early tests would be relatively small in scale and limited in complexity. Information gained from these early tests would help in understanding and interpreting results from larger, more complex tests of longer duration. In the first underground test, a long heating rod would be inserted in a horizontal hole to heat the surrounding rock. The next test that DOE intends to perform is intended to heat a larger volume of rock with rows of heating rods emplaced in the walls of an excavated room and in heaters, shaped like waste containers, placed on the floor of the room. DOE considers this test, called a drift-scale test, to be a smaller, less complex, and less costly surrogate to a large-scale, long-duration test that would address information needs that could only be answered by tests that approach the scale of several waste storage rooms (drifts) in the repository.

In addition to its planned underground thermal tests, DOE initiated a test on the surface near Yucca Mountain in a large isolated block of rock. This test was intended to develop and evaluate techniques and data for monitoring the changes in thermal and hydrological properties in a heated rock mass with controlled boundary conditions and provide data to understand the larger and more complex tests in Yucca Mountain. DOE stopped this large-block test in fiscal year 1996 due to budget reductions but restarted it in fiscal year 1997.

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In 1995, DOE established a team of six experts to conduct an external peer review of its thermal testing program. The objective of the review was to evaluate the program's approach to understanding the thermohydrologic conditions at Yucca Mountain that would be generated by the heating of the repository. In its review of the thermal testing program, the review team's primary recommendation was that a large-scale, long-duration test and the large-block test be carried out. The review team concluded that the smaller, less complex tests with single and multiple heating rods are not needed because these tests would be insufficient in scope to fully develop relevant processes. Only the large-scale, long-duration test, the review team said, would give results over a cross-sectional area large enough to be meaningful. The review team noted that DOE is in a major undertaking involving the thermohydrologic behavior of a fractured rock mass for which there is no precedent. By setting up a long-term experiment, DOE could acquire a substantial database, and analysis of the data could begin almost immediately after the experiment has begun. In addition, the review team said, critical design decisions cannot be made using smaller tests because the volume of rock being affected is too small to develop the effects that reveal the "global" picture. The team cautioned that the cost and time to perform the large-scale, long-duration test would be substantial but also stated that scientific defensibility must overrule mandated scheduling and cost constraints. If DOE is forced to choose from among all the tests, the review team said, the large-scale, long-duration test should be done.

DOE disagreed with the review team's recommendation on the large-scale, long-duration test. According to DOE, its planned approach to conducting the large-block test, the test with a single heating rod, and the drift-scale test is consistent with DOE's strategy of progressing from simple to complex and small to large thermal tests and will likely provide the necessary data to defend a thermal loading strategy for the site. Consequently, DOE's current plans do not include performing the large-scale, long-duration test; however, the Department will consider implementing the large-scale, long-duration test if it determines that the planned tests of smaller scale and duration do not provide sufficient data and confidence in related models.

In 1995, the Nuclear Waste Technical Review Board wrote that there is considerable uncertainty associated with the thermohydrologic processes at Yucca Mountain. According to the Board, there is agreement that some heater tests have to be done, but there is no clear enunciation of what types of data are to be collected, how they will be obtained, or the ultimate



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use to which the data will be put. Furthermore, the relatively limited experience of the scientific community in modeling complex thermohydrologic problems in areas like the unsaturated zone at Yucca Mountain will make it especially difficult for DOE to establish the validity of predictions through short-term thermal testing. The Board supported the initiation of a long-term, tunnel-scale thermal test, recommended that DOE give more thought to how more information can be obtained from all heater tests, and concluded that little data will be available for use in DOE's 1998 viability assessment.

Finally, as early as 1992, DOE's Lawrence Livermore National Laboratory had raised concerns about the length of heater tests at Yucca Mountain. DOE had established a task force to consider this issue.<sup>22</sup> A draft report by the task force recommended that in order to meet the schedule for submitting a license application in 2001, a heater test to be performed by the laboratory should be completed in 6 years. At that time, scientists at the laboratory argued that a 6-year test period would barely be long enough for geochemical reactions to take place that could be sampled. Therefore, the scientists said, the 6-year test duration was the minimum time that they could support from a technical standpoint. As currently planned, the drift-scale test would run for 4 years with options for a longer test period if evaluation of the test data warrants the longer duration.

