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FOREWORD

The Nuclear Waste Policy Act of 1982 (P.L. 97-425) as amended requires the Department of Energy (DOE) to report, not less than every 6 months, on the "nature and extent...of site characterization" and the "information developed from such activities." To meet this requirement, the DOE will prepare a series of semiannual progress reports and submit them to the Nuclear Regulatory Commission (NRC), the Governor and the legislature of the State of Nevada, and affected units of local government. The semiannual progress reports will also be made available to the Nuclear Waste Technical Review Board and the public. These reports will describe progress in the site characterization program conducted at the Yucca Mountain site in Nevada and identify any changes that are made during the reporting period in the DOE's plans and schedules for site characterization. The reporting period will close 3 months before the issuance of each report. This document is the first semiannual progress report to be issued. It covers the period between September 15, 1988, and April 15, 1989.

The DOE's plans for site characterization are described in the Site Characterization Plan (SCP) for the Yucca Mountain site, which has been submitted for review to the NRC, the State of Nevada, the affected units of local government, other interested parties, and the public. More detailed information on plans for site characterization will be presented in study plans for the various site characterization activities.

The principal purpose of the semiannual progress reports is to provide information on the status of site characterization activities, as mandated by the Nuclear Waste Policy Act of 1982, as amended, and to identify significant changes in the DOE's plans and schedules for site characterization. These reports, however, will not provide technical information in a form that can be used for decision making or program planning. Furthermore, they will not contain the details and analyses needed to support changes in plans and schedules or represent the official documentation needed to implement a change in the site characterization program. The DOE is currently developing a baselined controlled document that describes the testing program. This document will serve as a vehicle for implementing changes to the testing program and for referencing documents that provide the technical information to support decision making, program planning, and any required changes. Any changes in the testing program will be subject to a rigorous change-control procedure and will be reported to all participants in the DOE's waste-management program, including the NRC, the State of Nevada, and affected units of local government. Thus, the semiannual progress reports are the vehicles for reporting on the status of site characterization and not the vehicles for decision making or implementing changes in the site characterization program.

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1. INTRODUCTION

1.1 PURPOSE AND SCOPE OF THE SEMIANNUAL PROGRESS REPORT

In accordance with the statutory requirements of Section 113(b)(3) of the Nuclear Waste Policy Act of 1982 (P.L. 97-425), as amended, and the regulatory requirements of the Nuclear Regulatory Commission (NRC), stated in 10 CFR Part 60, the Department of Energy (DOE) has prepared this report on the progress of site characterization activities at Yucca Mountain in southern Nevada. This report is the first of a series of reports that will be issued at intervals of approximately 6 months during site characterization; it covers the period September 15, 1988, through April 15, 1989. This and future progress reports will be submitted to the NRC, and the Governor and legislature of Nevada. It will also be made available to the Nuclear Waste Technical Review Board, affected units of local government, and the public.

The semiannual progress report presents short summaries of the status of site characterization activities and cites the technical documents that provide more detailed information on the activities. The report provides highlights of the work started during the reporting period, work in progress, and work completed and documented during the reporting period. In addition, the report discusses any major changes to the DOE's site characterization program as information about the site is collected and evaluated, as more-detailed designs of the repository and the waste package are developed, and as new results from performance assessments are obtained. It also discusses any major changes to the site characterization program made in response to external concerns.

The semiannual progress report conveys information in a convenient summary form. This information is not intended to be the primary basis for presenting or documenting technical or policy positions. Any technical data included in the progress report are intended to be used for information purposes only. The analyses or studies that produced the data are presented in the cited technical reports; all of these reports have been published and are available for inspection at DOE public reading rooms located in Washington, DC and the State of Nevada.

The progress report consists of three main sections: (1) an introductory section, (2) a section on the status of site characterization activities, and (3) a section providing updated schedule information relevant to site characterization. Complete lists of the documents cited and acronyms used in the text are also provided. In addition, the report includes a selective annotated bibliography of recent publications relevant to site characterization.

1.2 BACKGROUND INFORMATION

As stated in Section 5011 of the Nuclear Waste Policy Amendments Act of 1987 (the Amendments Act--P.L. 100-203), the Yucca Mountain site in Nevada has been selected by the U.S. Congress for detailed study as the candidate site for the first U.S. geologic repository for spent nuclear fuel and high-level radioactive waste. The Yucca Mountain site has not been selected for a repository; rather, it has been designated as the only candidate site for characterization to assess its suitability for development as a repository.

The purpose of this detailed study is to obtain the information necessary to determine whether the Yucca Mountain site is suitable for a geologic repository and, if so, to provide the information necessary to prepare a license application for submittal to the NRC. Suitability will be determined by the DOE. If the finding is negative, the DOE will terminate site characterization activities at the site as part of the actions required by the Amendments Act. If the finding is positive, a recommendation will be sent to the President for approval. If the President approves, a recommendation will be sent to the Congress for consideration. The State of Nevada retains the right of disapproval on which Congress would have to act for the repository program to proceed. If the President's recommendation becomes effective, a license application will be submitted to the NRC to obtain authorization to construct a repository at the site.

1.2.1 Site characterization

The detailed study mentioned in the preceding section is referred to as site characterization. It is a comprehensive program of activities to collect site information. These activities are integrated with activities to design a potential repository, a repository seals system, and a waste package (i.e., the waste form and the container in which it is packaged for disposal) and with the activities associated with performance assessments.

The site information consists of data on the natural features of the site, such as those related to the geologic, hydrologic, geochemical, climatological, and meteorological conditions at the site. This information is obtained by conducting both surface-based and underground field tests as well as tests in the laboratory. The underground investigations will be conducted in an exploratory shaft facility (ESF). The ESF will consist of two exploratory shafts, excavated to the depth of the proposed repository horizon, that provide access to underground testing rooms and tunnels. The ESF also will include various structures and buildings on the surface, such as a hoist house for the shafts and temporary buildings for laboratories and offices.

No significant adverse environmental, including socioeconomic effects, are expected to result from site characterization (DOE, 1986).

However, the DOE, in consultation with the State of Nevada and affected units of local government, will conduct activities during site characterization to monitor environmental and socioeconomic conditions and will implement appropriate mitigation measures that may be necessary. Plans for such monitoring and mitigation are described in the Environmental Monitoring and Mitigation Plan (DOE, 1988a) and the Socioeconomic Monitoring and Mitigation Plan (DOE, 1988b). Results of the monitoring activities will be reported semiannually in environmental and socioeconomic progress reports.

1.2.2 The Site Characterization Plan

In preparation for site characterization, the DOE issued the Site Characterization Plan (SCP) for the Yucca Mountain site (DOE, 1988c) in December 1988. An SCP overview (a summary of the SCP) and an informational public handbook also were released. Notices of the availability of the SCP and its accompanying documents were published in the Federal Register, and the Nevada news media were notified.

Chapters 1 through 7 of the SCP discuss the current understanding of the technical characteristics and features of the site and a preliminary conceptual design of the repository in sufficient detail so that the basis for the site characterization program can be understood. Chapter 8 of the SCP describes, in general, the tests and analyses that the DOE is conducting during site characterization and the rationale used to identify them. More-detailed descriptions of the tests and analyses are provided in study plans and technical procedures. Chapter 8 also discusses the design and construction of the ESF, the potential impacts of site characterization on the waste-isolation capabilities of the site, the schedule for site characterization activities, the quality-assurance program for site characterization, and the plans for decommissioning facilities used for characterization if the Yucca Mountain site is not found to be suitable as a repository site.

A consultation draft of the SCP was released in December 1987. Although much of the technical information contained in the consultation draft was updated in the statutory SCP (released in December 1988), some sections of the consultation draft remained unchanged. Some information from technical documents published between late 1987, when the consultation draft went into final production, and late 1988, when the statutory SCP went into final production, may not be discussed in the statutory SCP. However, the Yucca Mountain Project Office periodically publishes a bibliography of all technical reports and documentation of research relevant to Yucca Mountain. Information on any published documents not discussed in the SCP or in this progress report can be found in these bibliographies. The most recent bibliography covers the period from July 1988 through December 1988 (DOE, 1988d). Three other bibliographies cover the period from 1977 through June 1988 (DOE, 1987; DOE 1988e; DOE, 1988f).

1.2.3 Participation by the State of Nevada and affected units of local government

The Amendments Act established a specific role in the repository program for the State of Nevada and affected units of local government. (The affected units of local government are Nye County, Clark County, and Lincoln County.) This role includes review of: (1) the DOE's technical documents, including the SCP; (2) the results of site characterization activities; (3) the designs for the repository and the waste package; and (4) the results of performance assessments. The State of Nevada and the affected units of local government receive financial assistance to perform these review activities.

1.2.4 Review by the Nuclear Waste Technical Review Board

The Amendments Act established a Nuclear Waste Technical Review Board that is independent of the DOE. The Board is to consist of 11 members appointed by the President from at least 22 candidates nominated by the National Academy of Sciences. The Board is to evaluate the technical and scientific validity of DOE activities. These activities include site characterization activities and activities related to waste packaging and transportation. Twice a year, the Board is to report its findings and conclusions to the Secretary of Energy and to the Congress.

On January 18, 1989, the President appointed eight individuals to the Board: D. U. Deere, of the University of Florida, who has been designated Chairman; C. L. Allen, of the California Institute of Technology; J. E. Cantlon, of Michigan State University; M. W. Carter, professor emeritus at the Georgia Institute of Technology; D. Langmuir, of the Colorado School of Mines; D. W. North, of Decision Focus, Inc.; D. L. Price, of the Virginia Polytechnic Institute and State University; and E. D. Verink, of the University of Florida.

The Board has met with the DOE to receive a briefing on the overall waste-management program. In addition, the Structural Geology and Geoengineering Panel of the Board has met with the DOE to discuss plans for underground excavations during site characterization and methods for constructing the exploratory shafts, and the Risk and Performance Assessment Panel has met with the DOE to discuss risk and performance assessment. The Board received a copy of the SCP and is to receive a comprehensive briefing on the technical aspects of the Yucca Mountain site, including a trip to the site, in June 1989.

2. STATUS OF SITE CHARACTERIZATION

2.1 PREPARATORY ACTIVITIES

2.1.1 Quality assurance program

During the reporting period, the DOE commenced the qualification of the quality assurance (QA) programs of the DOE Office of Civilian Radioactive Waste Management (OCRWM), the DOE Yucca Mountain Project Office (Project Office), and project participants. Qualification of QA programs is required for the initiation of new site characterization activities. Data obtained through activities conducted before a fully qualified QA program is in place must be qualified, or the activity may have to be performed again, if the data are to be used in the licensing process. Qualification of data will be performed in accordance with NRC guidance on qualification of data (NRC, 1988b).

The OCRWM developed and issued the Quality Assurance Requirements (QAR) document on November 3, 1988, and the Quality Assurance Program Description (QAPD) document on December 20, 1988. The QAR defines the QA requirements governing activities affecting quality, and the QAPD describes the OCRWM responsibilities, interfaces, and provisions necessary to implement the requirements of the QAR. As of April 15, 1989, the documents were undergoing review by the NRC. The OCRWM also initiated the development of QA administrative procedures to implement the requirements of the QAR and QAPD. As of April 15, 1989, 10 of these procedures had been issued.

The Project Office issued Revision 2 of the Nevada Nuclear Waste Storage Investigations Quality Assurance Plan (QAP) 88-9 on December 7, 1988. The QAP defines, for the entire Yucca Mountain Project, the QA requirements governing activities affecting quality and the responsibilities, interfaces, and provisions necessary to implement the requirements. The NRC accepted the QAP on December 30, 1988. The Project Office and project participants reviewed and revised their individual Quality Assurance Program Plans (QAPPs) to meet the requirements of QAP 88-9, Revision 2. As of April 15, 1989, all QAPPs had been approved by the Project Office, and five QAPPs had been transmitted to the NRC for review and acceptance.

