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***Nuclear Waste Policy Act***  
***(Section 113)***

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***Site Characterization Progress Report:***  
***Yucca Mountain, Nevada***

***April 1, 1993 - September 30, 1993***

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***Number 9***

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***February 1994***

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***U.S. Department of Energy***  
***Office of Civilian Radioactive Waste Management***

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Radioactive Waste Management (OCRWM).

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OCRWM Information Center  
P.O. Box 44375  
Washington, DC 20026



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***Washington, DC 20585***

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## Department of Energy

Washington, DC 20585

February 10, 1994

### NOTE TO READERS:

*In accordance with section 113(b)(3) of the Nuclear Waste Policy Act of 1982, as amended, the Department has prepared the ninth in a series of progress reports focused on site characterization at the Yucca Mountain candidate site in Nevada. The document is entitled "Site Characterization Progress Report: Yucca Mountain, Nevada" and covers the period from April 1, 1993 through September 30, 1993.*

*The Civilian Radioactive Waste Management Program made significant progress at the Yucca Mountain Site Characterization Project during this reporting period. Construction of the Exploratory Studies Facility North Ramp Starter Tunnel began on April 2, 1993, and was completed on September 9, 1993, to a distance of about 200 feet. In addition, a contract was awarded for purchase of the Tunnel Boring Machine that will be used to excavate the remainder of the main ramps and tunnels. Deep borehole drilling and testing continued, with the second deep borehole reaching a depth of 1300 feet. All boreholes, 99 in total, were completed for the Neutron Access Program. Surface trenching and excavation continued to determine geologic faulting and volcanism history as well as to define seismic hazard basis.*

*Advanced conceptual design of the waste package continued, and feasibility and implementation studies were conducted for the use of a Multipurpose Canister system. Field testing progressed on the large block heater test and engineered barrier system tests.*

*Review and revision of the entire set of System Requirements Documents were completed during this period and implemented.*

*Formal interactions continued between the Project Office and the Nuclear Waste Technical Review Board in April, July, and September. In April, the Yucca Mountain Site Characterization Project hosted a tour of Yucca Mountain and presented its process for resolving difficult issues. In July, the Department presented its approach for Electing and Validating a thermal loading strategy to the Review Board. On September 21-23, the Project Office held a workshop to discuss alternative concepts for the repository waste package in response to recommendations by the Review Board.*

*In interactions with the Nuclear Regulatory Commission, the Department forwarded Revision 2 of the "Mined Geologic Disposal System Annotated Outline Skeleton Text for the Preparation of a License Application." In addition, the Department and the Commission participated in a technical exchange on "Substantially Complete Containment and the Waste Package/Engineered Barrier System Design Concepts" in August.*




*The Department continues to interact with the National Academy of Sciences as the Academy develops recommendations on health-based standards for protection of the public from releases from a repository at the Yucca Mountain site, as described in Section 801 of the Energy Policy Act of 1992.*

*To comply with requirements of Section 803 of the Energy Policy Act of 1992, the Department prepared and issued for public review and comment a draft report entitled "Adequacy of Management Plans for Future Generations of Spent Nuclear Fuel and High-Level Radioactive Waste."*

*Public outreach activities were continued with 68 tours of Yucca Mountain conducted for about 2600 members of the public and other interested parties. In addition, various programmatic and technical workshops and presentations were conducted by Yucca Mountain Site Characterization Project staff.*

*The Department will continue to issue progress reports on a semi-annual basis, as specified in the Nuclear Waste Policy Act.*

*Sincerely,*

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

Please Add

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my name for receiving the Site Characterization Progress Report  
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## **FOREWORD**

For ease of use of this document, the reader should note that the Executive Summary is intended to provide a summary of major decisions, activities, accomplishments, and issues of interest during the reporting period. Chapter 1, Introduction, provides background information to assist the reader in understanding the current status of the program. Chapter 2 provides specific detailed discussions of activities conducted during the current reporting period and has two major divisions. Section 2.1, Preparatory Activities, provides information on select preparatory activities necessary to conduct site characterization and design activities. Sections 2.2 through 2.7 provide specific details on studies and activities conducted during the reporting period and follow the original structure of the Department's 1988 Site Characterization Plan. Chapter 3 contains the current summary schedule, while Chapter 4 presents an epilogue of significant events that occurred after the end of the reporting period, but prior to printing of this report, and that are believed to be of interest to the reader. Therefore, for general interest a reader may wish to first review the Executive Summary, Introduction and Epilogue prior to turning to more detailed discussion of technical studies and activities of interest in Sections 2.2 through 2.7.

Information in this Progress Report is conveyed in a summary form for convenient information exchange. Additional specific information is available in reference documents identified in the Appendix. Also, while serious effort has been made to minimize the use of acronyms throughout the document, a list of acronyms, abbreviations, and symbols used throughout this document is included to further assist the reader.

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### EXECUTIVE SUMMARY

In accordance with requirements of Section 113(b)(3) of the Nuclear Waste Policy Act of 1982, as amended, and 10 CFR 60.18(g), the U.S. Department of Energy has prepared this report on the progress of site characterization activities at Yucca Mountain, Nevada, for the period April 1, 1993, through September 30, 1993. This report is the ninth in a series issued at intervals of approximately six months during site characterization of Yucca Mountain as a possible site for a geologic repository for the permanent disposal of high-level radioactive waste. Also included in this report are activities such as public outreach and international programs that are not formally part of the site characterization process. Information on these activities is provided to report on all aspects of the Yucca Mountain studies.

On April 2, 1993, a major Program milestone was reached as excavation of the Exploratory Studies Facility North Ramp Starter Tunnel began. The Exploratory Studies Facility is designed to be an underground laboratory to enable scientists and engineers to examine, at depth, the geologic, hydrologic, geoengineering, and geochemical characteristics of the potential repository host rock. The facility will consist of two main access ramps from the surface ("North Ramp" and "South Ramp") to either end of a 3.2-kilometer long main tunnel oriented at N 34° E at the potential repository level in the Topopah Spring geologic unit. Two additional smaller-diameter ramps will extend from the main ramps to either end of a second main drift lying directly below the Topopah Spring level main drift at a lower level in the Calico Hills geologic unit. Various side tunnels will be driven to provide access to fault zones and other areas of potential interest. In total, 23,400 meters of tunnel will be excavated, resulting in approximately 1,550,000 metric tons of excavated rock.

The Starter Tunnel was completed on September 9, 1993, using conventional drill and blast techniques. In future construction of the Exploratory Studies Facility, mechanical excavation methods will be used when possible with conventional excavation only in situations where mechanical methods will not work. A modified version of the New Austrian Tunnelling Method was used to excavate this portion of the North Ramp. This method sequentially removes material, and the entry is supported to ensure maximum possible safety to the workers. The resultant tunnel measured approximately 9.8 meters by 9.8 meters and is 61 meters long. A large-diameter Tunnel Boring Machine will be employed to excavate the remainder of the main ramps and tunnels. The contract to fabricate the 7.6-meter-diameter Tunnel Boring Machine was awarded on May 27, 1993, to Construction Tunnel Services, and the machine is due to arrive in early April 1994.

An enhanced Exploratory Studies Facility layout is being considered, which would change the orientation of the main tunnel to almost north-south, and would substantially reduce the inclination of the North Ramp. The enhanced configuration also could have advantages for future repository designs, should a repository be developed at Yucca Mountain. If formally approved, the new configuration will become part of the technical baseline and serve as the basis for future design work.

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In other activities associated with the excavation of the Exploratory Studies Facility Starter Tunnel, geologic mapping was completed to the end of the Starter Tunnel and a Consolidated Sampling Program was conducted to obtain samples for geomechanical and mineralogical analyses.

Boreholes, drilled into Yucca Mountain to obtain information on geological structure, faults, rock characteristics, depth to water table, water quality, infiltration, and water movement in soil and rock, continue to be a very important part of the site characterization program. During this reporting period, all boreholes, 99 in total, for the Neutron Access Program were completed. Early results from this program suggest that infiltration models will need to distinguish among ridge tops, sideslopes, alluvial terraces and active channels. In addition, five boreholes along the North Portal Ramp alignment were completed.

Also as part of site characterization, trenches and test pits are excavated to expose subsurface layers of soil and rock in order to allow evaluation of possible geologic faults and to interpret volcanic history. Such trenching and evaluation proceeded during this reporting period, with particular interest focused on trenches across the Stagecoach Road, Solitario Canyon, and Bare Mountain faults. In addition, a surface excavation across an exposure of the Ghost Dance fault, which transects the repository block, was constructed for mapping. Information of recency of movement and slip rates will be used to define the seismic hazard design basis for potential repository facilities.