In commenting on a draft of our report, NRC stated that its principal concern is that the thermal testing be representative of the range of repository conditions, rather than the scale or duration of the tests. It added that the testing information that will be available at DOE's current planned date of license application will be limited and will need to be confirmed by additional data collected during performance confirmation or, if the additional data differ significantly from the original design bases and assumptions in the license application, the design may be modified through the license amendment process.

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## Limitations on Waste Package Research

NRC has questioned whether DOE is allowing enough time to test potential materials for waste packages before it submits a license application to NRC. The waste package refers to the waste form and any containers, shielding, packing, and other absorbent materials surrounding an individual waste container. According to DOE, waste packages will consist of multiple metal

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<sup>22</sup>The Yucca Mountain Project Office established the Heater Test Duration Task Force to consider required test durations for the project. The task force consisted of representatives of the organizations responsible for testing on the Yucca Mountain Project as well as management and operating contractor representatives.

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barriers designed to contain the wastes by resisting corrosion for thousands of years. In July 1995, NRC's representatives observed DOE's audit of the effectiveness of the waste package design processes used by the Department's primary contractor for the repository project. Following the audit, NRC's representatives reported to their managers at NRC's headquarters that DOE is following a strategy of continuing development and analytical work on a selected set of candidate waste package materials. According to this report, the final choice of materials for waste packages will not be made until a prototype waste package is made or by the time DOE submits its license application to NRC. Also, DOE's primary contractor for the repository project indicated that none of the currently available data on the performance of materials, such as corrosion, will be used for licensing. NRC's report stated that the contractor plans to obtain test data over only 5 years to analyze long-term failures of waste packages in the license application. Validating waste package performance is expected to continue during the operation of the repository. In their report, NRC's representatives concluded that predicting the long-term performance of waste packages will be difficult using only the relatively short-term test results that will be available when the license application is submitted in 2002.

DOE does not agree with the comments in NRC's report. The Department expects that available data on mechanical and corrosion performance of materials will be used to support a license application. Also, DOE said it is not clear that NRC's conclusion about predicting long-term performance of waste packages from short-term test results is accurate. NRC said it may still be possible to show, with reasonable assurance, that the overall system performance standard is met at the time of license application. NRC added that its licensing regulations anticipate that additional research may be required to determine the adequacy of the design and provide that a license to construct a repository may have conditions related to the satisfactory resolution of safety questions for which research is being conducted.

# Comments From the Department of Energy



## Department of Energy

Washington, DC 20585

December 23, 1996

Mr. Victor S. Rezendes  
Director, Energy, Resources,  
and Science Issues  
U. S. General Accounting Office  
Washington, D.C. 20548

Dear Mr. Rezendes:

I have read with interest, and shared with appropriate members of my staff, your draft report (GAO/RCED-97-30), entitled "Impediments to Completing the Yucca Mountain Repository Project." General comments on the draft follow and specific comments are provided as an enclosure.

The Viability Assessment will be completed, as the Administration has proposed and the Congress has directed, in September of 1998. That report will provide a comprehensive and contemporary set of documents that set forth the description of the repository that can be constructed at Yucca Mountain, its projected performance in the geologic setting, and its estimated cost. This description will be based upon the available data, which has been collected and analyzed over more than fifteen years at a cost of approximately \$2.5 billion. For the first time a wealth of available data, analysis, and theory will converge in a comprehensive assessment of a total project concept. We also believe that it will address the major technical challenges confronting the construction of the repository and its performance and provide realistic responses.

Although the report recognizes that the availability of the Viability Assessment will provide information for policy decisions, it recommends that decisions involving the probability of construction of a repository be suspended until the formal site recommendation to the President by the Secretary of Energy. That action is planned to take place in the year 2001.