During the reporting period, the Project Office and project participants initiated a review of existing administrative procedures and quality management procedures to determine whether existing procedures need to be revised and whether new procedures need to be developed. All quality-related procedures were grouped into four categories:

1. Procedures required for the start of Title II design of the exploratory-shaft facility (ESF).

2. Procedures required for the start of long-lead-time procurement.

3. Procedures required for the start of site-preparation activities.

4. Balance of procedures required for QA program qualification.

A two-part verification surveillance was initiated on the procedures identified in the first category. The first part of this surveillance consists of a documented review of each procedure to ensure the incorporation of all applicable requirements of QAP 88-9, Revision 2. The second part of this surveillance consists of a review of the implementation of procedural requirements where such documentation exists. All deficiencies discovered as well as the actions taken to correct the deficiencies are formally documented. The results of root-cause analyses are formally documented, and the actions taken to prevent recurrence are tracked until closure.

The implementation of NUREG-1318, the NRC technical position on QA for a geologic repository (NRC, 1988b), also was initiated during the reporting period. The NRC technical position provides guidance for the identification of items important to safety, items important to waste isolation, and activities related to natural barriers important to waste isolation. To implement the NRC technical position, the Project Office developed four administrative procedures:

1. AP-6.8Q, "Identification of Items Important to Waste Isolation."

2. AP-6.9, "Candidate List of Items and Activities Subject to the Quality Assignment Process."

3. AP-6.10Q, "Identification of Items Important to Safety."

4. AP-6.11Q, "Identification of Activities To Be Placed on the Quality Activities List."

The procedures were implemented to identify those elements and activities related to the ESF that are items important to safety or activities to be placed on the Quality Activities List (DOE, 1989a, b).

The OCRWM developed and implemented a schedule for surveillances of both OCRWM and Project Office activities to support QA program qualifications before the initiation of new site characterization activities. A schedule for the qualification audits of the QA programs of the OCRWM, the Project Office, and the project participants also was developed.

The Project Office has performed a total of 4 participant audits. Also, a Surveillance Task Force was established to review procedures and implementation of procedures. The task force conducted approximately 75 surveillances of the Project Office and the project participants for the purpose of establishing a fully qualified QA program. Deficiencies un-

covered through these surveillances have undergone, or are undergoing, corrective action.

In a QA-related activity, the DOE initiated the application process called for in the Privacy Act of 1974 to receive Congressional authorization for a new records system. This records system will be used to gather and maintain personnel qualification and training documentation needed to satisfy the personnel requirements of the OCRWM and Project Office QA programs.

2.1.2 ESF design and construction

The Title I design for the ESF was completed with the release of a summary report of the design on December 21, 1988 (DOE, 1988g). Prior to the release of this report, the NRC raised a concern regarding the DOE's design-control process used in developing the ESF Title I design, including the incorporation of the requirements of 10 CFR Part 60 into the design. Meetings between the DOE and the NRC on this topic were held on October 19-21, 1988, November 3, 1988, November 23, 1988, and December 18, 1988.

On December 12, 1988, the DOE initiated a technical assessment review (TAR) of the ESF Title I design in accordance with Project Office procedure QMP-02-08, "Technical Assessment Review." The purpose of this TAR was twofold: (1) to perform a design-acceptability analysis of the ESF Title I design to address the concern of the NRC regarding the design-control process and (2) to perform an evaluation of alternative exploratory-shaft locations, with respect to differences in waste-isolation potential and potential adverse effects of shaft sinking, to provide the NRC with additional information on alternative shaft locations. (This evaluation included an assessment of what influence, if any, these differences might have had on the selection of the preferred shaft location, had the differences been explicitly considered in the location-selection process.)

The TAR found that the ESF Title I design sufficiently incorporated the applicable requirements of 10 CFR Part 60, given that the Title I design was preliminary. Regarding exploratory-shaft location, it was concluded that waste-isolation potential was not a discriminating factor among alternative exploratory-shaft locations and, had it been explicitly considered, would not have affected the selection of the preferred shaft location. On the basis of this review, the DOE determined that there was no need to make any changes to the ESF Title I design that would require significant modification of the schedule, configuration, or technical approach for the site characterization activities described in the SCP. The results of the ESF Title I design TAR are documented in a review record memorandum dated February 3, 1989 (DOE, 1989c).

Preparations for the start of the ESF Title II design resulted in significant progress in various areas during the reporting period. The

design of the Integrated Data System, a computer-based central data-collection utility, was submitted to a TAR, the results of which were issued on February 24, 1989 (DOE, 1989d). The ESF Subsystems Design Requirements Document (SDRD) for Title II design (DOE, 1989e), which presents the functional requirements and performance criteria for systems and subsystems within the scope of the ESF, was revised to include numerous criteria developed as a result of the ESF Title I design TAR and other activities. The revised SDRD underwent an extensive review and was issued as Revision 0 on April 11, 1989, to support the start of ESF Title II design. Version 4 of the Reference Information Base, a data base that maintains the values for site-specific parameters to be used for design and performance assessment, was issued on February 1, 1989 (DOE, 1989f), after coordination with the staff responsible for ESF Title II design activities.

A management review of the prerequisites for the start of ESF Title II design was conducted during March and April of 1989. As a result of this review, the DOE began the Title II design for ESF surface facilities in late April 1989. Title II design for the remaining portions of the ESF is expected to begin on completion of a two-part verification surveillance of QA procedures related to ESF design activities.

2.1.3 Surface-based testing program

The Surface-Based Investigations Plan (SBIP) (DOE, 1988h) was issued in December 1988. The SBIP covers all activities that are related to surface (e.g., mapping, trenching) and surface-based (e.g., drilling) site characterization work (excluding the activities related to the ESF) and are described in Chapter 8 of the SCP. The SBIP is not a substitute for the information presented in the SCP, nor is it used in lieu of study plans. The SBIP includes the following information for each field activity: references to the SCP and other planning documents; responsible project participants; basic activity information, including type, location, and purpose of the planned activity; relevant technical information (e.g., equipment to be used, borehole depths, and survey-area descriptions); and the projected schedule. The SBIP also includes a summary of planned activities, a general discussion of the technical rationale for various activities, and a portfolio of detailed maps showing the locations of planned surface-based testing and construction activities.

Before starting surface-based exploratory drilling for unsaturated-zone studies, the DOE is implementing a prototype dry-drilling and coring program. A dry-drilling technique is desirable so as not to alter parameters (e.g., the moisture content of the tuff) that must be measured and also has the advantage of reducing water usage. Dual-wall reverse circulation was selected as the drilling method to be used for the prototype drilling tests. Prototype drilling will consist of two bore holes, one with a diameter of 8 inches and one with a diameter of 12 to 14 inches to cover the expected range of borehole sizes for the planned drilling program. Cores will be taken using conventional dry-coring techniques,

including an exploratory-type wireline coring assembly. Since no drill rig used in the mining industry for this type of dry sample drilling is capable of drilling the above-mentioned borehole diameters to the required depths (2500 feet or more), rigs of the size required will be specially built for the DOE.

Yucca Mountain drill cores and related records that were stored in the Nevada Test Site core library were transferred to the Sample Management Facility (SMF). The SMF is a central storage facility for samples obtained during site characterization. Much effort was expended during the reporting period in preparing procedures to control the interfaces with project participants for the handling of sample materials at the SMF.

2.1.4 Permits

A Programmatic Agreement between the DOE and the Advisory Council on Historic Preservation was signed December 15, 1988. The Programmatic Agreement identifies the actions the DOE will undertake during site characterization to comply with the National Historic Preservation Act and other Acts related to historic preservation and archaeology.

An application for a registration certificate for surface disturbances was filed with the Nevada Division of Environmental Protection on January 20, 1988. The State of Nevada has not taken action on this permit application.

On October 19, 1988, the Nevada State Engineer deemed the DOE application for a Ground-Water Appropriation Permit complete and placed a notice in the Pahrump Valley Times notifying the public of the DOE's intent to appropriate public waters. A 30-day comment period followed the notice. On January 3, 1989, the State Engineer received a protest from the National Park Service, citing potential conflicts with the Ash Meadows area. On January 27, 1989, the State of Nevada also protested the appropriation.

On February 9, 1989, the DOE published a notice of the potential involvement in floodplains in the Federal Register. The floodplain assessment necessary to satisfy both Executive Order 11988, "Floodplain Management" and the DOE regulations contained in 10 CFR Part 1022, "Compliance with Floodplain/Wetlands Environmental Review Requirements," was initiated.

The DOE filed with the State of Nevada, on April 6, 1989, an application for an Underground Injection Control Permit. This permit was requested for the conservative and reactive tracer tests to be conducted in the wells of the C-hole complex.

During the reporting period, applications were being prepared for two other permits: a permit for the discharge of mine waste water and a permit for the drinking water supply. Documentation for a Resource Con-

servation and Recovery Act Identification Number for the handling and management of hazardous waste is also being prepared. In addition, applications were being prepared to obtain a Free-Use Permit, which is required pursuant to the Materials Act in order to use sand and gravel on Bureau of Land Management land, and for a permit exemption from the Nevada State Engineer to exempt wells drilled into the water table and used for pump tests from the Nevada Ground-Water Appropriation Law.

2.1.5 Land acquisition

The process for obtaining a right-of-way reservation for the portion of the Yucca Mountain site that is located on the Nellis Air Force Base Range continued.

Under the authority of the Federal Land Policy and Management Act, the DOE filed an application for a temporary land withdrawal with the Bureau of Land Management, Nevada State Office, on December 27, 1988. The application requested the withdrawal of approximately 4,255 acres of public land from settlement, sale, location, or entry (including any use under the mining and mineral leasing laws) for a period of 12 years. The temporary land withdrawal was requested to formally notify the public of particularly sensitive areas in and around the Yucca Mountain site that could be adversely affected by activities other than those planned by the DOE for characterizing the site. The withdrawal would also prevent public activities from interfering with the planned site characterization activities. Notice of this application was published in the Federal Register on January 13, 1989. This publication started a 2-year segregation period during which the DOE must provide a case file (i.e., the documentation) for completion of the withdrawal.

2.1.6 Public outreach

In March 1989, three public hearings on the SCP were held at various locations in Nevada: Amargosa Valley (March 20), Las Vegas (March 21), and Reno (March 23). Notices of the schedule for the public hearings were published in the Federal Register and in local Nevada newspapers. At the request of Nevada Governor Miller, contingency arrangements for additional sessions were made to ensure that everyone wishing to speak had the opportunity to do so. Afternoon and evening sessions were held in each location. About 450 people attended the hearings, with a total of 165 people commenting on the SCP and other issues. The proceedings were recorded and transcribed by a certified court reporter, and copies of the transcript are available at the DOE public reading room in Las Vegas; at the Yucca Mountain Information Office in Beatty; at the libraries of the University of Nevada, Las Vegas, and the University of Nevada, Reno; and at six community public libraries in the State.

Four Project-update meetings that included information on the SCP were held in Nevada in early 1989: Beatty (February 15), Las Vegas (February 16), Caliente (February 21), and Reno (February 23). Notices of the schedule for the meetings were published in the Federal Register and in local Nevada newspapers. The technical program described in the SCP was highlighted in presentations made during the 3-hour evening sessions. State and local governments were invited to participate in the meetings, and time was provided for questions from the audience. About 350 people attended the four meetings, which received wide media coverage.

At the request of Governor Miller of Nevada, the deadline for the initial comment period on the SCP was extended from April 15, 1989, to June 1, 1989 (Watkins, 1989). Written responses to all SCP comments will be provided in comment-response packages. The DOE is developing a system to track and respond to the comments.

During the reporting period, work continued on responding to NRC, the State of Nevada, U.S. Geological Survey, and the Edison Electric Institute/Utility Nuclear Waste Management Group (EEI/UNWMG) comments on the consultation draft of the SCP. Comments made by the NRC and the U.S. Geological Survey were received in time to be explicitly considered while preparing the statutory SCP. However, comments submitted by the State of Nevada and EEI/UNWMG were not received in time for consideration. A comment-response package addressing the NRC comments was transmitted to the NRC in December 1988. Comment-response packages addressing the State of Nevada, the U.S. Geological Survey, and EEI/UNWMG comments were under preparation.