In the area of repository and waste package design, advanced conceptual design of the waste package, which commenced in October 1992, has proceeded with detailed thermal, criticality, and shielding evaluations on the seven concepts previously selected for advanced conceptual design. Advances have been made in the hydrologic modeling of Yucca Mountain, and planning and testing moved forward on the large block test and the engineered barrier system field tests. These tests will provide essential information for near-field and container performance models.

Also with regard to the waste package system, the Director of the Office of Civilian Radioactive Waste Management instructed that a study be conducted to evaluate the feasibility of using a multipurpose canister in the Civilian Radioactive Waste Management System. The feasibility study was completed in March 1993. Based on the results of this study, the Department directed the Civilian Radioactive Waste Management System Management and Operating Contractor to complete the Multipurpose Canister Implementation Program Conceptual Design Phase Report. This report was completed in September 1993, and will assist the U.S. Department of Energy in making a final decision on whether to proceed with further development of the multipurpose canister for the Civilian Radioactive Waste Management System.

Repository design activities have included evaluations of alternative emplacement modes. Consideration of a multipurpose canister leads to the need to evaluate the concept of n-drift emplacement to accommodate larger canisters. Thermal loading alternatives are being evaluated as part of advanced conceptual repository design, as well as alternative types of

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equipment and shielding that could be used for transporting waste packages to underground emplacement areas.

The second Total System Performance Assessment was conducted during this period. Improvements over previous assessments include a more realistic source term, enhanced site stratigraphy, and a more realistic representation of hydrologic flow processes. In addition, a broader suite of sensitivity calculations were completed. A summary of this work will be presented to the Nuclear Waste Technical Review Board in January 1994, and a Department of Energy document describing the effort is scheduled to be completed in Spring 1994.

Before the Yucca Mountain Site Characterization Project Office can conduct some of its site characterization activities, it must obtain permits and approvals from other Federal and State of Nevada regulatory agencies. Within this reporting period, the State of Nevada issued several new permits to the Yucca Mountain Site Characterization Project Office. These included water appropriation permits and a permit for a potable water supply system for the Exploratory Studies Facility.

To ensure compliance with the large number of requirements imposed upon it by many laws, regulations, orders, and standards, the Office of Civilian Radioactive Waste Management has systematically reviewed and revised the System Requirements Documents. These System Requirements Documents were developed based on a systematic review of regulatory documentation and the functions the system must perform. The set of documents includes an overall Civilian Radioactive Waste Management System Requirements Document and subordinate documents addressing the Mined Geologic Disposal System, the Monitored Retrievable Storage System, the Transportation System and the Waste Acceptance System. Five subordinate Project-level documents were also approved addressing the Repository, Engineered Barrier, Site Design and Test Requirements, Exploratory Studies Facility, and Surface-Based Test Facilities. The entire set of requirements documents was completed during this period and implemented, replacing the previously existing documents.

In the conduct of its site characterization activities, the Department continues to interact with the State of Nevada, affected counties, and a number of external agencies and groups, including the Nuclear Waste Technical Review Board, the Nuclear Regulatory Commission, the National Academy of Sciences, and others, including the international community. Continuing its interactions with the Nuclear Waste Technical Review Board, in May 1993, the Department formally responded to the recommendations made by the Review Board in its Sixth and Special Reports.

The Department conducted formal interactions with the Review Board in April and July 1993. In April, the Yucca Mountain Site Characterization Project hosted a tour of the environmental activities at the candidate Yucca Mountain site prior to the Board's spring meeting. During the spring Full Board meeting, the Project presented its process for resolving difficult scientific issues using infiltration as an example. In July 1993, the Department presented its approach for selecting and validating a thermal loading strategy to the Board. These discussions focused on integration of engineering and science to carefully evaluate a range of thermal loading options prior to the selection of a preferred strategy.



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On September 21-23, 1993, the Yucca Mountain Site Characterization Project Office held a three-day workshop in Las Vegas, Nevada, to discuss alternative concepts for the repository waste package as recommended by the Nuclear Waste Technical Review Board in its Fourth Report. The workshop was open to the public and was attended by over 100 interested people. Participants included members of the Review Board and its staff, representatives from the State of Nevada and the regulatory agencies, international experts in the fields of engineering materials and corrosion, Project personnel, and members of the public.

In interactions with the Nuclear Regulatory Commission, the Program sent Revision 2 of the "Mined Geologic Disposal System Annotated Outline Skeleton Text for the Preparation of a License Application" to the Nuclear Regulatory Commission, the Advisory Committee on Nuclear Waste, the State of Nevada, and to Affected Counties in May 1993. The focus of this revision was the framework and layout for the Performance Assessment and Performance Confirmation programs.

On August 24, 1993, the Department of Energy and the Nuclear Regulatory Commission conducted a Technical Exchange on Substantially Complete Containment and the Waste Package/Engineered Barrier System design concepts. The purpose of the Technical Exchange was to discuss the Department's interpretation of Substantially Complete Containment and its use in design, the status and progress of the Department's waste package design effort, and the Department's plans for resolving related open Site Characterization Analysis comments and questions.

A topical report entitled "Topical Report: Methodology To Assess Seismic Hazards At Yucca Mountain" is in preparation. The topical report presents the Department's methodology to assess seismic hazards for a potential geologic repository at Yucca Mountain. A Technical Exchange with the Nuclear Regulatory Commission on this subject is planned for November 1993.

The Project continues to work toward resolving the Nuclear Regulatory Commission's Site Characterization Analysis open items. During this reporting period, the Nuclear Regulatory Commission agreed, by letter dated April 21, 1993, that the Office of Civilian Radioactive Waste Management had provided the technical basis to resolve Question 17. Therefore, as of the end of this reporting period, 78 items have been closed (including the two objections) and 120 remain open. The majority of the remaining open items await data acquired through site characterization activities for their resolution. Of the 120 open items, 19 are presently being reviewed by the Nuclear Regulatory Commission.

The Department of Energy continues to interact with the National Academy of Sciences. Section 801 of the Energy Policy Act of 1992 directed the Environmental Protection Agency to contract with the Academy to perform a study and provide recommendations regarding development of health-based standards for protection of the public from releases from a repository at the Yucca Mountain site. As a result, the Academy formed a Committee on Technical Bases for Yucca Mountain Standards in April 1993, which is currently evaluating the question. The Department supports the activities of the Committee

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and has responded to requests for input. The Department is currently evaluating issues associated with development of standards and regulations and is preparing an overall position on preferences for a new standard. This position will be completed by April 1994, in time to provide timely support for deliberations by the Committee prior to their transmitting recommendations to the Environmental Protection Agency by December 1994.

The U.S. Congress, in the Energy Policy Act of 1992, instructed the Department of Energy to evaluate whether its current programs and plans for management of nuclear waste were adequate to deal with volumes or categories that might be generated through new nuclear power plants. The Congress also asked the Secretary of Energy to report on additional transportation, interim storage, and geologic repositories needed for these new wastes. A draft report entitled "Adequacy of Management Plans for the Future Generation of Spent Nuclear Fuel and High-Level Radioactive Waste" was released in June 1993 for public review and comment. A revised version is undergoing Department review.

In the international program, cooperative efforts have continued with a number of countries including major cooperative research project agreements with Canada, Switzerland, and Sweden. In addition, the program participated in a workshop on Near-Field Performance Assessment held at Cadarache, France, May 11-13, 1993, where topics included near-field environment, releases, transport, modeling, and performance assessment integration. The program is also beginning work in New Zealand, where geothermal field observations will be used for a geochemical code validation program. The results of this work will directly complement laboratory-based model validation activities and will provide a direct demonstration of the ability of the codes to model relevant processes in natural systems.

The Yucca Mountain Site Characterization Project Office continued its public outreach activities regarding nuclear waste disposal concepts and the Yucca Mountain site characterization program. Sixty-eight tours of Yucca Mountain were conducted for about 2,600 members of the public and other interested parties during this period. Numerous programmatic and technical workshops and presentations were conducted by the Yucca Mountain Site Characterization Project staff. Meetings were held in various communities in Nevada to provide current information to the public and appropriate agency personnel regarding progress on site characterization. These meetings were structured to allow the public to have good opportunities to communicate with the Yucca Mountain staff.