The comprehension of the Yucca Mountain site and its ability to house a repository for high level nuclear waste has been progressively increasing since the first geologists made reconnaissance surveys of surface evidence with that objective in mind in 1978. The comprehension, and therefore the confidence, that such a repository will be both viable and acceptable in a policy sense will continue to increase throughout the investigation, licensing, and construction phases of the repository and, indeed, throughout the retrievability period mandated by Nuclear Regulatory Commission regulations which will not end until well into the second half of the 21st century.

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**Appendix III**  
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What level of comprehension or certainty is appropriate to inform the policy decision on interim management of spent reactor fuel must, and will, be made in the legislative process with the participation of the President exercising his Constitutional role.

With regard to site suitability, the Yucca Mountain Project long range schedule calls for an interim evaluation in 1999 of the suitability of the Yucca Mountain site in accordance with the guidelines established in 10 CFR Part 960. These guidelines, which were originally promulgated to address multiple sites, are currently being amended to clarify and focus the evaluation specifically on the Yucca Mountain site. That evaluation of the assessment of performance of the total system will consider, in an integrated manner, the technical information that is expected to be available at that time with respect to site characteristics and the repository and waste package designs. While the interim guideline evaluation does not constitute an agency action, it is an interim status report on important information that leads to a decision by the Secretary to recommend the site for repository development to the President. The Secretary's recommendation would constitute the final agency action, which would need to take into account those aspects required by Section 114 of the NWPA, as follows:

- A description of the repository and waste package designs and site data obtained
- A Final Environmental Impact Statement
- Preliminary comments from the Nuclear Regulatory Commission concerning the extent to which the site characterization analysis and waste form proposal seem to be sufficient for inclusion in a License Application
- The views of any State or affected Indian tribe, with responses from the Department
- Any impact report submitted by the State of Nevada
- Any other information the Secretary considers appropriate.

With respect to the Commission's preliminary sufficiency comments mentioned above, the Department plans to provide information to and interact with the Commission staff over the next several years. The Department expects that this exchange of information on a real-time basis, supplemented by ongoing interactions at various technical and management levels, would form a good basis for the Commission's preliminary sufficiency comments.

The GAO appears to be misinformed on the Department's plans for site characterization between 1996 and 2000 to address the uncertainties related to hydrologic flow models (saturated and unsaturated zones), thermal loading, and waste package materials. The Department plans to continue drilling and testing of the hydrologic system through the year 2000 to address the specific uncertainties. The Department also recognizes that the large scale thermal test may require additional time for the heating phase. In recognizing this, the Department has established a major milestone to address the issue of continuing the heating phase or initiating the cool down phase of the large scale heater test. The Department recognizes the difficulty in projecting the long-term performance of waste package materials. In so doing the Department and its contractors continue to address possible ways of reducing this uncertainty. It is important to note that the Department is not required to demonstrate the performance of the system or subsystems

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prior to the submittal of the license application. The Department intends to make every reasonable effort to reduce uncertainties; however, for those major uncertainties that remain, we will articulate them in our discussions of the safety case and specifically in the license application. We will also identify in the license application those planned performance confirmation activities and tests designed to further reduce the uncertainties.

I appreciate the opportunity to review your draft report and hope that these comments will assist you in producing a fair, complete and accurate final document.

Sincerely,

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

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

Enclosure

**Specific Comments on Draft GAO/RCED 97-30**

Now on p. 2.

1. On page 2, the statement that “DOE curtailed most investigation activities at Yucca Mountain in favor of analyzing the information already collected and continuing a few critical activities” misrepresents the way that the FY 1996 science program was developed. Based on the considerable amount of data already collected and the programmatic decision to keep the TBM operating, the following guidelines were developed and applied to modify the program:
  - Highest priority was given to synthesis and modeling because we need to understand what we have found to better focus test programs on key uncertainties and spend our budget most wisely.
  - Second priority was given to ESF tests since we had almost no information from the repository horizon. The whole point of the ESF was to get to depth and do in situ testing related to the unsaturated zone and geology.
  - Third priority was to do surface testing, with highest priority within this category given to saturated zone tests (c-wells and G-2).