2.2 SITE PROGRAMS

The site programs consist of the planned field and laboratory investigations for obtaining the technical information needed to adequately characterize the Yucca Mountain site. This information is integrated with design and performance-assessment activities throughout site characterization. The field and laboratory investigations are organized into 16 distinct site programs, each with a specific technical focus (e.g., geohydrology, geochemistry, rock characteristics). Investigations are subdivided into studies and specific activities. A description of the site programs is provided in Section 8.3.1 of the SCP.

During the reporting period of this semiannual progress report, significant effort was focused on the development, review, and approval of study plans. Study plans are the documents that describe, at a greater level of detail than that provided in the SCP, the studies and activities of the site programs. They are the link between the studies described in the SCP and the technical procedures that will be used in conducting tests in the field and the laboratory. The DOE has identified 106 studies in the SCP for which study plans need to be developed.

On December 15, 1988, the DOE and the NRC held a technical meeting to discuss study plans. The State of Nevada also attended the meeting. During the meeting the following subjects were addressed: (1) the purpose and scope of study plans; (2) quality assurance concerns related to study plans; (3) the procedures of the DOE and the NRC for reviewing study plans; and (4) the schedule for study plan preparation and release.

The development of study plans for ongoing activities is a high priority. An activity is considered to be ongoing if it was in progress at the time the Yucca Mountain site was originally selected as one of the three sites to be characterized. Examples of ongoing activities include (1) hydrologic, meteorologic, and seismic monitoring at the site; (2) geodetic surveys; and (3) laboratory analyses of degradable and irreplaceable samples.

Ongoing activities continued without approved study plans under the control of Scientific Investigation Plans (SIPs). When a study plan for an ongoing activity is developed and approved by the DOE, the study plan will then replace the SIP as the document controlling the activity. Prior to the initiation of a new site activity, however, a study plan for the activity must be developed, reviewed, and approved by the DOE. All study plans will be submitted to the NRC, as they become available, for comment. The NRC has agreed to identify any potential major concerns within 3 months of receiving each plan and to complete detailed technical reviews of selected plans within 6 months of receipt.

As of April 15, 1989, five study plans were approved by the DOE and submitted to the NRC for comment, with 22 study plans undergoing review within the DOE. The study plans submitted to the NRC were:

1. Water Movement Tracer Tests Using Chloride and Chlorine-36 (8.3.1.2.2.2).

2. Characterization of Percolation in the Unsaturated Zone--Exploratory Shaft Investigation (8.3.1.2.2.4).

3. Characterization of Site Structural Features (8.3.1.4.2.2).

4. Excavation Investigations (8.3.1.15.1.5).

5. Characterization of the Site Ambient Stress (8.3.1.15.2.1).

As requested by the NRC at the December 15, 1988, DOE-NRC meeting on study plans, the DOE initiated an assessment of the process used to develop, review, and approve the five study plans identified above. The assessment is undergoing review within the DOE and will be provided to the NRC upon approval.

In addition to the development of study plans, prototype testing related to various site programs continued. Prototype testing is used primarily to develop testing methods, equipment, and procedures in preparation for the start of new activities. An example is the testing of

equipment and procedures to develop methods for measuring underground moisture, solar radiation, precipitation, evapotranspiration, heat flux, and soil temperature, for future use in the natural-infiltration studies. Prototype testing does not produce data that can be used in the license application.

Specific progress made during the reporting period in several of the site programs is discussed in the sections that follow. During the reporting period, more progress was made in several of the larger site programs, such as geohydrology and geochemistry, than in some of the other site programs; in some of the site programs, no significant progress was made. The discussions that follow state whether the work is related to ongoing studies or is considered to be prototype work. It should be noted that, although testing may have been conducted during the reporting period, a summary of test results is not provided unless a DOE-approved report has been published.

2.2.1 Geohydrology (SCP Section 8.3.1.2)

As part of the ongoing studies of the Regional Hydrologic System Investigation (8.3.1.2.1), several types of hydrologic monitoring continued. In addition to continuing limited precipitation monitoring, an expanded regional precipitation and meteorology network of about 50 stations was designed to obtain data for several of the future geohydrology and climate studies. Surface-water runoff monitoring continued at 4 continuous-recording gauges and at 10 peak-flow gauges. A new continuous-recording streamflow gauge was constructed on Beatty Wash; several new peak-flow gauges were also added to the monitoring network. Drilling in the Amargosa Desert by mining companies was monitored to: (1) collect hydrogeologic data to be used in characterizing the regional ground-water flow system and (2) identify boreholes suitable for piezometer installation.

In addition to ongoing hydrologic monitoring, prototype work continued to develop methods for characterizing the regional ground-water flow system. Methods employing geophysical techniques were being developed to investigate the cause of the large hydraulic gradient northwest of the Yucca Mountain site. Methods were also being developed for measuring evapotranspiration.

As part of the ongoing studies of the Unsaturated-Zone Hydrologic System Investigation (8.3.1.2.2), monitoring of natural infiltration continued through monthly neutron-moisture logging of 74 existing boreholes and semiannual sampling of gases and water vapor for isotope analyses at borehole USW UZ-1. The evaluation of geohydrologic data from boreholes UE-25 UZ-4, UE-25 UZ-5, and USW UZ-7 also continued. Prototype work included the seasonal monitoring of airflow, temperature, relative humidity, atmospheric pressure, and gas composition at open boreholes USW UZ-6 and USW UZ-6S. Prototype work also included the continued monitoring in

borehole USW UZ-1 to evaluate the in situ fluid-flow potential in the unsaturated zone.

A prototype program for the cross-validation of geostatistical models was developed for future statistical analyses of the spatial variability of infiltration properties and precipitation data. This program will be utilized in an unsaturated-zone infiltration study. A geostatistical analysis was performed to identify optimal locations for future unsaturated-zone and systematic-drilling boreholes. Prototype shallow seismic surveys were conducted in Pagany Wash and on Busted Butte to develop methods for determining the thickness and infiltration-related properties of alluvial material. The initial phase of prototype testing of methods to determine the matrix hydrologic properties of rock core for the unsaturated-zone percolation studies was completed.

Prototype hydrologic testing was conducted to develop technical methods and procedures for use in the unsaturated-zone percolation tests conducted in the ESF. These include intact-fracture, radial borehole, and hydrochemistry testing. In addition, preparation for prototype testing was under way for percolation, bulk-permeability, and multipurpose-borehole tests. The published reports on prototype testing covered the triaxial-compression extraction of pore water from unsaturated tuffs (Yang et al., 1988) and radiocarbon dating (Yang, 1988).

Progress was also made toward developing conceptual and numerical models of flow in the unsaturated, fractured tuffs at Yucca Mountain. Numerical simulations of fluid flow in unsaturated, fractured rock were performed to help evaluate the feasibility of the ESF intact-fracture and percolation tests. A computer code was written that accounts for the dependence of both the magnitude and the direction of the principal hydraulic conductivities on matrix potential. An approach to account for diffusion into the matrix during transient water movement through unsaturated fractured rock was developed and incorporated into the TOUGH computer code for multiphase fluid flow. In addition, a mathematical formulation was developed for computer-based particle tracking with both continous-flow-path and random-walk approaches; this formulation will be used for site-scale modeling of the unsaturated zone. Numerical studies of the effects of air and liquid-water drilling on moisture conditions in unsaturated fractured rock were published (Bodvarsson et al., 1988). The development of a numerical model for evaluating fluid flow in major faults and fracture zones also began.

Significant progress was made in developing the Integrated Data Acquisition System (IDAS). The IDAS is a surface-based system for processing data obtained through the testing and monitoring of unsaturated-zone boreholes. Design, coding, and field testing of prototype IDAS software for unsaturated-zone borehole testing and monitoring was completed. Software for IDAS microwave communications and system maintenance was tested. Work continued on developing the overall IDAS system manual, as well as the design, construction, and testing of the prototype IDAS instrument shelter. Construction of the IDAS archiving

center was completed. Prototype IDAS hardware was installed at boreholes USW UZ-1 and UE- 25 UZ-4, and field testing of the system began.

As part of the ongoing studies in the Saturated-Zone Hydrologic System Investigation (8.3.1.2.3), water-table levels in the vicinity of Yucca Mountain were monitored through the use of continuous transducer-recorder systems in 23 zones of 14 wells and by periodic manual measurements in 11 other wells. Satellite data-collection platforms were installed on selected wells at Yucca Mountain to provide early warning of equipment failure or sudden water-level fluctuations. Systematic review of transducer data to identify and analyze apparent anomalous water-level fluctuations continued. A report on water levels in periodically measured wells from 1981 through 1987 (Robison et al., 1988) was published.

Model development associated with the Saturated-Zone Hydrologic System Investigation (8.3.1.2.3) continued. Development, optimization, and testing of the TRINET computer code for the fracture-network saturated-flow model continued. Work began on developing an equivalent discontinuum model to simulate saturated fracture flow at the scale of well tests and at the site scale. Statistical analysis of fracture-orientation data obtained from the C-holes was performed to aid conceptual-model development.

Analysis of approximately 35 hydraulic-stress tests previously completed in the saturated, fractured tuffs at the C-hole complex continued. Equipment and technologies for conducting cross-hole hydrologic and tracer tests at the C-hole complex were evaluated, and a preliminary conceptual design of a multiple-packer well-testing system was completed. Duplicate water samples have been obtained for chemical and isotope analyses in connection with the sampling of selected water-table wells at Yucca Mountain by the Nevada Desert Research Institute. Additional water samples were obtained for chemical and isotopic analyses from mining-company boreholes in the Amargosa Desert to support technical-procedure development and to provide quality assurance for water samples analyzed at various laboratories. Preliminary evaluations were performed of downhole hydrochemical sampling tools available from the Swedish and Canadian repository programs.

The ESF Radial-Boreholes Test described in the SCP (Activity 8.3.1.2.2.4.4) has been modified. The modified test is described in Study Plan 8.3.1.2.2.4, Characterization of Yucca Mountain Percolation in the Unsaturated Zone--Exploratory Shaft Facility Investigation. Modifications included the elimination of the lowermost set of "short" radial boreholes, which were planned at a location just below the lower breakout room of the ESF. This was done because the planned depth of the first exploratory shaft was provisionally decreased pending a risk/benefit analysis for penetration of the Calico Hills unit. In addition, six sets of "long" radial boreholes (100 feet) have been added to the test design to perform gas-phase permeability testing at the midpoints of major hydrogeologic units. To substantially increase the volume of rock tested, the long radial boreholes will be used to conduct air-permea-

bility interference tests with one of the multipurpose boreholes (USW MP-1).

2.2.2 Geochemistry (SCP Section 8.3.1.3)

Work was conducted during the reporting period as part of the ongoing studies of the investigation of the mineralogy, petrology, and rock chemistry within the potential emplacement horizon and along potential flow paths (Investigation 8.3.1.3.2). Core from well J-13 was selected, sampled, examined, and analyzed. Comparisons of J-13 core with core from boreholes USW G-4, USW G-1, and UE-25a#1 suggest that the intervals where heulandite is found in fractures in nonzeolitic rock have not been below the water table since the formation of the heulandite (Carlos, 1989). Manganese oxide minerals in fractures in the Crater Flat Tuff from borehole USW G-4 were also studied. The dehydration properties of the basal vitrophyre of the Topopah Spring Member were being studied by dynamic thermogravimetric analysis and long-term isothermal experiments.