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### CHAPTER 1 - INTRODUCTION

#### 1.1 PURPOSE AND SCOPE

In accordance with Section 113(b)(3) of the Nuclear Waste Policy Act of 1982 (NWPAA, 1982), as amended (NWPAA, 1987) (hereinafter referred to as "the Act") and 10 CFR 60.18(g), the U.S. Department of Energy (hereinafter referred to as the "Department") has prepared this report for the U.S. Nuclear Regulatory Commission (hereinafter referred to as the "Commission") on the progress of site characterization activities at Yucca Mountain, Nevada, for the period April 1, 1993, through September 30, 1993. This report is the ninth in a series issued at intervals of approximately six months during site characterization activities undertaken to evaluate Yucca Mountain as a possible geologic repository for the permanent isolation of spent nuclear fuel and high-level radioactive waste.

Section 113(b)(3) of the Act states that "During the conduct of site characterization activities at the Yucca Mountain site, the [DOE] Secretary shall report not less than once every 6 months to the Commission and to the Governor and legislature of the State of Nevada, on the nature and extent of such activities and the information developed from such activities." In conjunction with these requirements, 10 CFR 60.18(g) states that "During the conduct of site characterization activities, DOE shall report not less than once every six months to the Commission on the nature and extent of such activities and the information that has been developed, and on the progress of waste form and waste package research and development. The semiannual reports shall include the results of site characterization studies, the identification of new issues, plans for additional studies to resolve new issues, elimination of planned studies no longer necessary, identification of decision points reached and modifications to schedules where appropriate. DOE shall also report its progress in developing the design of a geologic repository operations area appropriate for the area being characterized, noting when key design parameters or features which depend upon the results of site characterization will be established. Other topics related to site characterization shall also be covered if requested by the Director."

This Site Characterization Progress Report presents summaries of the status of site characterization activities and cites technical reports and research products that provide more detailed information on such activities. The report highlights work started during the reporting period, work in progress, and work completed and documented during the reporting period. In addition, this report is the vehicle for documenting and discussing changes to the Office of Civilian Radioactive Waste Management (OCRWM) Site Characterization Program (hereinafter referred to as the "Program") resulting from ongoing collection and evaluation of site information, systems analyses, development of repository and waste package designs, and results of performance assessment activities.

Documents cited in the text are available for inspection at U.S. Department of Energy (DOE) public reading rooms in Washington, D.C. and Nevada. They can also be obtained through the DOE Office of Scientific and Technical Information at Oak Ridge, Tennessee.

## 1.2 BACKGROUND INFORMATION

Yucca Mountain has not been selected for a repository. Rather, it has been designated by the U.S. Congress as the only candidate repository site to be characterized. In accordance with Section 113 of the Act, OCRWM is conducting a program of detailed site-specific investigations and evaluations to assess whether Yucca Mountain is suitable for development as a geologic repository. The plans, activities, and results of the site characterization program are reviewed by the State of Nevada, the Commission, the Nuclear Waste Technical Review Board (hereinafter referred to as the "Review Board"), and other external organizations and interested parties.

If Yucca Mountain is found to be suitable for development as a repository and is recommended for such development by the President and approved by Congress, then the Program will be required to demonstrate to the Commission that the potential repository system will meet applicable regulations. If, during the course of scientific investigations, information supports a finding that the Yucca Mountain site is unsuitable for development as a repository, the Program will terminate all characterization activities at the site. Should that occur, OCRWM will, in accordance with provisions of the Act, notify Congress and the Governor and legislature of the State of Nevada of its action and the reason for such action.

The Program plans for site characterization are described in the Site Characterization Plan (SCP) (DOE, 1988a). More detailed information is presented in study plans for the various site characterization studies and their component activities. The SCP was submitted to the Commission in December 1988, and their "NRC Staff Site Characterization Analysis of the U.S. Department of Energy's Site Characterization Plan, Yucca Mountain, Nevada" (NRC, 1989) (hereinafter referred to as the "Site Characterization Analysis") issued in July 1989. Responses to over 5000 comments from the Commission, State of Nevada, affected units of local government, other interested parties and agencies, and the public were sent by OCRWM and the Yucca Mountain Site Characterization Project (hereinafter referred to as the "Project"). Changes to the statutory SCP are documented in Project technical baseline documents, primarily the Site Characterization Program Baseline (DOE, 1993a).

Activities planned for site characterization consist of surface-based studies, underground studies conducted in an Exploratory Studies Facility (ESF), laboratory tests, modeling, and analyses. Performance Assessment will assist in evaluating (1) whether a repository can be constructed and operated at the site without adversely affecting the health and safety of the public and workers during repository operations, and (2) whether nuclear waste emplaced in a repository will remain isolated from the accessible environment.

According to the current Program schedule (see Chapter 3), all site characterization activities are to be completed by the end of the year 2001. The baseline schedule which was last published in September 1992, and upon which this date is based, is currently under review and will be revised upon completion of the Secretary's review of the Program and the issuance of any new Program guidance. During site characterization, a performance confirmation program, as required by 10 CFR 60.140, will be initiated. As part of this program, if the site is found to be suitable for a geologic repository, selected surface-based

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and underground tests will continue beyond the site characterization phase. Appropriate new tests and monitoring will also be initiated and continued while the Program is constructing the repository and during waste emplacement, until there is adequate confidence that the repository is performing as expected, and the Commission issues a license amendment to permanently close the repository.

Studies have been conducted at Yucca Mountain since the late 1970s to support programmatic site screening and provide information for the Environmental Assessment (DOE, 1986). Surface-based studies at Yucca Mountain have been in progress since May 1986. Initially, these studies consisted of non-surface-disturbing testing in existing exploratory boreholes and wells; analyses of, and experiments with rock and water samples; geophysical surveys; meteorological, hydrologic, and seismic monitoring; geologic mapping, and sampling of surficial materials. New surface-disturbing work began in July 1991 when the State of Nevada granted necessary permits, with expanded surface-based activities started in November 1992, to support construction of the ESF North Portal.

### 1.3 PROGRAM OUTREACH

#### 1.3.1 International Program

The OCRWM international program continued to cooperate with a number of countries and international organizations to exchange information of mutual interest, to work towards achieving consensus on common issues, and to develop and conduct cooperative activities of mutual benefit.

Work also continued on three major cooperative research agreements with Canada (Atomic Energy of Canada, Ltd [AECL]), Switzerland (National Cooperative for the Disposal of Radioactive Waste [NAGRA]) and Sweden (Nuclear Fuel and Waste Management Co.).

The cooperative agreement with Canada includes eight technical tasks concerning: radionuclide retardation model development, field tracer test development, natural analogue studies at Cigar Lake, fundamental materials investigations, in situ stress determination, spent fuel dissolution model development, hydrochemical tool testing, and performance assessment technology.

High-temperature tests on cementitious sealing materials have been conducted in Canada at facilities not available in the United States, but at conditions expected at Yucca Mountain. Existing Canadian instruments have been modified for measuring in situ stress in fractured tuff at Yucca Mountain. Quality affecting spent-fuel dissolution tests have been conducted for Yucca Mountain Site Characterization Project (YMP) waste package and performance assessment analyses. Prototype tests were conducted on complex downhole packer strings to be used at C-Wells testing at Yucca Mountain; this testing resulted in major modifications to the system. Planning was done for large-block radioactive tracer testing in Canada at facilities not available in the United States for a tuff sample obtained at Yucca Mountain. Release and transport rates for ground water were measured at a high-grade

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uranium site in Canada for use in Yucca Mountain performance assessment analyses. A Swedish hydrochemical tool was purchased for use at Yucca Mountain C-Wells; planning was done for calibration testing in Canada at laboratory and field sites not available in the United States. An automated ground water flow data acquisition system was developed for use at Yucca Mountain. This type of technology is being developed using the AECL Underground Research Laboratory and laboratories and facilities in Canada.

The cooperative agreement with the Swiss includes five technical tasks concerning: transport characterization in fractured rocks, multi-phase flow in fractured porous rocks, seismic tomographic imaging, mechanistic approach to sorption of radionuclides, and borehole fluid logging. Accomplishments include: building and demonstrating an experimental facility to characterize two-phase flow conditions that apply to unsaturated Yucca Mountain regimes; development of a conceptual model for fracture flow systems that will be encountered at Yucca Mountain; development of a mechanistic model to predict sorption and radionuclides at Yucca Mountain; improvement of seismic imaging hardware, data acquisition and processing systems to provide real-time interpretation in site characterization efforts at Yucca Mountain; and development of advanced borehole logging techniques and fluid property conditions that may exist at Yucca Mountain. This technology is being developed using the underground rock laboratory at the Grimsel Test Site and laboratories and surface facilities operated by NAGRA.