The draft implies that DOE was wrong to emphasize modeling. As noted in the USGS memo cited in the draft report, modeling is the key to identifying the data that we still need to collect.

Now on p. 5.

2. On page 8, the funding chart shows \$245 million appropriated for the project in FY93. The correct amount is \$259 million.

Now on pp. 6,7.

3. The discussion of drilling on pages 8 and 9 is inaccurate and misleading. For example, on page 8, the draft report correctly states that the 1994 Program Plan included “25 to 30 deep boreholes” planned from 1995-2000 for license application. On page 9, the report states incorrectly that “only one new borehole” will be completed, implying that no additional boreholes will be completed for license application. It fails to make it clear that the plan to drill only one new borehole applied to Fiscal Year 1996. It also fails to acknowledge that at least 7 holes were dropped because they were no longer justified technically. The report also neglects to acknowledge out-year plans for the southern test complex (5-7 holes), which is in the project long-range plan.

Now on p. 8.

4. On page 10, the report misrepresents the intent of the viability assessment. It is suggested that the OCRWM Program Plan, Revision 1, or Dr. Dreyfus’ testimony to the NWTRB be utilized as sources of a clear articulation of the purpose of the viability assessment.

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Now on p. 11.

5. On page 15, the text misrepresents the 1999 completion of the Project Integrated Safety Assessment (PISA). The PISA will present interim status information about the geologic/hydrologic description and models, repository and waste package design, and total system performance assessment. It will provide an integrated discussion of the elements of the safety case and will be used in the dialogue with NRC on the sufficiency of site characterization.

DOE's intent is to use the PISA as a means of focusing the NRC on critical issues by presenting a comprehensive integrated discussion of the safety case and anticipated performance of Yucca Mountain, and to give the NRC an integrated access to all available information (e.g., designs, scientific models, all calculations).

Now on p. 13.

6. The report correctly states on page 20 that the large drop in the groundwater level ("large hydrologic gradient") north of the Yucca Mountain site, has not been fully evaluated. However, the available data from several existing wells indicate that the potential large hydrologic gradient does not impact the water level and flow system of the aquifer beneath it. It should also be noted that YMSCO recently completed a pumping test (G-2 well) in an attempt to further define the large hydrologic gradient. A full interpretation of the data is currently under way. Preliminary observations of the pump-test data indicate that this phenomenon to the north has no effect on the groundwater flow system in the aquifer beneath the potential repository site. Consequently, there is no evidence that the large hydrologic gradient will impact waste isolation.

Due to Congressional FY 96 budget reductions, plans to drill several additional holes (e.g., WT-23 and WT-24) were postponed in order to allocate the limited available funds to the other parts of the site-characterization effort with recognized impacts on waste isolation.

Now on p. 14.

7. Page 21 of the draft report should reflect the fact that DOE does not intend to ask the NRC, or anyone else, to review the viability assessment.

Now on p. 24.

8. Page 31 should be revised for accuracy. The USGS is not studying the transport of radionuclides; that is a LANL task. Regarding groundwater flow, DOE recognizes that more data on the saturated zone is needed. For this reason, surface-based testing in Fiscal Year 1996 focused on c-wells and G-2 (saturated zone testing).

Now on p. 33.

9. It should be noted that G-2 was designed to test hypotheses regarding the origin of the large hydraulic gradient discussed on pages 44-46. OCRWM's long-range plan includes additional saturated zone tests. It also should be noted that 4 of 5 attributes of importance in the Waste Containment and Isolation Strategy (WCIS) are related to unsaturated zone parameters; therefore, primary focus remains on the unsaturated zone.

Now on pp. 33,34.

10. On pages 45-47 the selective quotes from the USGS memos and the QA audit report are misleading. The discussion of the large hydraulic gradient fails to describe the ongoing tests and analyses at G-2 from FY 1996 and FY 1997. These tests are explicitly directed at understanding the gradient. The USGS is currently interpreting the test data. The data may tell us what we need to know or indicate how best to approach the problem, i.e., where to site an additional hole or what type of test to conduct.