Prototype work associated with Investigation 8.3.1.3.2 was also conducted. The reduction of X-ray diffraction data was completed for the exploratory-shaft prototype mineralogy-petrology test. The collection of data by neutron-activation analysis continued, and analysis of the collected samples by X-ray fluorescence was initiated. The initial results of the X-ray fluorescence analyses support the X-ray diffraction data in showing that centimeter-scale variability may be as significant as larger scale stratigraphic variations in the devitrified rhyolitic Topopah Spring Member (Broxton, 1989). Preliminary Mossbauer data on trace minerals bearing ferrous and ferric iron are in accord with petrologic observations of abundant iron oxidation throughout the devitrified Topopah Spring Member; the only significant concentrations of ferrous iron are in the basal vitrophyre zone of the Topopah Spring Member.

Accomplishments related to the ongoing studies of the Mineral and Glasses Stability Investigation (8.3.1.3.3) included the development of a preliminary conceptual model of mineral evolution. The conceptual model stresses the factors that control mineral transformations and the time scale on which the transformations are likely to take place. Also, the development of the flexible-cell hydrothermal system procedure and data acquisition have been initiated to conduct scoping studies of the kinetics of silica transition and of silica concentrations in equilibrium with silica polymorphs.

Progress was made in the ongoing studies of radionuclide retardation by sorption processes along flow paths (Investigation 8.3.1.3.4). Batch sorption experiments of nickel on tuff under various water compositions were completed. The waters used in the experiments were from wells J-13, H-3, and UE-25p#1, with J-13 water used as a reference. The H-3 and UE-25p#1 waters represent extremes in water composition found at Yucca Mountain, each showing higher cation concentrations than J-13 water.

Mass-spectrometry analysis of the sorption behavior of americium in Yucca Mountain tuffs continued.

Sorption measurements were initiated to determine the sorption ratios for strontium, cesium, and barium at different solution-to-solid ratios, using a tuff sample as the solid. The study of the sorption of neptunium on goethite was also started. The work on goethite has been separated into two related tasks. One concerns the characterization, by extended X-ray-absorption fine-structure analysis, of the species of neptunium that are sorbed on pure goethite. The second task involves a more detailed experimental and theoretical investigation of the behavior of neptunium on the goethite surface. The current sorption data base was used to develop models using the linear, Langmuir, Freundlich, and modified Freundlich isotherm methods. Development of surface complexation modeling strategies in support of the single mineral-sorption work started.

The study of biological sorption and transport continued. A major mechanism by which microorganisms may influence the mobility of actinide elements is chelation. Iron (Fe^{3+}) and plutonium (Pu^{4+}) are similar in their charge-to-ionic radius ratio. Pu^{4+} may be chelated by the Fe^{3+} siderophores (microbial iron-chelating compounds). Investigation of the chelation of Pu^{4+} by microbially produced siderophores will continue. Siderophore purification techniques were developed. Work is continuing on determining the effect of microorganisms on the rate of colloidal agglomeration and on preparing a progress report on chelation.

Ongoing studies of radionuclide retardation by precipitation processes (Investigation 8.3.1.3.5) continued. Efforts to study the properties of the Pu^{4+} colloid have focused on three main areas: (1) chemical oxidation of the colloid with cerium (Ce^{4+}), (2) electrochemical reduction and oxidation by voltammetry, and (3) size determination by autocorrelated photon spectrometry. The determination of the oxidation states of americium is in progress, and solubility experiments for neptunium, plutonium, and neodymium/americium mixtures in J-13 water at 25°C and with pH values of 5.9, 7.0, and 8.5 were completed. Photothermal spectroscopy capabilities, specifically photoacoustic spectroscopy, are continuing to be developed.

Ongoing studies of radionuclide retardation by dispersive, diffusive, and advective mechanisms (Investigation 8.3.1.3.6) continued. The behavior of three colloids (fluorescent carboxylated polystyrene spheres of varying diameters) was investigated during flow through a saturated column of densely welded, fractured tuff from the Topopah Spring Member to study the ability of the tuff to act as a natural filter for particulate matter, plutonium colloids prepared under various conditions were characterized by autocorrelated photon spectrometry.

Diffusion experiments in rock beakers were initiated. Two different solutions, one containing strontium, cesium, and barium and the other containing strontium, cesium, barium, americium, and neptunium were placed in a number of rock beakers. The solutions in the rock beakers

will be sampled periodically for 2 years. In addition, experiments testing the filtration capability of Yucca Mountain tuff have begun; these experiments use solid rock columns (two of Calico Hills tuff and two of Topopah Spring tuff).

Model development, taking into account all retardation processes, continued as part of the ongoing studies of Investigation 8.3.1.3.7. The COVE2a benchmarking calculations were completed with the computer code TRACR3D. The COVE2a activity consisted of 12 isothermal one-dimensional problems, 6 steady and 6 nonsteady cases, of flow through a vertical column of five fractured geologic layers. Other work included adding a nonvertical gravity vector to the TRACR3D code to facilitate the modeling of tilted geologic layers and horizontal and tilted boreholes. The computer codes FEHM and FEHMS, to be used to investigate the coupled effects of heat and stress on mass transport at Yucca Mountain, were modified to better represent processes that may occur. In FEHM, capabilities to model the unsaturated zone were added, an algorithm to efficiently solve the unsaturated-flow equations was created, and the tracer solution was improved to operate with time scales different from those of the flow solution. In FEHMS, the stress and flow solution are being coupled, and three-dimensional stress is being added.

The study of fracture flow in the unsaturated zone of Yucca Mountain continued. A first calculation of tracer flow through a 1-millimeter open fracture in the lower unit of the Topopah Spring Member was completed. The three-dimensional stress module, F3DE, for incorporation into FEHMNS is operational. This work on possible coupled pore-fluid stress effects at Yucca Mountain is being completed in cooperation with the U.S. Geological Survey. The TRACKHD code has been brought under software configuration management. Version 1.0 of TRACRN is the baseline version. The Colloid Transport Code Number is under development. Verification planning for TRACRN and FEHMN has begun. A new matrix-solving routine was inserted into TRACRN. For large grids, this change will decrease run times by a factor of about 5 and memory requirements to less than half that required previously. This modification will allow large three-dimensional calculations that were not previously possible.

Prototype work associated with Investigation 8.3.1.3.7 consisted of testing activities in the field to support the development of field-test design and study plans. Design calculations were run for the validation experiment (unsaturated flow and transport) planned at the Caisson facility to determine whether a three-dimensional tracer distribution can be obtained by adding a lens of sorbing material into the porous medium. This type of distribution could be used to validate TRACRN and the inverse-code TRACRN.

2.2.3 Rock characteristics (SCP Section 8.3.1.4)

Prototype studies of shaft-wall mapping techniques for the investigations of the geologic framework of the Yucca Mountain site (Investiga-

tion 8.3.1.4.2) continued. These studies include equipment development and improvements in photogrammetric methods and the use of analytical plotters. Results indicate the potential for not only greater speed in mapping shaft and drift walls but also enhanced quantitative analysis of geologic features before and after the loss of rock exposures because of shaft lining.

2.2.4 Climate (SCP Section 8.3.1.5)

As part of the ongoing studies of future climatic change (Investigation 8.3.1.5.1), monitoring of the southern Great Basin dust trap network continued. This monitoring allows an evaluation of the significance of airborne-dust contributions to the development of soils in the Yucca Mountain region and is part of soil-modeling activities designed to provide information on the paleoenvironment of the region. Related prototype activities included experimenting with techniques to establish the ages of soils and other young surficial deposits. The techniques investigated included uranium-series dating of carbonate root casts, thermoluminescence dating, and the use of cation ratios from rock varnish for age determinations.

In preparation for characterizing the future regional climate, a feasibility study was completed by the National Center for Atmospheric Research. This study focused on the feasibility of using an existing global climate model to drive a high-resolution regional climate model of the southern Great Basin extending over the next 100,000 years.

Monitoring of hydrologic conditions at the Kawich Creek and the Stewart Creek analog recharge basins in central Nevada continued as part of the ongoing studies of the effects of future climate conditions (Investigation 8.3.1.5.2). Study sites were upgraded through the installation of additional meteorological stations, flumes on stream channels, and satellite communications systems. The prototype testing associated with this investigation included the evaluation of techniques for the collection and analysis of terrestrial and aquatic organisms, which can provide information about hydrologic conditions in past discharge areas. Prototype testing of remote-sensing imagery of paleodischarge deposits was also performed.

Preliminary studies began at the arid-zone monsoonal analog research site near Tucson, Arizona. These studies surveyed atmospheric conditions to determine the type of instrumentation needed for collecting data to support the soil-chemistry/climate model.

2.2.5 Postclosure tectonics (SCP Section 8.3.1.8)

A preliminary geologic map of the Lathrop Wells volcanic center was completed (Crowe et al., 1988) as part of the ongoing effort to obtain

information required for tectonic analyses and assessments (Investigation 8.3.1.8.5). Current interpretations of data from field, paleomagnetic, geomorphic, soils, and rock-varnish studies indicate that the eruptive events at the Lathrop Wells volcanic center occurred as described below.

First, a northwest-trending fissure zone, marked by local accumulations of scoria and spatter, developed east of the main volcanic cone. Small-volume lava flows erupted from several localities along the fissure zone. Numerous small scoria cones formed at the south end of the main scoria cone. The major part of the main scoria cone formed during the initial stages of volcanic activity. Second, one and possibly two small fissure zones, marked by scoria mounds, formed at the north and northeast flanks of the main scoria cone. These fissure zones vented small-volume block lava flows from numerous localities along the fissure zone. Finally, one or more small-volume (approximately 10,000 cubic meters) scoria eruptions occurred from the summit of the main scoria cone of the Lathrop Wells center. These eruptions draped the cone summit, cone slopes, and immediately adjacent area with thin scoria-fall deposits. The geomorphic and soil characteristics of this last eruption suggest that it could have occurred as recently as the late Pleistocene or Holocene epoch.

Work also continued on evaluating the results of potassium-argon age determinations of the lava-flow units at the Lathrop Wells volcanic center. In addition, geologic studies are ongoing at two small-volume Quaternary volcanic centers located 47 kilometers northwest of the Yucca Mountain site (basalt of Sleeping Butte).

Prototype work included the development of analytical techniques to establish the age of Quaternary volcanic units in the Yucca Mountain region. The primary techniques include uranium-thorium disequilibrium measurements by solid-source-mass spectrometry and the measurement of surface exposure ages by the helium-isotope dating technique. Geochemical techniques for identifying the sources and number of ash horizons exposed in fault trenches in the Yucca Mountain area were also evaluated. Proton-probe analysis of trace elements at the parts-per-million level have been completed for individual ash grains from the trenches and from the Lathrop Wells volcanic center. These data are currently being evaluated.

2.2.6 Meteorology (SCP Section 8.3.1.12)

The site meteorological monitoring program continued normal operation during the reporting period. Data collected at the site have been used in a dispersion model to calculate pollutant concentrations.

2.2.7 Thermal and mechanical properties (SCP Section 8.3.1.15)

Prototype creep and low-strain-rate tests were completed to establish technical procedures. A report on thermal data (Sass et al., 1988)

from earlier studies was published. Prototype field testing continued during the reporting period at the G-Tunnel complex at the Nevada Test Site to determine whether a stable repository-scale drift could be constructed in jointed welded tuff and reinforced with only rock bolts and wire mesh. Analyses of this experiment continued.

2.2.8 Preclosure tectonics (SCP Section 8.3.1.17)

Characterization of the effects of underground nuclear explosions (UNEs) and the development of empirical models for predicting ground motion from UNEs continued as part of the ongoing studies of vibratory ground motion (Investigation 8.3.1.17.3). Work was conducted to develop empirical models for ground motion from UNEs. Equations for predicting peak ground motion at Yucca Mountain were evaluated. Ground motion from UNEs was analyzed, and two-dimensional velocity models for paths from Pahute Mesa to Yucca Mountain were developed.

Monitoring of seismic events as part of the ongoing studies for collecting data for the preclosure tectonics program (Investigation 8.3.1.17.4) continued. Work continued on the upgrading of the seismic network covering Yucca Mountain and vicinity. A portable array of seismometers was deployed near Hoover Dam to help understand how seismicity in that area relates to Yucca Mountain. In addition, a level line across the Yucca Mountain site was rerun.