The cooperative agreement with Sweden includes five technical tasks concerning: flow and transport characterization in fractured rocks; disturbed zone effects; geochemical modeling; ground-water flow and water-rock interactions using radiogenic isotopes; and the development of the capability for integration of construction and testing related to the exploratory studies facility. Other nations participating in studies at Sweden's Hard Rock Laboratory (HRL) include the United Kingdom, Finland, France, Japan, and Canada.

United States scientists have observed HRL operation and brought back technical and management techniques for the United States to use for integration and coordination of scientific efforts during ESF construction. Other activities have involved developing a two-phase flow model to analyze ground-water flow in fractured, unsaturated rocks at Yucca Mountain; participation in an international fracture flow modeling task force for comparison and transfer of technology to the YMP; developing a method to assess ground-water travel time requirements and to determine a ground-water travel time distribution range appropriate for Yucca Mountain; participation in design and evaluation of underground hydrological and geochemical testing at the HRL—this experience will be used in the ESF effort; and development and performance of isotopic analyses of samples obtained from the HRL—the results will be used to establish sampling and analysis techniques for preconstruction site characterization, including that for Yucca Mountain. This underground technical program relates directly to the development of site characterization activities at Yucca Mountain and the development of an integrated testing program for both natural and engineered barrier components at the Yucca Mountain ESF.

The international program is also beginning work in the New Zealand Geothermal Field Geochemical Code Validation Program. The proposed studies in New Zealand are to be

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implemented by Lawrence Livermore National Laboratory in cooperation with the New Zealand Crown Research Institute for Geochemistry and Nuclear Science to validate geochemical and hydrologic codes and models used to simulate transport and hydrological processes, especially in the near-field. Planning is essentially complete, and some preliminary and scoping investigations were completed.

**Forecast:** The international program will sponsor and support the development of the 1994 Commission of European Communities Natural Analogue Working Group Workshop No. 6 in the United States. It is proposed that the workshop will be hosted by OCRWM Program scientists from Los Alamos National Laboratory. The workshops are held biennially; the 4th Workshop was held in Scotland in 1990, and the 5th in Spain in 1992.

The National Research Council of the National Academy of Sciences (hereinafter referred to as "NAS" or the "Academy") and the Review Board have urged OCRWM to enhance the role of natural analogues. By hosting this workshop in the United States the Program will benefit by a number of Department staff being able to attend presentations by international experts, who have developed and implemented successful programs to study natural analogues that apply to radioactive waste disposal.

Activities described above under the Canadian, Swedish and Swiss programs will continue in keeping with the applicable international agreements. Of particular significance will be the start of cooperative work in New Zealand, the scope and purpose of which has been noted earlier.

### **1.3.2 Public Outreach**

Efforts continue to provide a broad-based, thorough, and extensive public information program. This program has been met with a high degree of public approval and has resulted in a heightened public understanding of the Program.

Tours of Yucca Mountain continue to be among the most successful of the outreach activities. Sixty-eight tours of Yucca Mountain were conducted for approximately 2600 members of the public and other interested parties. Six of these were Public Open House tours, while the rest were special group tours, including the U.S. Council for Energy Awareness, the French Radiation Waste Regulatory Agency, International High-Level Radioactive Waste Management Conference, Institute of Shaft Drilling Technology, International Safeguards Group, Empresa Nacional de Residuos Radiactivos S.A., Congressman John T. Myers and two staff members of the Energy and Water Development Appropriations Subcommittee, Nuclear Programs from China, Edison Electric Institute High-Level Waste Working Group, and the Western Legislative Conference.

The Project conducted numerous programmatic and technical workshops, and presentations, including meetings held in various Nevada communities to provide current information to the public and appropriate agencies regarding progress on site characterization. Among these were the Project Public Update Meetings held in Beatty, Reno, and Las Vegas.

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The Project conducted a workshop on Developing a Consultative Process for Stakeholders and the Public at the University of Nevada, Las Vegas, on August 10, 1993. This workshop provided an opportunity to involve stakeholders in the Program's decision-making process. Although a wide-ranging and robust discussion took place and no consensus was reached on any one best method for involving the public, the workshop did offer a unique opportunity for stakeholders to meet face-to-face on this issue. The resulting summary report, entitled "Summary of Discussion and Suggestions at the Workshop on Developing a Consultative Process" (JK Research Assoc., Inc., 1993) summarizes and synthesizes the workshop discussion and suggestions so they can be considered in planning a process for public involvement in the Program.

In addition, the Project continued to operate the Yucca Mountain Science Centers located in Las Vegas, Beatty, and Pahrump. These centers received approximately 7700 visitors during this period. The Project also continued to produce and distribute the public newsletter "Of Mountains and Science," staffed public events, prepared new exhibits for the Field Operations Center, and completed three information videos, as well as a variety of information products, including a new fact sheet.

A total audience of approximately 9220 people attended 148 speaking presentations during this period. These included 9 technical presentations, 63 general Project overview presentations, 67 educational presentations, and 9 pretour briefings.



## CHAPTER 2 - STATUS OF SITE CHARACTERIZATION

Specific details regarding site characterization activities during this reporting period are presented throughout Chapter 2. Figures 2.1-1 and 2.1-2 show the locations where such activities were being performed.

### SECTION 2.1 - PREPARATORY ACTIVITIES

This section provides discussions of activities, conducted during the current reporting period, which are necessary to plan and conduct actual site characterization and design studies and activities.

#### 2.1.1 Interactions with U.S. Nuclear Regulatory Commission and Other Organizations

##### 2.1.1.1 Interactions with U.S. Nuclear Regulatory Commission

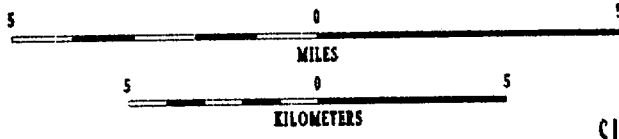
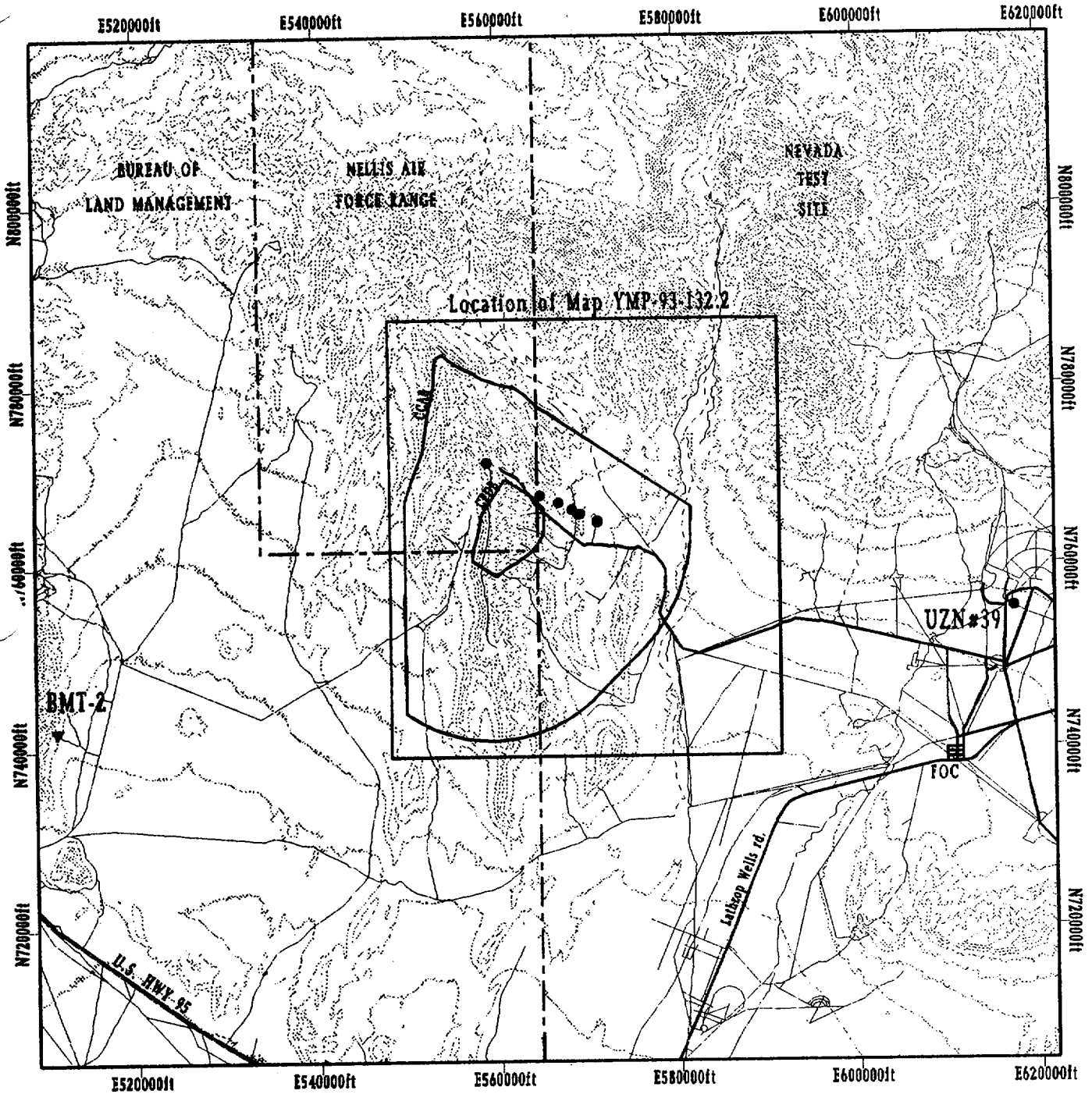
During the reporting period the Department participated in the following interactions with the Commission:

- |                 |   |
|-----------------|---|
| April 15, 1993  | Quality Assurance (QA) Meeting in Rockville, Maryland, to discuss the status of implementation of the Quality Assurance Requirements Document (QARD), the QA oversight of field activities, the fiscal year (FY) 1993 audit schedule, recent audit results, and the Department evaluation of the Civilian Radioactive Waste Management System Management and Operating Contractor (hereinafter referred to as "the M&O") QA program implementation. |
| May 3, 1993     | Management Meeting in Las Vegas, Nevada, to discuss the Department use of topical reports and the Commission Draft Topical Report Review Plan.  |
| May 25-26, 1993 | Site visit to Yucca Mountain, Nevada, to provide the U.S. Nuclear Regulatory Commission (NRC) staff an opportunity to observe the preliminary results of the U.S. Department of Energy (DOE) trench mapping activities at Crater Flats and the Exploratory Studies Facility (ESF), and to discuss the results with DOE and principal investigators.   |
| June 7, 1993    | Management Meeting in Las Vegas, Nevada, to discuss and agree to the interactions to be conducted by DOE and NRC during the period of July to December 1993.  |

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- June 8, 1993 Technical Exchange in Las Vegas, Nevada, to discuss the integration of the geophysics program and progress in resolving Site Characterization Analysis Comments 51, 52, and 59 as related to the integration of planned geophysical activities with other site characterization activities.
- June 9, 1993 Technical Exchange in Las Vegas, Nevada, to discuss the progress and results of volcanism studies at Yucca Mountain as detailed in the Los Alamos National Laboratory (Los Alamos) status report on volcanic hazard investigations.
- July 20, 1993 QA Meeting in Rockville, Maryland, to discuss the status of the implementation of the DOE QARD, QA oversight of field activities, the FY 1993 audit schedule, QA review of study plans, DOE response to NRC comments on the DOE QARD, QA role in issue resolution, and the status of the new DOE QA support contractor.
- August 10, 1993 Appendix 7 Meeting in Denver, Colorado, to discuss and demonstrate the use of the three-dimensional modeling (LYNX) program.
- August 11, 1993 Appendix 7 meeting in Las Vegas, Nevada, to discuss the Earth Vision dynamic graphics three-dimensional modeling program and its interface with the LYNX modeling program.
- August 24, 1993 Technical Exchange in Bethesda, Maryland, to discuss Substantially Complete Containment and Waste Package/Engineered Barrier System Design concepts, DOE interpretation of Substantially Complete Containment regulations and their use as a guide in design, status/progress of the waste package design effort, and plans for addressing related Site Characterization Analysis open items.
- September 17, 1993 Management Meeting in Rockville, Maryland, to discuss the NRC letter dated August 20, 1993, regarding ESF design and design control problems.

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FAR FIELD  
SURFACE ACTIVITIES  
1 April 1993 to 30 September 1993

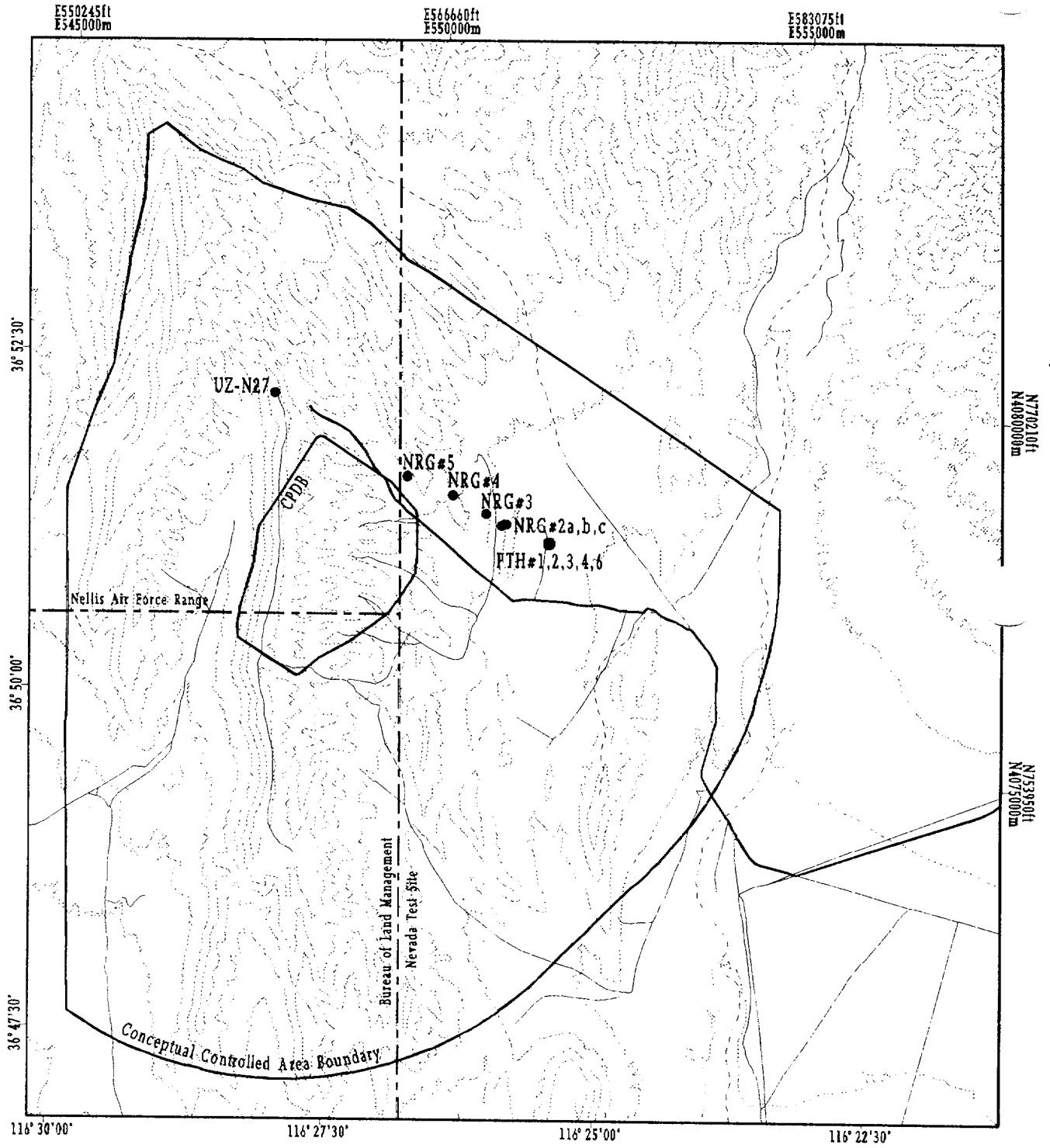
- Borehole
- ▼ Trench

Contour Interval 200 Feet

YUCCA MOUNTAIN  
SITE CHARACTERIZATION PROJECT  
ACTIVITIES REPORTED COMPLETE  
(Far Field)

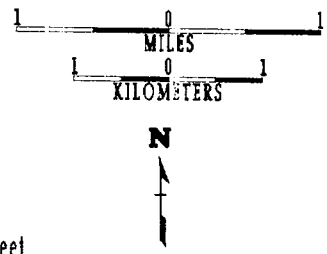
Figure 2.1-1

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NEAR FIELD  
SURFACE ACTIVITIES  
1 April 1993 to 30 September 1993  
● Borehole

Contour Interval 200 Feet



YUCCA MOUNTAIN  
SITE CHARACTERIZATION PROJECT  
ACTIVITIES REPORTED COMI  
(Near Field)

Figure 2.1-2

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### 2.1.1.2 Resolution of U.S. Nuclear Regulatory Commission Open Items

Resolving Site Characterization Analysis (NRC, 1989) open items is a bilateral process that consists of (1) the Program providing documentation or other basis to the Commission to claim resolution of specific open items, and (2) the Commission accepting (or not accepting) the basis for resolution, and informing the Office of Civilian Radioactive Waste Management (OCRWM). Both steps are needed to remove open items from further consideration.