Now on p. 34.

11. On page 47, the draft report appears to confuse field activity with knowledge. More drilling for the sake of drilling is not prudent use of funds. The models, including the Total System Performance Assessment, need to catch up with the data collection activities to produce an enhanced understanding of the site. Then the models can be used to guide the field activities to focus on reducing the most important uncertainties in the overall performance of the site. These uncertainties may or may not correlate with what any individual investigator sees as important to his model; for example, DOE may get better performance by changing waste package materials than by better defining some aspect of water flow in the unsaturated zone. The USGS memo, (from Luckey to Craig), cited by GAO, clearly makes this point.

The statement that USGS scientists say that “drilling and instrumenting more boreholes would provide more information, but project officials are considering an alternative approach of compensating for uncertainty in this area by backfilling the repository with a material that would keep water away from waste longer,” misrepresents DOE’s position. The backfill concept is one option for improving performance; it is unrelated to the need or lack thereof for more boreholes and testing to reduce uncertainties concerning the hydrologic properties of Yucca Mountain. No decision has yet been made whether to backfill the repository, but the design should not preclude the adoption of this option.

Now on p. 37.

12. On page 52, the schedule for the drift-scale test indicates a four year duration. However, the draft report does not clearly state that there is a DOE decision point (level-2 milestone) built into the plan. The decision point requires the OCRWM Management and Operating Contractor (M&O) to provide a recommendation to DOE on continuing the heat up phase or turning off the heaters and beginning the cool down phase. The hold point clearly requires the M&O to base its recommendation on an analysis of the data. DOE can overrule the recommendation and fully recognizes that it may take more than four years to obtain the required data.

Now on p. 39.

13. To make the discussion of waste packages on page 53 accurate and complete, the following points should be considered:
- o Because of physical constraints, the material for a prototype must obviously be chosen before the prototype is completed. Because of regulatory constraints, the material for actual disposal containers must be chosen before a license application is submitted.



As written, the draft could be incorrectly interpreted to mean that the final choice of material will not have been made at the time DOE submits its license application to NRC. It is recognized, however, that the results of prototyping, welding, and corrosion studies could modify the selection.

- o The statement "DOE's primary contractor for the repository project indicated that none of the currently available data on the performance of materials, such as corrosion, will be used for licensing" is inaccurate. Materials performance includes, for example, mechanical performance, and currently available data on mechanical performance are being used in analyses that are expected to support a license application. A related but weaker statement, "...none of the currently available data on the corrosion performance of materials will be used for licensing" is also inaccurate. It is expected that currently available data on corrosion performance will be used as partial support for a license application.
- o The word "initial" should be deleted from the sentence "Validating waste package performance is expected to continue during initial operation of the repository."
- o NRC's representatives may have reached the conclusion that predicting the long-term performance of waste packages will be difficult using only the relatively short-term test results that will be available when the license application is submitted in 2002; however, it is not clear that the conclusion is accurate. It would be helpful to specify which aspects of performance were deemed difficult to predict.

# Comments From the Nuclear Regulatory Commission



UNITED STATES  
NUCLEAR REGULATORY COMMISSION  
WASHINGTON, D.C. 20555-0001

January 3, 1997

Mr. Victor S. Rezendes  
Director, Energy, Resources,  
and Science Issues  
U.S. General Accounting Office  
Washington, D.C. 20548

Dear Mr. Rezendes:

Your letter of December 16, 1996, requested our review and comment on the U.S. General Accounting Office's draft report entitled "Nuclear Waste: Impediments to Completing the Yucca Mountain Repository Project." I have enclosed our comments for your consideration in response to your request.