Prototype work associated with Investigation 8.3.1.17.4 included the evaluation of various methods for dating Quaternary materials at Yucca Mountain so that reliable studies of fault offset and recurrence intervals can be conducted during site characterization. The use of photogrammetric methods and analytical plotters as an aid to rapid and accurate trench mapping was also tested. These methods may provide not only an effective way to accomplish the work but also a permanent record of exposures that can be used in quantitative analyses at a later time.

During the reporting period, preparation for a technical assessment review (TAR) of geologic and geophysical data pertaining to inferred faulting in Coyote Wash was initiated. The TAR will reverify the structural geology of the area.

2.3 REPOSITORY DESIGN

The repository-design program consists of the activities associated with designing both the surface and the underground facilities of the repository. These activities include the development of design criteria as well as design analyses. There are several stages of repository design. The most recent stage to be completed is the SCP conceptual design, which is documented in a comprehensive design report (SNL, 1987). This conceptual design provided the basis for the repository-design program de-

scribed in Section 8.3.2 of the SCP. Three more design stages are yet to follow: the advanced conceptual design, the license-application design, and the final procurement and construction design.

In developing the advanced conceptual design, studies will be conducted to assist in determining and refining design criteria and the identifying concepts to be incorporated into the license-application design. Furthermore, changes in design may result from a redefinition of the functions to be performed at the repository.

In the SCP conceptual design, two waste-handling buildings were proposed as part of the surface facilities because it was assumed that the spent fuel received would be consolidated at the repository. However, as of April 15, 1989, the DOE is reevaluating the option of consolidation. An evaluation of the impacts of fuel-rod consolidation on waste-handling facilities at the repository was completed and published (O'Brien, 1989). The results indicate that consolidation offers no advantages for the operation or the underground layout of the repository.

Since the development of the input to the SCP and the SCP conceptual design, much of the design effort has been focused on the exploratory-shaft facility. These efforts are described in Section 2.1.2. However, a number of studies related to the design of the repository were initiated or completed during the reporting period. Several of these studies were related to seismic design. They included an evaluation of the potential for seismic ground motion at the site of the repository surface facilities (Sanders, 1988; Kiciman and Abrahamson, 1988) and an evaluation of the impacts of seismic events on repository waste-handling facilities (Subramanian et al., 1988; Ma and Jardine, 1988). A related site study evaluated the quantity of additional data needed on underground nuclear explosions (Easterling and Hall, 1988).

A preliminary cost-benefit assessment was made of the repository waste-handling facilities to evaluate the options for the seismic-design basis for the advanced conceptual design (Subramanian et al., 1989). An analysis of repository waste-handling operations was conducted to evaluate the operational characteristics of the current conceptual design. Also evaluated during the reporting period were methods for the treatment and disposal of the radioactive waste generated at the site as a result of repository operations (Subramanian and Jardine, 1988) and the potential impacts of abnormal events on waste-handling facilities.

In addition, design methods were developed and evaluated for the underground facilities, including shafts (Richardson and St. John, 1988; Richardson et al., 1988) and underground openings (Wallace and Zerga, 1988; Hardy and St. John, 1988). A study was also conducted to determine the preferred underground-emplacement orientation for the waste package.

2.4 SEALS-SYSTEM DESIGN

For the permanent closure of the repository, the DOE currently plans to seal all shafts, ramps, exploratory boreholes, and emplacement drifts. The overall strategy that guides the design of the seals system is to prevent water that may be encountered in the unsaturated zone from coming into contact with emplaced waste and to reduce, to the extent practicable, the potential for creating during the preclosure period preferential pathways for ground water or radionuclide migration. The seals-system design program includes materials testing, design development, and design analysis.

Since seals generally would not be installed until the underground repository is closed, design development and seal testing will take place, for the most part, during the period of repository operations. Current plans for work to be conducted during site characterization are aimed at developing design concepts and evaluating seal materials. The activities to be conducted during site characterization are described in Section 8.3.3 of the SCP.

During the reporting period, the seals-system design program focused on the analyses necessary to support the evaluation of the postclosure performance of the exploratory shafts. Included were analyses related to hydrologic phenomena and convective airflow. The sealing-related requirements of the exploratory-shaft facility were developed for inclusion in the Exploratory Shaft Facility Subsystem Design Requirements Document (DOE, 1989e). Sealing requirements for the repository are still under development.

Other work during the reporting period included an initial evaluation of possible microbial effects on drainage from a shaft sump and an evaluation of the evaporation rate from a bare soil. Analyses of geochemical interactions between a concrete liner and tuff and between cementitious sealing materials and tuff continued.

2.5 WASTE-PACKAGE DESIGN

The waste package consists of the waste form and the container in which the waste form is placed. The objective of the waste-package design program, described in Section 8.3.4 of the SCP, is to develop a waste package that is compatible with the characteristics of the emplacement environment. The design of the waste package must be integrated with the performance-assessment program to ensure that the waste package will contribute to meeting the performance objectives for waste containment and controlling the release of radionuclides from the engineered-barrier system.

The waste-package design program includes the development of waste-package design bases, design analysis, container-materials testing, the development of a reference design, waste-form testing, and the character-

ization of the waste-package emplacement environment. Progress made during the reporting period in designing and evaluating the waste package and its host-rock environment is discussed in the sections that follow.

2.5.1 Postemplacement near-field environment

As part of the Postemplacement Near-Field Environment Investigation (8.3.4.2.4), an evaluation of potential changes in the host rock that would result from the emplacement of waste packages continued. Analyses of data from hydrothermal experiments on vitric, vitrophyric, and zeolitic tuff also continued, with emphasis on evaluating the composition of solid reaction products and solution chemical behavior. Evaluations of thermodynamic data obtained through literature searches were initiated. These data are needed for simulations with the EQ3/6 geochemical modeling code.

Long-term rock-water interactions were investigated through simulations of reactions in concentrated water from well J-13. The collection and evaluation of published water analyses continued, and the simulation of chemical speciation in the various waters was initiated. To determine how grout, concrete, and other repository materials might affect groundwater chemistry, literature evaluations were started.

Mineral dissolution and precipitation experiments continued. The dissolution rates of cristobalite, kaolinite, and heulandite were measured at 25°C and varying pH. Characterization of the cristobalite crystal structures in reaction cells continued, as did work on the precipitation of cristobalite from solution.

Prototype testing to assist in developing field tests of the engineered-barrier system continued in the G-tunnel complex at the Nevada Test Site. The prototype test monitors rock characteristics (e.g., rock temperature, changes in moisture content) near a heater emplaced in partially saturated welded tuff.

The EQ3/6 geochemical modeling code was used to analyze the effects of oxygen fugacity on the solubility of radionuclides released by the dissolution of spent fuel. This is associated with the examination of the processes involved in the transport of radionuclides after release from the waste form. Evaluation of the aqueous transport of uranium in tuff samples under static conditions (McKeegan et al., 1988) continued. Work continued on the development and implementation of techniques for measuring the transport properties of conservative (nonsorbing) and nonconservative (sorbing or reactive) radionuclide tracers under flowing conditions.

The existing data for the geochemical modeling used in evaluating radionuclide transport in the near-field environment was moved into a relational-data-base format, providing controls on data integrity and eliminating the need for hand calculations. This format will be used for

automated data analysis in the future. Work was started with the National Institute of Standards and Technology (formerly the National Bureau of Standards) to incorporate its data-analysis procedure into the data base.

2.5.2 Characteristics and behavior of the waste form

Studies of the characteristics and behavior of the waste-form materials continued. Investigations were conducted on the dissolution and oxidation behavior of spent fuel and the corrosion and radionuclide-release characteristics of irradiated Zircaloy cladding. Oxidation tests with spent fuel from boiling-water reactors were started (Einziger, 1988a, 1988b), and long-term oxidation tests on spent fuel from pressurized-water reactors continued. Preliminary conceptual models were developed for addressing the oxidation behavior of spent fuel. In addition, electrochemical and spectroscopic measurements of the oxidative dissolution of uranium dioxide were initiated to assist in developing a model for the reaction kinetics of this process.

Preliminary conceptual models were developed to address the potential failure of Zircaloy cladding by stress rupture, stress-corrosion cracking, and hydride reorientation. Experiments to examine the effect of fluoride ions on Zircaloy corrosion were started, and experiments to examine the susceptibility of cladding to failure by stress-corrosion cracking continued. The results of this testing program are being used to model the processes involved.

Work to define the inventory and distribution of carbon-14 in the cladding continued. Experiments to measure the release of gaseous carbon-14 (as carbon dioxide) from cladding were started, and conceptual models for the release of gaseous carbon-14 at elevated temperatures were being developed and checked against the available experimental data.

To determine the behavior of high-level waste in the form of borosilicate glass, studies were continued to determine the rate at which borosilicate glass is altered by liquid water and water vapor and the subsequent radionuclide release due to these alteration processes. Long-term unsaturated tests of waste-glass compositions similar to those to be produced at the Defense Waste Processing Facility (high-level waste from Savannah River) and at the West Valley Demonstration Project (commercial high-level waste) continued. Parametric tests to determine important parameters, including materials interactions that may affect the release of radionuclides from waste glasses, were also conducted. Dynamic flow-through experiments to determine the pH and temperature dependence of kinetic rate constants for the reaction of glass were started, using simplified waste-glass compositions. The results of this testing program are being used to model the processes involved.

2.5.3 Characteristics and behavior of disposal-container materials

Progress was also made during the reporting period in investigating potential materials for the disposal container--the principal metal barrier in the waste package. Six metallic alloys are being evaluated as candidate materials for the container: 304L stainless steel, 316L stainless steel, a high-nickel alloy, oxygen-free copper, a 70/30 copper-nickel alloy, and aluminum bronze. An annotated history of the 1981-88 metal-barriers program is being prepared to document the methods used to identify the six candidate materials.

Criteria for selecting among the six candidate materials for the advanced conceptual design of the waste package were developed. Both the projected performance of the material in the repository environment and the engineering aspects of container production were taken into consideration in developing the selection criteria. The criteria were formally reviewed by an independent peer review panel of six prominent metallurgists and engineers.

A survey was conducted of the degradation modes that could affect the six candidate waste-package container materials in the repository environment. The survey was based on an analysis of the technical literature and included an assessment of the corrosion behavior, oxidation behavior, and metallurgical-phase stability of each of the candidate materials. Parametric studies were initiated to quantify some of the performance criteria for evaluating the candidate container materials, particularly with respect to the localized-corrosion and stress-corrosion behavior of the materials.

2.6 PERFORMANCE ASSESSMENT

Performance assessment is the process of evaluating component, subsystem, or system behavior relative to radiological health and safety or the containment and isolation of radioactive wastes. The objectives of these assessments are to demonstrate compliance with the numerical criteria associated with 10 CFR Part 60, to support the development of the repository system, and to guide testing during site characterization. The performance-assessment program is discussed in SCP Section 8.3.5. For convenience, the program is divided into four categories: preclosure safety assessment, postclosure performance assessment, design analysis, and site characteristics analysis.

2.6.1 Preclosure safety assessment

The objective of preclosure safety assessment is to predict the probable radiological consequences of repository operations and to compare the consequences with acceptance criteria. Preclosure safety as-

sessment includes the evaluation of risks to repository workers and the general public under both normal operations and accident conditions.

A number of analyses supporting the assessment of preclosure safety were completed. Potential repository structures, systems, and components important to safety were identified (Jardine and Laub, 1988). Assessments of worker and nonworker radiation safety (Laub, 1988) and a preliminary safety analysis for normal operating conditions (Laub et al., 1988) were completed. A preliminary safety analysis for accident conditions and an uncertainty analysis of the radiological consequences of accidents at the repository were conducted. A radiation-safety analysis was also conducted for the exploratory-shaft facility to assist in identifying items important to safety.