The Project continues to work toward resolving the open items. During this reporting period, the Commission agreed, by letter dated April 21, 1993, that the Program had provided the technical basis to resolve Question 17. In addition, OCRWM provided supplementary responses to Comments 3, 7, 45, 47, 95, 105, 115 and Questions 12, 25, and 38 and stated that these items should be resolved. In a letter dated May 5, 1993, the Commission informed DOE that the proposed December 1991 resolution of Question 1 did not sufficiently address the staff's concerns and Question 1 remained open. Therefore, as of the end of this reporting period, 78 items have been closed (including the 2 objections) and 120 remain open. The majority of the remaining open items await data acquired through site characterization activities for their resolution. Of the 120 open items, 19 were being reviewed by the Commission.

Table 2.1-1 identifies all remaining Site Characterization Analysis open items. For each item the actions that need to be performed to close the item are identified. Open items will continue to be resolved as site characterization and other programmatic activities provide information pertinent to each of the items.

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Table 2.1-1. Status of Site Characterization Analysis Open Items

Open Item #	Description of Open Item
<b>COMMENTS</b>	
1	<p>A systematic, iterative approach to identify and collect data for a license application.</p> <p><u>Further Action Required:</u> Submit Mined Geologic Disposal System (MGDS) License Application Annotated Outline, Rev. 3 to NRC. Complete linkage to site data through performance assessment.</p>
2	<p>Confidence in performance allocation goals.</p> <p><u>Further Action Required:</u> Prepare a supplemental response and submit it to NRC.</p>
3	<p>Reliance on expert judgment for supplying licensing information.</p> <p><u>Further Action Required:</u> None. Supplemental response submitted to NRC to close the item. Awaiting NRC confirmation.</p>
4	<p>Rationale for testing needs; integration of testing with design and performance assessment.</p> <p><u>Further Action Required:</u> Develop Parametric Calculations to refine parameter goals and complete the development of plans to collect that data.</p>
5	<p>Waste package: Interpretation of "substantially complete containment."</p> <p><u>Further Action Required:</u> Develop a position on how technological limitations and uncertainties might impact demonstration of compliance with 10 CFR 60.113. Coordinate with Comment 80.</p>

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Table 2.1-1. Status of Site Characterization Analysis Open Items (Continued)

Open Item #	Description of Open Item
<b>COMMENTS (Continued)</b>	
6	<b>Performance assessment: Hypothesis Testing Table and alternative conceptual models.</b>  <b><u>Further Action Required:</u></b> Prepare a supplemental response and submit it to NRC.
7	<b>Use of expert judgment versus peer review.</b>  <b><u>Further Action Required:</u></b> None. Supplemental response submitted to NRC to close the item. Awaiting NRC confirmation.
8	<b>Alternative Tectonic Models.</b>  <b><u>Further Action Required:</u></b> Prepare and issue Study Plan 8.3.1.17.4.12, "Tectonic Models and Synthesis."
9	<b>Use of Expert Judgment during the development of Hypothesis Testing Tables.</b>  <b><u>Further Action Required:</u></b> Prepare a supplemental response and submit it to NRC.
10	<b>Assessment of significance of site hydrologic characteristics.</b>  <b><u>Further Action Required:</u></b> Resolution of Comment 1.
11	<b>No hypothesis on the thermal effects of waste emplacement in hydrologic environment.</b>  <b><u>Further Action Required:</u></b> Prepare a supplemental response and submit it to NRC.

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Table 2.1-1. Status of Site Characterization Analysis Open Items (Continued)

Open Item #	Description of Open Item
<b>COMMENTS (Continued)</b>	
15	<p>Solitario Canyon horizontal borehole activity is inadequate to discriminate between the hypotheses that faults are barriers to fluid flow in nonwelded tuff units, or that faults are conduits for liquid-water flow.</p> <p><u>Further Action Required:</u> Revise Study Plan 8.3.1.2.2.4, "Characterization of the Yucca Mountain Unsaturated Zone in the Exploratory Studies Facility" to add the activity entitled "Hydrologic properties of major faults encountered in the Exploratory Studies Facility."</p>
18	<p>Initial modeling studies are not supported by planned activities.</p> <p><u>Further Action Required:</u> Resolve Comment 1.</p>
19	<p>Saturated zone work is not adequate for saturated zone characterization.</p> <p><u>Further Action Required:</u> Develop a plan to sufficiently test and define the saturated zone.</p>
20	<p>Potentiometric surface is not adequately defined.</p> <p><u>Further Action Required:</u> Identify what additional work/drilling needs to be done to characterize the southern area.</p>
21	<p>Saturated zone: <sup>99</sup>Tc and <sup>129</sup>I are not included to characterize ground-water flow and nuclide background concentrations.</p> <p><u>Further Action Required:</u> None. Supplemental response submitted to NRC to close the item. Awaiting NRC confirmation.</p>



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Table 2.1.1-1. Status of Site Characterization Analysis Open Items (Continued)

Open Item #	Description of Open Item
<b>COMMENTS (Continued)</b>	
22	Saturated zone: Hydrochemical sampling.  <u>Further Action Required:</u> None. Supplemental response submitted to NRC to close the item. Awaiting NRC confirmation.
24	Standard solubility approaches are not adequate for thermodynamic properties of zeolites.  <u>Further Action Required:</u> Prepare and issue Study Plan 8.3.1.3.3.2, "Kinetics and Thermodynamics of Mineral Evolution."
25	Waste package degradation products and interactions between radionuclides on sorption.  <u>Further Action Required:</u> Prepare and issue Study Plan 8.3.4.2.4.1, "Characterization of Chemical and Mineralogical Changes in Post-Emplacement Environment."
31	Some parameters for speciation, kinetics, and matrix diffusion are not planned.  <u>Further Actions Required:</u> Prepare and issue Study Plan 8.3.1.3.6.1, "Dynamic Transport Column Experiments."
32	Integration of geophysics and discussion is not included.  <u>Further Actions Required:</u> Issue the integration strategy developed by the Geophysics Integration Task Force.

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Table 2.1-1. Status of Site Characterization Analysis Open Items (Continued)

Open Item #	Description of Open Item
<b>COMMENTS (Continued)</b>	
33	Engineering rock characteristics are not integrated into three-dimensional models.  <u>Further Action Required:</u> Prepare and issue Study Plan 8.3.1.4.2.3, "Three Dimensional Geologic Modeling."
34	Integration of drilling program.  <u>Further Action Required:</u> Complete and issue Study Plans 8.3.1.4.2.1, "Characterization of the Vertical and Lateral Distribution of Stratigraphic Units Within the Site Area" and 8.3.1.2.2.4, "Characterization of the Yucca Mountain Unsaturated Zone in the Exploratory Studies Facility."
36	Adequacy of location of perimeter drift and the concentration of faults.  <u>Further Action Required:</u> Conduct a DOE-NRC Technical Exchange to discuss how many faults represent a "significant concentration."
42	Adequacy of evaluation of escarpment retreat  <u>Further Action Required:</u> None. Supplemental response submitted to NRC to close the item. Awaiting NRC confirmation.
43	Adequacy of numerical goals in erosion, postclosure tectonics, and preclosure tectonics performance assessment tables.  <u>Further Action Required:</u> None. Supplemental response submitted to NRC to close the item. Awaiting NRC confirmation.

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Table 2.1-1. Status of Site Characterization Analysis Open Items (Continued)

Open Item #	Description of Open Item
<b>COMMENTS (Continued)</b>	
45	Volcanic rate calculations independent of underlying volcanic tectonic processes.  <u>Further Action Required:</u> None. Supplemental response submitted to NRC to close the item. Awaiting NRC confirmation.
47	Relationship of postclosure tectonics to the waste package and engineered barrier system requirements.  <u>Further Action Required:</u> None. Supplemental response submitted to NRC to close the item. Awaiting NRC confirmation.
48	Use of fault slip rates on the repository facilities are not conservative.  <u>Further Action Required:</u> Issue a topical report on seismic hazards methodology.
49	Investigations on basaltic volcanism will fail to meet overall system performance.  <u>Further Action Required:</u> Resolve Comment 1.
51	Adequacy of geophysics to determine deep and shallow crustal features.  <u>Further Action Required:</u> Issue the integration strategy developed by the Geophysics Integration Task Force.