Sincerely,

  
James M. Taylor  
Executive Director  
for Operations

Enclosure: As stated

Appendix IV  
Comments From the Nuclear Regulatory  
Commission

U.S. NUCLEAR REGULATORY COMMISSION COMMENTS ON  
THE U.S. GENERAL ACCOUNTING OFFICE DRAFT REPORT ENTITLED "NUCLEAR WASTE:  
IMPEDIMENTS TO COMPLETING THE YUCCA MOUNTAIN REPOSITORY PROJECT"

1. Clarify the impact of NRC's budget reductions.

Now on p. 14.

Page 20 of the U.S. General Accounting Office (GAO) draft report states that the U.S. Nuclear Regulatory Commission stopped reviewing 3 of the 10 key technical issues because of budget reductions. This sentence should be revised to state that: "For FY 1996 and 1997, NRC eliminated its contractor support for 3 of the 10 key technical issues, but the staff assigned to these issues have monitored and will monitor U.S. Department of Energy (DOE) activities to address the most significant regulatory issues to the extent limited resources permit. As a result, future reviews for these three issues will be limited and based on available knowledge unless the NRC obtains the requested funding for these reviews. There will be no further independent studies and regulatory issues will be bounded by conservative assumptions."

Now on p. 14.

The last sentence in the paragraph at the top of page 21 should also be revised as follows: "If this budget trend continues, according to NRC's staff, the Agency would have to discontinue contractor work on two more key technical issues, and would not be able to complete its license review in the 3-year licensing period required by the Nuclear Waste Policy Act of 1982 (NWPA)."

Now on p. 14.

The following revisions to the last sentence in the first full paragraph on page 21 should also be made: "For technical issues where contractor technical work has been eliminated, NRC's reviews of DOE's designs and technical basis for performance assessments and cost estimates in the viability assessment will be limited and based on conservative assumptions and available knowledge."

2. Recognize the importance of ongoing NRC feedback to DOE.

Now on p. 14.

Page 21 of the draft report describes NRC's review and comment on DOE's viability assessment as providing the first insights into NRC's formal position regarding the contents of an acceptable license application. The draft report also states that the first formal opportunity for providing a formal position are the comments provided to DOE in January 2000. The report should be revised to recognize that: "For years the staff's prelicensing reviews and interactions with DOE have documented feedback to DOE regarding what is needed for licensing. Continuing to provide DOE feedback is a primary objective of resolving key technical issues under NRC's refocused program. Therefore, the staff considers that its comments on DOE's plans for the license application in the viability assessment will reflect whatever significant differences remain between the staff and DOE as a result of our ongoing issue resolution efforts with DOE. Interactions with DOE will continue after the viability assessment and will focus on resolving the remaining differences important to licensing. Should such differences persist, they will be documented in the Commission's preliminary comments on the sufficiency of at-depth site characterization analysis and waste form to be included in DOE's site recommendation report."

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Now on p. 39.

**3. Clarify NRC comments on waste package testing and performance.**

The concerns attributed to NRC's representatives at the repository site in Appendix II, page 53, were actually statements made in an Observation Audit Report by NRC Headquarters staff, dated August 23, 1995. Although it is true that limited data will be available on performance of waste package materials at time of license application, it may still be possible to show, with reasonable assurance, that the overall system performance standard is met. NRC regulations anticipate that, at time of license application, additional research and development may be required to confirm the adequacy of the design and require DOE to provide a detailed description of programs designed to resolve safety questions. NRC regulations provide that a construction authorization granted to DOE may have conditions related to satisfactory resolution of safety questions for which research and development are being conducted.

Now on p. 10.

**4. Clarify DOE's schedule for site recommendation and need for standards and regulations.**

The draft GAO report states on page 15 that DOE needs to have the standards and licensing regulations in place by July 1998 to meet DOE's schedule for making the site-suitability determination in July 1999. DOE's plans indicate that it will complete a 10 CFR Part 960 Compliance Report, not the formal site-suitability determination, in July 1999. The Compliance Report will be followed by numerous other activities needed to support a proposed site recommendation to the Secretary of Energy in May 2001 and a final site recommendation to the President in July 2001. Although NRC agrees that the standards and regulations should be available for DOE to complete its Compliance Report, this report is followed by 2 years of other supporting work before the final Agency action of site recommendation. NRC suggests that the GAO report clarify that the Compliance Report in July 1999 is an initial step toward the final site-suitability determination in the site recommendation to the President in July 2001.