A number of technical studies were initiated to develop further the technical basis for the preclosure safety assessment. These studies focused on such subjects as the source-term characterization for normal and accident conditions and the identification and screening of accident scenarios.

2.6.2 Postclosure performance assessment

The objective of postclosure performance assessment is to predict the behavior of the repository system and its subsystems after permanent closure in order to evaluate compliance with NRC requirements. Postclosure performance assessments are conducted for the following:

1. Total system (to evaluate waste isolation after permanent closure).

2. Engineered-barrier system (to evaluate containment by the waste packages and the rate of release from the engineered-barrier system after the containment period).

3. Natural barriers (to evaluate the ground-water travel time).

Progress in total-system performance assessment during the reporting period included the initial documentation of the TOSPAC system computer code (Dudley et al., 1989). Other developments included the adaption of the PORFLO-3 code as a component of the SUMO system computer code. In addition, the results of preliminary analyses of total system performance were compiled to support design of the exploratory-shaft facility (Peters, 1988; Peterson, 1989).

Progress was also made in the assessment of engineered-barrier performance. Version 3245.0888 of the EQ3/6 geochemical modeling computer code was released for testing and verification, and final coding for the advanced conceptual design version of EQ3/6 was in progress. User's manuals for the modeling and data-base-handling codes were written. Version 3245 is being extensively tested on systems of interest to performance

assessment (spent-fuel and glass dissolution, water chemistry in the unsaturated zone, and container-material effects).

A preliminary kinetic model of glass alteration by liquid water, derived from experimentally observed phenomena and basic thermodynamic principles, was developed and incorporated into the EQ3/6 geochemical modeling computer code. The predictions of this model are continuing to be checked against new experimental data.

The first version of the waste-package performance-assessment computer code, PANDORA-1, was developed and put into testing. Other progress included the development and testing of the FACSIMILE computer code for simulating nonuniform corrosion of Zircaloy and container materials in the presence of tuff ground water.

Progress in assessing the performance of natural barriers included the evaluation of the ground-water flow system at the site, as presently understood. This included the evaluation of: (1) lateral fluid flow at Yucca Mountain (Wang and Narasimhan, 1988); (2) uncertainty in hydrologic parameters (Kaplan and Yarrington, 1989); (3) fluid and heat flow near waste packages (Doughty and Pruess, 1988); (4) gas-phase flow (Tsang and Pruess, 1988); and (5) capillary-driven flow in fractures (Martinez and Prindle, 1988).

Progress in developing calculational models for assessing the performance of natural barriers included: (1) evaluating various approaches to calculating ground-water travel time (Kaplan et al., 1989); (2) evaluating the hydrologic effects of constructing the exploratory-shaft facility (Peterson, 1989); (3) analyzing proposed laboratory experiments (Eaton et al., 1989); and (4) developing computational and experimental procedures for predicting flow (Eaton et al., 1988). In addition, a three-dimensional steady-state flow system that takes into account the construction of an exploratory shaft was analyzed.

2.6.3 Design analysis

The third category of performance assessment, design analysis, integrates the performance-assessment program with the design program. In this respect, design analysis refers to the performance assessments that are used to develop design requirements and to evaluate the design against those requirements. Work during the period focused on developing the process that will be used in establishing the design requirements for the exploratory-shaft facility.

2.6.4 Site characteristics analysis

The fourth category of performance assessment, the site characteristics analysis, integrates the performance-assessment program with the

investigations of the site programs. Site characteristics analyses include the following: (1) the development of site conceptual models, scenarios, and process and constitutive models that can be used in performance assessments; (2) model-validation activities, including the testing of any alternative conceptual models or hypotheses; (3) performance-assessment activities to support the site programs, such as test planning, evaluation of potential interferences between and among tests, and the evaluation of the adequacy of the information obtained; and (4) activities to support the performance-confirmation program. The process to evaluate site characterization results involves comparisons with goals set as a part of performance allocation and comparison with the performance objectives, as described in Section 8.1 of the SCP. During the reporting period, work continued to develop the program of analyses in this performance-assessment category.

3. SCHEDULES

Over the next several months, a senior DOE management team, together with OCRWM management, will conduct a thorough evaluation of the existing schedule for the repository program. During this time, the DOE will also be receiving the NRC and State of Nevada comments on the SCP and will be obtaining a clearer view of likely State of Nevada action on the DOE permit applications. The DOE's goal is to develop a realistic schedule for the repository program that will be aggressively followed to minimize delay and, along with other initiatives being taken, will establish confidence that the schedule will be met. An increased emphasis on strategic and contingency planning and management controls will also be used to help ensure that the newly established schedule is met.

For this reason, schedule information is not provided in this first progress report. Information regarding the newly established repository schedule will be provided in future reports.

REFERENCES

Bodvarsson, G.S., A. Nemi, A. Spencer, and M.P. Attanayake, 1988. Preliminary Calculations of the Effects of Air and Liquid-Water Drilling on Moisture Conditions in Unsaturated Rocks, LBL-25073, Lawrence Berkeley Laboratory, Berkeley, CA.

Broxton, D., 1989. Petrography of Phenocryst Chemistry of Volcanic Units at Yucca Mountain: A Comparison of Outcrop and Drill Hole Sample, LA-11503-M3, Los Alamos National Laboratory, Los Alamos, NM.

Carlos, B., 1989. Fracture-Coating Minerals in the Topopah Spring Member and Upper Tuff of Calico Hills From Drill Hole J-13, LA-11504-M5, Los Alamos National Laboratory, Los Alamos, NM.

Crowe, B., C. Harrington, L. McFadden, F. Wells, B. Turrin, and D. Champion, 1988. Preliminary Geologic Map of the Lathrop Wells Volcanic Center, LA-UR-88-4155, Los Alamos National Laboratory, Los Alamos, NM.

DOE (Department of Energy), 1986. Final Environmental Assessment: Yucca Mountain Site, Nevada Research and Development Area, Nevada, DOE/RW-0073, Washington, DC.

DOE (Department of Energy), 1987. Nevada Nuclear Waste Storage Investigations, 1977-1985, A Bibliography, DE86013045, Nevada Operations Office, Las Vegas, NV.

DOE (Department of Energy), 1988a. Environmental Monitoring and Mitigation Plan for Site Characterization: Yucca Mountain Site, Nevada Research and Development Area, Nevada, DOE/RW-0208 (Rev. 2), Washington, DC.

DOE (Department of Energy), 1988b. Socioeconomic Monitoring and Mitigation Plan for Site Characterization, DOE/RW-0179 (Rev. 1), Las Vegas, NV.

DOE (Department of Energy), 1988c. Site Characterization Plan: Yucca Mountain Site, Nevada Research and Development Area, Nevada, 8 Volumes, DOE/RW-0199, Washington, DC.

DOE (Department of Energy), 1988d. Yucca Mountain Project Bibliography, July-December 1988, An Update, DE89005394, Nevada Operations Office, Las Vegas, NV.

DOE (Department of Energy), 1988e. Nevada Nuclear Waste Storage Investigations, 1986-1987, A Bibliography, DE88004834, Nevada Operations Office, Las Vegas, NV.

DOE (Department of Energy), 1988f. Yucca Mountain Project Bibliography, January-June 1988, An Update, DE88015230, Nevada Operations Office, Las Vegas, NV.

DOE (Department of Energy), 1988g. Yucca Mountain Project Exploratory Shaft Facility Title I Design Summary Report, 4 Volumes, YMP/88-20, Las Vegas, NV.

DOE (Department of Energy), 1988h. Surface-Based Investigations Plan, 4 Volumes, YMP/88-25, Las Vegas, NV.

DOE (Department of Energy), 1989a. Identification of Items Important to Safety (List Generated by Application of AP-6.10Q), YMP/CM-0003, Las Vegas, NV.

DOE (Department of Energy), 1989b. Identification of Activities to be Placed on the Quality Activities List (List Generated by Application of AP-6.11Q), YMP/CM-0002, Las Vegas, NV.

DOE (Department of Energy), 1989c. Review Record Memorandum, Exploratory Shaft Facility (ESF) Title I Design Acceptability Analysis and Comparative Evaluation of Alternative ESF Locations, YMP/89-3, Las Vegas, NV.

DOE (Department of Energy), 1989d. Integrated Data System Title I Preliminary Design Technical Assessment Review Record Memorandum, L89-ESF-JHM-014, Las Vegas, NV.

DOE (Department of Energy), 1989e. Exploratory Shaft Facility (ESF) Subsystem Design Requirements Document (SDRD) for Title II, YMP/CC-0003 (Rev. 0), Las Vegas, NV.

DOE (Department of Energy), 1989f. The Yucca Mountain Project Reference Information Base, YMP/CC-0002, Las Vegas, NV.

Doughty, C., and K. Pruess, 1988. A Similarity Solution for Two-Phase Fluid and Heat Flow Near High-Level Nuclear Waste Packages Emplaced in Porous Media, SAND88-7071A, Sandia National Laboratories, Albuquerque, NM.

Dudley, A., R. Peters, M. Tierney, and E. Klavetter, 1989. Total System Performance Assessment Code (TOSPAC): Volume 1: Physical and Mathematical Basis, SAND85-0002, Sandia National Laboratories, Albuquerque, NM.

Eaton, R., N. Bixler, and R. Peters, 1988. Computational and Experimental Procedures for Predicting Flow Through Low-Permeability, Partially Saturated, Fractured Rock, SAND88-2626A, Sandia National Laboratories, Albuquerque, NM.

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Eaton, R., R. Dykhuizen, and A. Russo, 1989. Analysis of Proposed Laboratory Experiments in Partially Saturated, Small-Pore Fractured Rock, SAND89-0074A, Sandia National Laboratories, Albuquerque, NM.

Easterling, R.C., and I.J. Hall, 1988. Additional Underground Test Data Required for Yucca Mountain Repository Characterization, SAND87-2073, Sandia National Laboratories, Albuquerque, NM.

Einziger, R.E., 1988a. Test Plan for Thermogravimetric Analyses of BWR Spent Fuel Oxidation, PNL-6745/UC/70, Pacific Northwest Laboratory, Richland, WA.

Einziger, R.E., 1988b. Test Plan for Long-Term, Low-Temperature Oxidation of BWR Spent Fuel, PNL-6427/UC/70, Pacific Northwest Laboratory, Richland WA.

Hardy, N.P., and C.N. St. John, 1988. Underground Repository Design Methodology for a Repository in Tuff, SAND88-7059A, Sandia National Laboratories, Albuquerque, NM.

Jardine, L.J., and T. Laub, 1988. Use of Performance Assessments to Generate a Repository Q-List, SAND88-0140A, Sandia National Laboratories, Albuquerque, NM.

Kaplan, P., E. Klavetter, and R. Peters, 1989. Approaches to Groundwater Travel Time, SAND88-2868C, Sandia National Laboratories, Albuquerque, NM.

Kaplan, P., and L. Yarrington, 1989. Modeling the Uncertainties in the Parameter Values of a Layered, Variably Saturated Column of Volcanic Tuff Using the Beta Probability Distribution, SAND88-2247C, Sandia National Laboratories, Albuquerque, NM.

Kiciman, O.K., and N.A. Abrahamson, 1988. A Probabilistic Estimation of Seismic Damage at Waste-Handling Facilities of a Repository Located at Yucca Mountain, Nevada, SAND88-7067A, Sandia National Laboratories, Albuquerque, NM.

Laub, T., 1988. Assessment of Worker and Non-Worker Radiological Safety of a Repository, SAND88-0292A, Sandia National Laboratories, Albuquerque, NM.

Laub, T., L.J. Jardine, C. Ma, R. Sit, S. Zavosky, and D. Hartsann, 1988. Preliminary Radiological Safety Analysis for Normal Operations of a Prospective Yucca Mountain Repository, SAND87-2070C, Sandia National Laboratories, Albuquerque, NM.

Ma, C.W., and L.J. Jardine, 1988. Offsite Radiation Doses Resulting from Seismic Events at the Yucca Mountain Repository, SAND88-7066A, Sandia National Laboratories, Albuquerque, NM.