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Table 2.1-1. Status of Site Characterization Analysis Open Items (Continued)

Open Item #	Description of Open Item
<b>COMMENTS (Continued)</b>	
52	Use of geophysics in evaluating basaltic volcanism.  <u>Further Action Required:</u> Complete an assessment by an independent geophysical consultant. Submit results of assessment to NRC.
53	Adequacy of natural resource assessment; consideration of ore deposition models  <u>Further Action Required:</u> None. Supplemental response submitted to NRC to close the item. Awaiting NRC confirmation.
55	Adequacy of geostatistical approach to geomechanical and thermal properties.  <u>Further Action Required:</u> Evaluate the performance allocations for Activity 8.3.1.15.
56	Validation of models for mechanical and thermal properties.  <u>Further Action Required:</u> Prepare and issue Study Plans 8.3.1.15.1.5, Rev. 1, "Excavation Investigations," 8.3.1.15.1.6, "In Situ Thermomechanical Properties," and 8.3.1.15.1.7, "In Situ Mechanical Properties." Evaluate the performance allocations for Activity 8.3.1.15.
59	Preclosure tectonics activities to be performed and timing of activities  <u>Further Action Required:</u> Prepare and issue Study Plans 8.3.1.17.3.5, "Ground Motion at the Site from Controlling Seismic Events" and 8.3.1.17.4.7, "Subsurface Geometry and Concealed Extensions of Quaternary Faults at Yucca Mountain." Geophysical Integration Task Force to sequence activities.

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Table 2.1-1. Status of Site Characterization Analysis Open Items (Continued)

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Open Item #	Description of Open Item
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COMMENTS (Continued)

60 Adequacy of preclosure design and performance goals and characterization parameters.

Further Action Required:  
Resolve comment 1.

61 Assumption that future faulting will follow previous faulting.

Further Action Required:  
Prepare and issue Study Plan 8.3.1.17.2.1, "Faulting Potential at the Repository."

62 Use of standoff distances in preclosure tectonics for surface facilities.

Further Action Required:  
Prepare and issue Study Plan 8.3.1.17.2.1, "Faulting Potential at the Repository."

63 Use of pre-existing and unavailable information for the preclosure tectonics program and the surface facilities.

Further Action Required:  
Prepare a supplemental response and submit it to NRC.

64 Adequacy of study of faults for design and performance.

Further Action Required:  
Conduct a DOE-NRC interaction on identification and investigations of fault displacement and seismic hazards.

PROGRESS REPORT #9

Table 2.1-1. Status of Site Characterization Analysis Open Items (Continued)

Open Item #	Description of Open Item
<b>COMMENTS (Continued)</b>	
66	<p>Release via a single event (10,000 year cumulative slip earthquake).</p> <p><u>Further Action Required:</u> Prepare and issue report on how the facility will withstand an event exceeding the design basis ground motion.</p>
68	<p>Adequacy of treatment on detachment faulting affects.</p> <p><u>Further Action Required:</u> Prepare and issue Study Plan 8.3.1.17.4.12, "Tectonic Models and Synthesis."</p>
69	<p>Synthesis of data on the northwest trending of faulting.</p> <p><u>Further Action Required:</u> Prepare and issue Study Plan 8.3.1.17.4.12, "Tectonic Models and Synthesis."</p>
71	<p>Adequacy of technologies in assessing faulting for construction, operation, and closure.</p> <p><u>Further Action Required:</u> Prepare and issue topical report on seismic hazards methodology.</p>
73	<p>Adequacy of required backfill hydraulic conductivity.</p> <p><u>Further Action Required:</u> Continue work on the seals program. Prepare the study plan for the determination of the hydraulic conductivity of the backfill.</p>
74	<p>Testing of seal components.</p> <p><u>Further Action Required:</u> Prepare and issue Study Plan 8.3.3.2.2.3, "In Situ Testing of Seal Components."</p>

PROGRESS REPORT #9

Table 2.1-1. Status of Site Characterization Analysis Open Items (Continued)

Open Item #	Description of Open Item
<b>COMMENTS (Continued)</b>	
75	Definition of and inconsistent use of "geologic setting."  <u>Further Action Required:</u> Prepare supplemental response and submit it to NRC.
77	Adequacy of consideration of retrieval operations.  <u>Further Action Required:</u> During the development of the Advanced Conceptual Design, evaluate the effects of credible accidents on radiological exposures during retrieval operation.
79	Adequacy of waste package corrosion tests for the repository.  <u>Further Action Required:</u> Prepare and issue Study Plan 8.3.4.2.4.1, "Characterization of Chemical and Mineralogical Changes in the Post Emplacement Environment." Supply NRC with the Lawrence Livermore National Laboratory (LLNL) report entitled "Metal Barrier Selection and Testing," LLNL SIP CM-01.
80	Performance goals consistent with interpretation and intent of "substantially complete containment."  <u>Further Action Required:</u> Prepare a supplemental response and submit it to NRC.
81	Waste package: Adequacy of program in stress corrosion cracking behavior of the waste package.  <u>Further Action Required:</u> Complete the Metals Barrier Scientific Investigation Plan and initiate the study. Evaluate the extended dry concept with drift emplacement.

PROGRESS REPORT #9

Table 2.1-1. Status of Site Characterization Analysis Open Items (Continued)

Open Item #	Description of Open Item
<b>COMMENTS (Continued)</b>	
82	Waste package: Adequacy of waste package performance at licensing.  <u>Further Action Required:</u> Prepare and issue Study Plan 8.3.4.2.4.4, "Engineered Barrier System Field Test." Prepare and provide the NRC with the Waste Package Advanced Conceptual Design Report.
84	Adequacy of issue resolution strategy for the engineered barrier system and waste package.  <u>Further Action Required:</u> Evaluate the effect of unanticipated processes and events on the engineered barrier system and waste package.
85	Performance assessment: Accounting of temporal changes in state of stress due to corrosion of container.  <u>Further Action Required:</u> Complete the Metals Barrier Scientific Investigation Plan and initiate the study. Evaluate the extended dry concept with drift emplacement.
86	Waste package: Adequacy of degradation models of copper-based alloys.  <u>Further Action Required:</u> Complete the degradation mode surveys for candidate materials and test plans for promising materials.
87	Waste package: Adequacy of effect of the contact of dissimilar metals causing corrosion.  <u>Further Action Required:</u> Continue development of the waste package design until the number of package options is down to three designs. Describe the use of data from galvanic testing in the waste package design plan.



PROGRESS REPORT #9

Table 2.1-1. Status of Site Characterization Analysis Open Items (Continued)

Open Item #	Description of Open Item
<b>COMMENTS (Continued)</b>	
88	<p>Waste package: Assumption of reduced uncertainties because of the unsaturated zone.</p> <p><u>Further Action Required:</u> Supply NRC with LLNL report "Metal Barrier Selection and Testing" (LLNL SIP CM-01).</p>
89	<p>Waste package: Effect of introduction of materials that affect performance of the waste package and glass.</p> <p><u>Further Action Required:</u> Prepare and issue Study Plan 8.3.4.2.4.5, "Manmade Materials."</p>
90	<p>Waste package: Consideration of varying oxygen concentrations on corrosion of the waste package.</p> <p><u>Further Action Required:</u> Provide details in the Metal Barriers Scientific Investigation Plan on how the effect of oxygen on the waste package will be considered. Complete the evaluation of the drift emplacement alternative.</p>
91	<p>Waste package/performance assessment: Consideration of alternate canisters for reduction of <sup>14</sup>C releases.</p> <p><u>Further Action Required:</u> Evaluate and describe the performance of alternative waste package designs to be considered in the Advanced Conceptual Design. Review the new Environmental Protection Agency (EPA) standard, when available. Develop alternative waste package scenarios.</p>

PROGRESS REPORT #9

Table 2.1-1. Status of Site Characterization Analysis Open Items (Continued)

Open Item #	Description of Open Item
<b>COMMENTS (Continued)</b>	
95	Performance assessment: Adequacy of logic to screen and develop release scenarios.  <u>Further Action Required:</u> None. Supplemental response submitted to NRC to close the item. Awaiting NRC confirmation.
96	Adequacy of the use of $K_d$ for modeling heterogeneous medium.  <u>Further Action Required:</u> Prepare and issue Study Plans 8.3.1.3.4.1, "Sorption Study," 8.3.1.3.4.3, "Development of Sorption Models," and 8.3.1.3.5.1, "Dissolved Species Concentration Limit."
98	Performance assessment: Appropriateness of weighting complementary cumulative distribution function by expert judgment.  <u>Further Action Required:</u> Continue development of alternative conceptual models. Address the complementary cumulative distribution functions through the Total System Performance Assessment (TSPA) process. Submit documentation to NRC on the TSPA and sensitivity studies.
99	Performance assessment: Quantification of all release modes.  <u>Further Action Required:</u> Prepare a supplemental response and submit it to NRC.
101	Adequacy of Site Characterization Plan (SCP) equation 8.3.5.13-21.  <u>Further Action Required:</u> Prepare a supplemental response and submit it to NRC.