Now on pp. 10,15.

**5. Clarify reference to NRC's preliminary sufficiency comments required by NHPA.**

In a number of places, the draft GAO report (e.g., pages 15 and 21) refers to NRC's preliminary comments on sufficiency of investigations for a license application. NRC suggests that where it is first used, the text be revised to give the more specific wording of NHPA. In particular, it is suggested that the second paragraph on page 15 be revised to read

~~"Among other things, the comprehensive statement must contain NRC's preliminary comments on the sufficiency for a license application of DOE's analysis of its investigation of Yucca Mountain and the proposed form of the waste, concerning the extent to which the at-depth site characterization analysis and waste form proposal for such site seem to be sufficient for inclusion in any license application."~~

Subsequently, these comments could be more simply referred to as: "The Commission's preliminary sufficiency comments required by NHPA."

Now on p. 10.

The draft GAO report states on page 15 that NRC would not be in a position to comment on the sufficiency of DOE's site investigation unless the standards and

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regulations have been issued. This sentence should be revised to indicate NRC would not be in a position to finalize its preliminary sufficiency comments required by NWPA until the final standards and regulations have been issued.

**6. Schedule for completing revisions to NRC regulations.**

Now on p. 9.

The draft GAO report states on pages 13 and 14 that prior experience indicates that it could take 2 years or longer to issue the new standards and revised licensing regulations. Although it is true that it took 2 years from proposed to final technical requirements in 10 CFR Part 60, NRC did not have a statutory deadline at the time. The GAO report should be revised to recognize that: "Under the Energy Policy Act of 1992, NRC is directed to modify its regulations no later than 1 year after the U.S. Environmental Protection Agency (EPA) promulgates its standards."

Now on p. 29.

On page 38 the draft report states that DOE has advised the staff that it needs NRC to complete its revisions to its licensing regulations 1 year before DOE makes its determination of site suitability and 2 years beforehand if NRC makes major changes to the regulations. NRC staff does not have a record or recollection of receipt of this information.

**7. Strategy for revising NRC's regulations.**

Now on p. 9.

The last sentence in the first paragraph on page 13 should be revised as follows: "For example, when NRC's staff provides the Commission with comments on EPA's proposed standards for the Commission's consideration, the staff also plans to provide the Commission with a strategy for revising NRC's licensing regulations, including the need for subsystem performance requirements."

Now on p. 26.

In addition, page 35, paragraph one, should be revised as follows: "The staff expects to review...."

Now on p. 12.

Finally, the second paragraph on page 17 should be revised to read: "Currently, NRC's regulations require DOE to demonstrate compliance with EPA's generally applicable environmental standards. However, the EPA standards have been revised to pertain to repositories at sites other than Yucca Mountain."

**8. Limitations of DOE activities in key areas.**

The key areas identified in Appendix II are included in the ten Key Technical Issues identified by staff, and are being addressed in interactions between the staff and DOE. The significance of the limited data cited by GAO to total system performance is still undergoing evaluation. Studies to date have not shown a significant negative impact on performance as the result of the steep gradient noted in Appendix II of the draft GAO report. Also, although the results of thermal testing and corrosion testing of candidate waste package materials may be limited at time of license application, NRC regulations recognize that available information may be limited and provide for additional research and development to be conducted after license application and also require a program of performance confirmation to confirm that natural and engineered barriers are functioning as intended.

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**9. DOE's hydrology program.**

Appendix II discusses the limitations of DOE's hydrology program and makes a number of recommendations for additional testing. Considering the limitations on resources available for additional testing, NRC recommends concentrating testing programs on parameters and processes found to be most significant to total system performance.