Martinez, M., and R. Prindle, 1988. Capillary-Driven Flow in a Fracture Located in a Porous Medium, SAND84-1697, Sandia National Laboratories, Albuquerque, NM.

McKeegan, K.D., D. Phinney, V.M. Oversby, M. Buchholtz-tenBrink, and D.K. Smith, 1988. Uranium Transport in Topopah Spring Tuff: An Ion-Microscope Study, UCRL-99734, Lawrence Livermore National Laboratory, Livermore, CA.

NRC (Nuclear Regulatory Commission), 1988a. Qualification of Existing Data for High-Level Waste Geologic Repositories, NUREG-1298, Prepared by W.D. Altman, J.P. Donnelly, and J.E. Kennedy, Washington, DC.

NRC (Nuclear Regulatory Commission), 1988b. Technical Position on Items and Activities in the High-Level Waste Geologic Repository Program Subject to Quality Assurance Requirements, NUREG-1318, Prepared by A.B. Duncon, S.G. Bilhorn, and J.E. Kennedy, Washington, DC.

O'Brien, P., 1989. OGR Repository-Specific Rod Consolidation Study: Effect on Costs, Schedules, and Operations at the Yucca Mountain Repository, SAND86-2357, Sandia National Laboratories, Albuquerque, NM.

Peters, R.R., 1988. Hydrologic Technical Correspondence in Support of the Site Characterization Plan, SAND88-2784, Sandia National Laboratories, Albuquerque, NM.

Peterson, A., 1989. Technical Correspondence in Support of an Evaluation of the Hydrologic Effects of Exploratory Shaft Facility Construction, SAND88-2936, Sandia National Laboratories, Albuquerque, NM.

Richardson, A., and C.M. St. John, 1988. A Concrete Shaft Liner Design Methodology for Nuclear Waste Repositories, SAND88-7052, Sandia National Laboratories, Albuquerque, NM.

Richardson, A.M., B. Schmidt, and M. Christopher, 1988. A Proposed Concrete Shaft Liner Design Method for Underground Nuclear Waste Repositories, SAND88-7120A, Sandia National Laboratories, Albuquerque, NM.

Robison, J.H., D.M. Stephens, R.R. Luckey, and D.A. Baldwin, 1988. Water Levels in Periodically Measured Wells in the Yucca Mountain Area, Nevada, 1981-87, U.S. Geological Survey Open File Report 88-468.

SNL (Sandia National Laboratories), 1987. Site Characterization Plan Conceptual Design Report, SAND 84-2641, 6 Volumes, Sandia National Laboratories, Albuquerque, NM.

Sanders, M., 1988. Description of Ground Motion Data Processing Codes, SAND87-1176, Sandia National Laboratories, Albuquerque, NM.

Sass, J.H., A.H. Lachenbrunch, W.W. Dudley Jr., S.S. Priest, and R.J. Munroe,1988. Temperature, Thermal Conductivity, and Heat Flow near Yucca Mountain Nevada: Some Tectonic and Hydrologic Implications, USGS Open File Report 87-649, 188p.

Subramanian, C.V., and L.J. Jardine, 1988. Evaluation of Site-Generated Radioactive Waste Treatment and Disposal Methods for the Yucca Mountain Repository, SAND88-1937, Sandia National Laboratories, Albuquerque, NM.

Subramanian, C.V., C.L. Wu, C.D. Degrabrielle, and S.D. Leftwich, 1988. Seismic Design Study of the Waste-Handling Building at the Prospective Yucca Mountain Nuclear Waste Repository, SAND87-1915C, Sandia National Laboratories, Albuquerque, NM.

Subramanian, C.V., A.H. Hadjian, J. King, and R.P. Kennedy, 1989. Preliminary Seismic Design Cost-Benefit Assessment of the Tuff Repository Waste-Handling Facilities, SAND88-1600, Sandia National Laboratories, Albuquerque, NM.

Tsang, Y., and K. Preuss, 1988. Gas Phase Flow Effects on Moisture Migration in the Unsaturated Zone at Yucca Mountain, SAND88-7073A, Sandia National Laboratories, Albuquerque, NM.

Wallace, K., and D. Zerga, 1988. An Analysis of Air Cooling Prior to Reentering a Drift Containing Emplaced Commercial Nuclear Waste, SAND87-7076C, Sandia National Laboratories, Albuquerque, NM.

Wang, J.S.Y., and N.T. Narasimhan, 1988. Hydrologic Modeling of Vertical and Lateral Movement of Partially Saturated Fluid Flow Near a Fault Zone at Yucca Mountain, SAND87-7070, Sandia National Laboratories, Albuquerque, NM.

Watkins, J.D., 1989. Letter from J.D. Watkins (Secretary of Energy) to B. Miller (Governor of Nevada), March 10, 1989; regarding extension of comment period for the Site Characterization Plan.

Yang, I.C., 1988. "Radiocarbon Dates V: Radiocarbon", American Journal of Science, v. 30, No. 1, p. 41-60.

Yang, I.C., A.K. Turner, T.M. Sayre, and P. Montazer, 1988. Triaxial-Compression Extraction of Pore Water from Unsaturated Tuff, Yucca Mountain, Nevada, U.S. Geological Survey Water-Resources Investigation Report 88-4189.

ACRONYMS

The following is a list of acronyms that were used in the semiannual progress report:

AP	Administrative procedure
DOE	Department of Energy
EEI/UNWMG	Edison Electric Institute/Utility Nuclear Waste Management Group
ES	Exploratory shaft
ESF	Exploratory Shaft Facility
IDAS	Integrated Data Acquisition System
NRC	Nuclear Regulatory Commission
OCRWM	Office of Civilian Radioactive Waste Management
QA	Quality Assurance
QAP	Quality Assurance Plan
QAPD	Quality Assurance Program Description
QAPP	Quality Assurance Program Plan
QAR	Quality Assurance Requirements
QMP	Quality management procedure
SBIP	Surface-Based Investigation Plan
SCP	Site Characterization Plan
SDRD	Subsystem Design Requirements Document
SIP	Scientific Investigation Plan
SMF	Sample Management Facility
TAR	Technical assessment review
UNE	Underground nuclear explosion

BIBLIOGRAPHY

The following is a bibliography of selected documents that provide additional information to that which is provided in the text of the report. The bibliography was developed based on a systematic search of the Energy Data Base (EDB). The EDB is the principal data base of an information management system maintained by the DOE Office of Scientific and Technical Information at Oak Ridge, TN. The EDB contains unclassified energy-related scientific and technical information.

The bibliography contains those pertinent documents available in the EDB as of April 15, 1989. However, due to the mechanics of the system, there is a 2 to 3 month time lag involved in data entry of documents to the EDB. Therefore, the bibliography for this SPR contains those documents dated September 1988 through approximately February 1989.

Copies of most DOE and DOE sponsored documents identified in the bibliography can be ordered from:

National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161

Battelle Memorial Institute, 1988. Interface Management for the Yucca Mountain Project, DOE/CH/10290-T1, Columbus, OH.

This report addresses the physical interfaces that need to be controlled on the Yucca Mountain Project. Physical interfaces are interactions between physical elements of the mined geologic disposal system; for example, the repository shafts will interface with the exploratory shaft facility.

Bish, D.L., 1989. Evaluation of Past and Future Alterations in Tuff at Yucca Mountain, Nevada, Based on the Clay Mineralogy of Drill Cores USW G-1, G-2, and G-3, LA-10667-MS, Los Alamos National Laboratory, Los Alamos, NM.

For predictive purposes, it is important to understand the alteration history of Yucca Mountain, in particular how the tuff responds to changing conditions such as elevated temperatures. The clay mineralogy of tuff has been examined using X-ray powder diffraction, and approximation temperatures of alteration have been determined using available clay mineral data and fluid inclusion analyses. The clay minerals are predominately interstratified illite/smectites, with minor amounts of chloride, kaolinite, and interstratified chlorite/smectite.

Bish, D.L.; Chipera, S.J., 1989. Revised Mineralogic Summary of Yucca Mountain, Nevada, LA-11497-MS, Los Alamos National Laboratory, Los Alamos, NM.

The three-dimensional mineral distribution at Yucca Mountain, was evaluated using quantitative X-ray powder diffraction analysis. All data were obtained from core cuttings or sidewall samples obtained from drill holes at and around Yucca Mountain. The data support the presence of several zones of mordenite and clinoptilolite-heulandite. New data on several deep clinoptilolite-heulandite samples coexisting with analcime show that they are heulandite.

Bonano, E.J.; Davis, P.A.; Bras, R.L.; Kitanidis, P.K., 1988. "Methodology for Estimating Groundwater Travel Times at a Nuclear Waste Repository using a Physically Based Geostatistical Approach," from the International Geostatistics Congress; Avignon, France, Sept 1988, SAND-87-2226C, Sandia National Laboratories., Albuquerque, NM.

This paper summarizes the results of an investigation to test a methodology for estimating groundwater travel times at potential high-level nuclear waste repository sites. The procedure is based on parameter estimation that uses available hydraulic head and transmissivity observations and includes uncertainty in the boundary head values in the estimation of a transmissivity field.

Buscheck, T.A.; Nitao, J.J., 1988. Preliminary Scoping Calculations of Hydrothermal Flow in Variably Saturated, Fractured, Welded Tuff During the Engineered Barrier Design Test at the Yucca Mountain Exploratory Shaft Test Site, UCID-21671, Lawrence Livermore National Laboratory, Livermore, CA.

The hydrothermal system of Yucca Mountain was modeled as a discrete fracture/matrix system, using the integral finite difference code TOUGH and the best available data on the fracture and matrix properties of the Topopah Spring densely welded tuff. Calculations related to the volume of undisturbed rock in connection with various temperatures in different conditions are presented.

Day, R.A., 1988. Preliminary Technique Assessment for Nondestructive Evaluation Certification of the NNWSI [Nevada Nuclear Waste Storage Investigations] Disposal Container Closure, UCID-21323, Lawrence Livermore National Laboratory, Livermore, CA.

An evaluation of methods to certify closure of waste containers was performed. It is concluded that the waste container closure weld can best be nondestructively examined by a combination of ultrasonics and liquid penetrants. Ultrasonic and liquid penetrant methods can examine all closure methods currently being considered, including fusion welding and inertial welding.

Department of Energy, Office of Civilian Radioactive Waste Management, 1988. Site Characterization Plan Overview: Yucca Mountain Site, Nevada Research and Development Area, Nevada, DOE/RW-0198, Washington, D.C.

The SCP overview was prepared to help the public understand both the SCP and the site characterization program in general. The overview presents summaries of selected topics covered in the SCP. The organization of the overview is similar to that of the SCP, with brief descriptions of the Yucca Mountain site, the repository, and the containers in which the waste would be packaged, followed by a discussion of the characterization program to be carried out at the Yucca Mountain site.

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

This report to Congress addresses the potential impacts of locating a repository at the Yucca Mountain site, provides recommendations for mitigating those impacts, and analyzes authorities and sources of funds for mitigation. Based on its analysis, DOE concluded that, of the fourteen impact categories specified in Section 175 of the NWPA,

as amended, project-related effects may occur in twelve of the impact categories. DOE stated that a critical part of impact mitigation is a socioeconomic monitoring program and an initial evaluation of impacts and mitigation strategies by affected communities. DOE identified its primary mitigation strategy as the conduct of its activities in a manner that would avoid or minimize significant impacts to the maximum extent practicable, and DOE committed to work with affected parties to determine mitigation strategies. The report concludes that DOE has the necessary authority and sources of funds to address impacts that may occur throughout the course of the repository program, including financial assistance that can be provided by DOE per Section 116 of the NWPA, as amended.

Department of Energy, Office of Civilian Radioactive Waste Management, 1989. 1988 Bulletin Compilation and Index, DOE/RW-02221, Washington, D.C.

This document is published to provide current information about the national program for managing spent fuel and high-level radioactive waste. This document is a compilation of bulletin issues from the 1988 calendar year.

Department of Energy, Office of Civilian Radioactive Waste Management, 1988. Quarterly Report on Program Cost and Schedule: Fourth Quarter FY 1988, DOE/RW-0188-3, Washington, D.C.

This report provides the status of major program milestones and accomplishments for the Fourth Quarter FY 1988.

Farmer, J.C.; McCright, R.D., 1988. Localized Corrosion and Stress Corrosion Cracking of Candidate Materials for High-Level Radioactive Waste Disposal Containers in the US: A Literature Review, from the Materials Research Society; Berlin, DE, October 1988, UCRL-98756, Lawrence Livermore National Laboratory, Livermore, CA,

Container materials may undergo several modes of degradation in the repository environment, including: undesirable phase transformations due to lack of phase stability; atmospheric oxidation; general aqueous corrosion; pitting; crevice corrosion; intergranular stress corrosion cracking; and transgranular stress corrosion cracking. This paper is an analysis of data from the literature relevant to the pitting, crevice corrosion, and stress corrosion cracking of three austenitic alloys which are candidate materials for waste containers.

Grambow, B.; Strachan, D.M., 1988. A Comparison of the Performance of Nuclear Waste Glasses by Modeling, PNL-6698, Pacific Northwest Laboratory, Richland, WA,

Through a combination of data collection and computer modeling, the dissolution mechanism of nuclear waste glasses has been investigated and more clearly defined in this report. Data from static and dynamic leach tests are assembled, plotted, and successfully modeled and the kinetic parameters for these glasses are reported. The model can be used to calculate the effects of changes in the initial composition of the water contacting the glass and the effects of convective flow. Furthermore, glasses of different compositions can be readily compared using the model presented here.

Grenia, J.; Weyand, L., 1988. Impact Analysis on ESF Design for Calico Hills Penetration and Exploratory Drift and Tuff Main Extension to Limits of the Repository Block, DOE/NV/10322-35, Fenix and Scisson, Inc., Las Vegas, NV.

The study covers the impacts on project costs, schedule, human resources, and engineering designs caused by an increase in site characterization activity. Additional activities would include the penetration of the Calico Hills formation by the ES-1 shaft and exploratory drifting to the Ghost Dance fault and/or drifting 10,000 feet southward from the ESF test complex area to the end of the future repository block.

Harris, R.N.; Ponce, D.A., 1988. High-Precision Gravity Network to Monitor Temporal Variations in Gravity Across Yucca Mountain, Nevada, USGS-OFR-88-243, Geological Survey, Menlo Park, CA.

Repeatable high-precision gravity surveys provide a method of monitoring temporal variations in the gravity field. Fluctuations in the gravity field may indicate water table changes, crustal deformation, or precursors to volcanism and earthquakes. This report describes a high-precision gravity loop which has been established across Yucca Mountain. The purpose of this gravity loop is to monitor temporal variations in gravity across Yucca Mountain in an effort to interpret and predict the stability of the tectonic framework and changes in the subsurface density field.

Holmes and Narver, Inc., 1988. Nevada Nuclear Waste Storage Investigations Atlas of Field Activities, Yucca Mountain, Nye County, Nevada, Volume II, DOE/NV/10576-T1-Vol. 2.

This document contains engineering drawings and support text for the Yucca Mountain Project Site Atlas.

Huber, N.K., 1988. Late Cenozoic Evolution of the Upper Amargosa River Drainage System, Southwestern Great Basin, Nevada and California, USGA-OFR-87-617, Geological Survey, Menlo Park, CA.

This report provides a historical description of the evolution of the Upper Amargosa River drainage system which was formed 11 million years ago. The gross drainage pattern has changed little in that time, implying a tectonic stability of the area.

Johnson, G.L., 1988. Thermal Performance of a Buried Nuclear Waste Storage Container Storing a Hybrid Mix of PWR and BWR Spent Fuel Rods, UCID-21414 Lawrence Livermore National Laboratory, CA.

The container will provide the primary containment of the nuclear waste and the spent fuel rod cladding will provide secondary containment. A series of transient conduction and radiation heat transfer analyses were run to determine for the first 1000 years of storage if the temperature of the tuff at the borehole wall ever falls below 97°C and whether the cladding of the stored spent fuel ever exceeds 350°C.

Nimick, F.B.; Shepard, L.E.; Blejwas, T.E., 1988. Preliminary Evaluation of the Exploratory Shaft Representativeness for the Yucca Mountain Project, SAND-87-1685, Sandia National Laboratories, NM.

The representativeness of the data and information to be obtained in the exploratory shaft facility (ESF) relative to the site must be evaluated. This evaluation is based on evolving interpretations of limited data, much of which was obtained adjacent to or outside the designated boundaries of the primary area. The representativeness of information scheduled to be obtained in the ESF has been evaluated for a number of technical disciplines including geology, mineralogy, rock mechanics, hydrology, waste package and repository design, and performance assessment. Results of this evaluation indicate that most data obtained in the ESF are expected to be representative of the primary area at Yucca Mountain.

Oak Ridge National Laboratory, 1988. Integrated Data Base for 1988: Spent Fuel and Radioactive Waste Inventories, Projections, and Characteristics, DOE/RW-0006, Rev. 4, Oak Ridge, TN.

The Integrated Data Base Program has compiled current data on inventories and characteristics of commercial spent fuel and both commercial and US government-owned radioactive wastes through December 31, 1987. This data is based on the most reliable information available from government sources, the open literature, technical reports, and direct contacts. The current projections of future waste and spent fuel to be generated through the year 2020 and characteristics of these materials are also presented.

Reimus, M.A.H.; Repal, G.F.; Mellinger, G.B.; Bunnell, L.R., 1988. West Valley Glass Production Qualification Durability Studies, FY 1987-1988: Effects of Composition, Redox State, Thermal History, and Groundwater, PNL-6723, Pacific Northwest Laboratories, Richland, WA.

The product qualification subtask of the West Valley Support Task at Pacific Northwest Laboratory provides support for the waste form qualification efforts at West Valley Nuclear Services Co. Testing is being conducted to determine waste form chemical durability in support of these efforts. The effects of composition, ferrous/ferric ratio (redox state), thermal history, and groundwater are reported.

Reimus, P.W.; Liebetrau, A.M.; Apted, M.J.; Engel, D.W., 1988. "Performance Assessment for Spent Fuel Waste Packages at the Candidate Nevada Repository Site," from Spectrum 88: International Topical Meeting on Nuclear and Hazardous Waste Management, Pasco, WA. PNL-SA-15624, Pacific Northwest Laboratory, Richland, WA.

The Analytical Repository Source-Term (AREST) code is a preliminary performance assessment tool for evaluating waste package behavior in various geologic repository settings. The code is being enhanced to provide specific assessments of waste package performance in the hydrologically unsaturated welded tuff geology of Yucca Mountain.

Science Applications International Corporation, 1988. Yucca Mountain Project Site Atlas: Volume 1, DOE/NV/10516-T1-Vol.1, Las Vegas, NV.

The Yucca Mountain Project Site Atlas is a reference document of field activities which have been, or are being, conducted to support investigations of Yucca Mountain. The investigations will yield geologic, geophysical, geochemical, geomechanical, hydrologic, volcanic, seismic, and environmental data necessary to characterize Yucca Mountain and its regional setting.

Siegal, M.D.; Phillips, S.L.; Leckie, J.O.; Kelly, W.P., 1988. "Development of a Methodology of Geochemical Sensitivity Analysis for Performance Assessment," from Geostatistical Methods for Transport Modeling, San Francisco, CA, September 1988. SAND-87-1133C, Sandia National Laboratories, Albuquerque, NM.

The objective of this paper is the formulation of criteria for valid simplification of radionuclide transport models used in performance assessments. The complementary roles played by simple transport models designed to bound the radionuclide discharge over wide ranges of physiochemical conditions, detailed geochemical models that provide a structured method to obtain reliable information about

solute/rock/water interactions, and sensitivity and uncertainty analysis techniques used to assess the significance of errors in both data and models are addressed.

Smith, H.D., 1988. Initial Report on Stress-Corrosion-Cracking Experiments Using Zircoloy-Spent Fuel Cladding C-Rings, WHC-EP-0096, Westinghouse Hanford Company, Richland, WA.

C-ring stress corrosion cracking scoping experiments are being conducted as a first step in evaluating the potential for stress corrosion cracking of spent fuel cladding in a potential tuff repository environment. The objective is to assess the approximate behavior so that more precise pressurized tube testing can be performed over an appropriate range of stress conditions.

Smith, H.D., 1988. Electrochemical Corrosion-Scoping Experiments: An Evaluation of the Results, WHC-EP-0065, Westinghouse Hanford Company, Richland, WA.

Prior to emplacement in a nuclear waste repository, each waste form must be well characterized with respect to its behavior in the environments expected to develop in the repository. This scoping study was designed to obtain a qualitative idea of how spent fuel cladding would respond to a hot water environment that could develop in a tuff repository at a time when temperatures have cooled to approximately 95°C and hot liquid water has infiltrated the repository horizon.

West, K.A,; 1988. Nevada Nuclear Waste Storage Investigations: Exploratory Shaft Facility Fluids and Materials Evaluation, LA-11398-MS, Los Alamos National Laboratory, Los Alamos, NM.

The objective of this study was to determine if any fluids or materials used in the Exploratory Shaft Facility (ESF) of Yucca Mountain will make the mountain unsuitable for future construction of a nuclear waste repository. To properly characterize Yucca Mountain, it will be necessary to construct an underground test facility, in which in situ site characterization tests can be conducted. The candidate repository horizon at Yucca Mountain, however, could potentially be compromised by fluids and materials used in the site characterization tests. This analysis evaluates the kinds of fluids and materials that will be used and their potential impacts on the site and identifies fluids and materials, if any, that should be prohibited from, or controlled in, the underground.

West Valley Nuclear Services Co., Inc., 1989. West Valley Demonstration Project, West Valley, NY: Annual Report, WVOP-89AR, West Valley, NY.

Under the West Valley Demonstration Project Act, Public Law 96-368, liquid high-level radioactive waste stored at the Western New York Nuclear Services Center, West Valley, New York, that resulted from spent nuclear fuel reprocessing operations conducted between 1966 and 1972, is to be solidified in borosilicate glass and transported to a federal repository for geologic disposal. This report provides a summary of project progress for FY 1988.

Yabusaki, S.B.; Cole, C.R.; Holford, O.J.; Monti, A.M.; Gupta, S.K., 1988. HYDROCOIN (Hydrologic Code Intercomparison) Level I: Benchmarking and Verification Test Results with CFEST (Coupled Fluid, Energy, and Solute Transport) Code, PNL/SRP-6681, Pacific Northwest Laboratory, Richland, WA.

DOE participated in the International Hydrologic Code Intercomparison (HYDROCOIN) project for the purpose of improving our knowledge about the influence of various strategies for ground-water flow modeling for the safety assessment of final repositories for nuclear waste. The HYDROCOIN project consisted of three levels of effort: (1) Level 1 was concerned with verifying the numerical accuracy of the code, (2) Level 2 was involved with validation of models using field experiments, and (3) Level 3 was concerned with sensitivity and uncertainty analysis. This report presents the Level 1 results furnished by the project teams.

Zumberge, M.A.; Harris, R.N.; Oliver, H.W.; Sasagana, G.S.; Ponce, D.A., 1988. Preliminary Results of Absolute and High Precision Gravity Measurements at the Nevada Test Site and Vicinity, Nevada, USGS-OFR-88-242, Geological Survey, Menlo Park, CA.

This report presents the preliminary results of absolute gravity measurements made at four sites in southern Nevada using the absolute gravity free-fall apparatus. Three of the sites are located on the Nevada Test Site at Mercury, Yucca Pass, and in northern Jackass Flats. The fourth site is at the Kyle Canyon ranger station near Charleston Park.