**10. DOE's thermal testing strategy.**

Appendix II identifies the effects of heat on the surrounding rock, the ground water and the waste packages as a key issue, and the staff agrees and has included these effects in three of the Key Technical Issues it has identified as needing resolution. Staff has been interacting with DOE on DOE's thermal testing strategy, to achieve issue resolution. DOE has developed a thermal testing strategy involving a series of tests of increasing size and complexity to acquire the needed information. NRC's principal concern is that the testing be representative of the range of repository conditions, rather than the scale or duration of the tests. The thermal testing data that will be available at DOE's current planned date of license application will be limited and will need to be confirmed by additional data collected during performance confirmation. If the observations during the performance confirmation program differ significantly from the original design bases and assumptions in the license application, NRC regulations provide that the design may be modified through the license amendment process.

# Scope and Methodology

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To identify the adjustments the Department of Energy made to its disposal program and the potential impediments to achieving the Department's current objectives and schedule for the repository project, we performed our work primarily at DOE's headquarters in Washington, D.C., and its Yucca Mountain Site Characterization Project Office in Las Vegas, Nevada. At these locations, we obtained and reviewed information from officials of DOE's Office of Civilian Radioactive Waste Management, including officials assigned to the site investigation project; officials of DOE's management and operating contractor for the project; and officials of the U.S. Geological Survey, which is a participant on the project. We also visited the candidate repository site at Yucca Mountain, Nevada, including observing activities under way in the exploratory studies facility tunnel in the mountain.

We also obtained and reviewed information from officials of the (1) Division of Waste Management, Nuclear Regulatory Commission; (2) Office of Radiation and Indoor Air, Environmental Protection Agency, Washington, D.C.; (3) Agency for Nuclear Projects, state of Nevada, Carson City, Nevada; (4) comprehensive planning office of Clark County, Nevada; and (5) Nuclear Waste Technical Review Board, Arlington, Virginia.

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# Related GAO Products

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Department of Energy: Unethical Conduct at DOE's Yucca Mountain Project (GAO/OSI-96-2, Sept. 30, 1996).

Nuclear Waste: DOE's Management and Organization of the Nevada Repository Project (GAO/RCED-95-27, Dec. 23, 1994).

Nuclear Waste: Comprehensive Review of the Disposal Program Is Needed (GAO/RCED-94-299, Sept. 27, 1994).

Nuclear Waste: Foreign Countries' Approaches to High-Level Waste Storage and Disposal (GAO/RCED-94-172, Aug. 4, 1994).

Independent Evaluation (GAO/RCED-94-258R, July 27, 1994).

Nuclear Waste: Yucca Mountain Project Management and Funding Issues (GAO/T-RCED-93-58, July 1, 1993).

Nuclear Waste: Yucca Mountain Project Behind Schedule and Facing Major Scientific Uncertainties (GAO/RCED-93-124, May 21, 1993).

Energy Issues: Transition Series (GAO/OGC-093-13TR, Dec. 1992).

Nuclear Waste: Status of Actions to Improve DOE User-Fee Assessments (GAO/RCED-92-165, June 10, 1992).

Nuclear Waste: DOE's Repository Site Investigations, a Long and Difficult Task (GAO/RCED-92-73, May 27, 1992).

Nuclear Waste: Development of Casks for Transporting Spent Fuel Needs Modification (GAO/RCED-92-56, Mar. 13, 1992).

Nuclear Waste: Operation of Monitored Retrievable Storage Facility Is Unlikely by 1998 (GAO/RCED-91-194, Sept. 24, 1991).

Nuclear Waste: Changes Needed in DOE User-Fee Assessments (GAO/T-RCED-91-52, May 8, 1991).

Nuclear Waste: DOE Expenditures on the Yucca Mountain Project (GAO/T-RCED-91-37, Apr. 18, 1991).

Nuclear Waste: Changes Needed in DOE User-Fee Assessments to Avoid Funding Shortfall (GAO/RCED-90-65, June 7, 1990).

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**Related GAO Products**

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Nuclear Waste: Quarterly Report as of March 31, 1989 (GAO/RCED-89-178, Aug. 14, 1989).

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