PROGRESS REPORT #9

Table 2.1-1. Status of Site Characterization Analysis Open Items (Continued)

Open Item #	Description of Open Item
<b>COMMENTS (Continued)</b>	
102	Adequacy of Ross sequences in comparison to the hydrologic flow model.  <u>Further Action Required:</u> Prepare a supplemental response and submit it to NRC.
103	Ross sequences addressing anticipated conditions and not scenarios.  <u>Further Action Required:</u> Prepare a supplemental response and submit it to NRC.
105	Performance assessment: Rationale for elimination of scenarios.  <u>Further Action Required:</u> None. Supplemental response submitted to NRC to close the item. Awaiting NRC confirmation.
109	Adequacy of treatment of coupling time between matrix and fracture flow in hypothesis testing tables.  <u>Further Action Required:</u> Continue the TSPA activities which will analyze the coupling times for the transfer of radionuclides between matrix and fracture flow.
115	Adequacy of expanding of complementary cumulative distribution function in terms of scenario classes.  <u>Further Action Required:</u> None. Supplemental response submitted to NRC to close the item. Awaiting NRC confirmation.

PROGRESS REPORT #9

Table 2.1-1. Status of Site Characterization Analysis Open Items (Continued)

Open Item #	Description of Open Item
<b>COMMENTS (Continued)</b>	
116	Individual exposures via potable water may need to be expanded.  <u>Further Action Required:</u> Awaiting the issuance by EPA of a new standard for individual exposure per Energy Policy Act of 1992 (U.S. Congress, 1992). Revise issue resolution strategy for SCP Issue 1.2.
117	Individual exposure rates of $^{14}\text{C}$ may need to consider advective and diffusive flow rates.  <u>Further Action Required:</u> Address the behavior of $^{14}\text{C}$ through the iterative TSPA process.
118	Conduct long-term in situ laboratory waste package activities.  <u>Further Action Required:</u> Determine the testing requirements after site characterization has progressed far enough to define the performance confirmation program.
119	Adequacy of performance confirmation testing (10 CFR 60).  <u>Further Action Required:</u> Conduct a DOE-NRC interaction on the performance confirmation program. Prepare and issue Study Plans 8.3.3.2.2.3, "In Situ Testing of Seal Components," 8.3.1.15.1.6, "In Situ Thermomechanical Properties," and 8.3.4.2.4.4, "Engineered Barrier Field Tests."
120	Model and computer code validation studies.  <u>Further Action Required:</u> Prepare and issue the model and computer code validation strategy.

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Table 2.1-1. Status of Site Characterization Analysis Open Items (Continued)

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Open Item #	Description of Open Item
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### COMMENTS (Continued)

121 Adequacy of seismic design of ESF.

Further Action Required:

Submit the Exploratory Studies Facility Design Requirements Document (DOE, 1993b) to NRC.

122 Demonstration and acceptability of the dry coring method.

Further Action Required:

Prepare a supplemental response and submit it to NRC.

123 Assessment of effects of ventilation on the ESF.

Further Action Required:

Conduct evaluations to determine what monitoring is required to evaluate the affects of drying of the repository block by the ESF. Evaluate what impacts the drying will have on waste isolation.

130 Design Acceptability Analysis.

Further Action Required:

Submit the Exploratory Studies Facility Design Requirements Document (DOE, 1993b) to NRC.

### QUESTIONS

1 Integration of mapping efforts.

Further Action Required:

Prepare a supplemental response and submit it to NRC.

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Table 2.1-1. Status of Site Characterization Analysis Open Items (Continued)

Open Item #	Description of Open Item
<b>QUESTIONS (Continued)</b>	
3	Area of repository development.  <u>Further Action Required:</u> Evaluate existing data. Establish thermal boundaries. Evaluate the performance of the repository. Prepare and issue the Thermal Studies Report.
5	Adequacy of vertical boreholes for evaluation of faults and fractures.  <u>Further Action Required:</u> Prepare a supplemental response and submit it to NRC.
8	Rock properties: level of detail and uncertainty in three-dimensional model.  <u>Further Action Required:</u> Prepare and issue Study Plan 8.3.1.4.3.2, "Three-Dimensional Rock Characteristics Models."
9	Systematic drilling program: adequacy of sampling same specimens for rock properties.  <u>Further Action Required:</u> Prepare a supplemental response and submit it to NRC.
12	Rationale for exclusion of Lunar Crater basaltic field as analogue.  <u>Further Action Required:</u> None. Supplemental response submitted to NRC to close the item. Awaiting NRC confirmation.

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Table 2.1-1. Status of Site Characterization Analysis Open Items (Continued)

Open Item #	Description of Open Item
<b>QUESTIONS (Continued)</b>	
14	Natural resources: adequacy of evaluation of previous mining and drilling leases on the site.  <u>Further Action Required:</u> None. Supplemental response submitted to NRC to close the item. Awaiting NRC confirmation.
15	Resource exploration and mineral resource potential.  <u>Further Action Required:</u> None. Supplemental response submitted to NRC to close the item. Awaiting NRC confirmation.
20	Discussion on vertical or horizontal emplacement.  <u>Further Action Required:</u> Prepare a supplemental response and submit it to NRC.
21	Parameters for radiation shielding properties of the host rock.  <u>Further Action Required:</u> Further develop the Advanced Conceptual Design.
22	Parameters related to repository construction and operation.  <u>Further Action Required:</u> Develop the performance goals during the Advanced Conceptual Design of the repository.
23	Computer code verification and validation.  <u>Further Action Required:</u> Prepare and issue the model and computer code validation strategy.

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Table 2.1-1. Status of Site Characterization Analysis Open Items (Continued)

Open Item #	Description of Open Item
<b>QUESTIONS (Continued)</b>	
25	Heterogeneous air flow characteristics for seal program.  <u>Further Action Required:</u> None. Supplemental response submitted to NRC to close the item. Awaiting NRC confirmation.
28	ES-1 penetration of the Calico Hills Unit: impacts of the current sealing program and issue resolution strategy 4.4.  <u>Further Action Required:</u> Develop seal design concepts and conduct performance assessments.
30	Waste package: Water quality as related to waste package design.  <u>Further Action Required:</u> Complete the activities in the Metal Barriers Scientific Investigation Plan and Waste Form Scientific Investigation Plan. Complete evaluation of the drift emplacement alternative needs.
31	Integrity of spent fuel cladding.  <u>Further Action Required:</u> None. The OCRWM has submitted a supplemental response to NRC to close the item. Awaiting NRC confirmation.
32	Container "similarity" for borosilicate glass waste versus spent fuel.  <u>Further Action Required:</u> Continue development of the waste package design and narrow the design options to three designs.



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Table 2.1-1. Status of Site Characterization Analysis Open Items (Continued)

Open Item #	Description of Open Item
<b>QUESTIONS (Continued)</b>	
33	Emplacement hole drainage concerns.  <u>Further Action Required:</u> Evaluate the water-vapor interface, crevice corrosion, and galvanic corrosion testing in the Metal Barriers Scientific Investigation Plan during Advanced Conceptual Design. Complete evaluation of the drift emplacement alternative.
34	Meaning of undetected defective closures.  <u>Further Action Required:</u> Prepare a supplemental response and submit it to NRC.
35	Acceptance criteria for helium leak tests.  <u>Further Action Required:</u> Complete the leak rate calculations using current industry standards.
36	Contact of canisters with corrosive elements during shipping and handling.  <u>Further Action Required:</u> Continue development of the waste package design and narrow the options to three designs.
37	Basis for 10 cm of free fall for canister and contents.  <u>Further Action Required:</u> Prepare a supplemental response and submit it to NRC.
38	Basis for 1 mm of thinning of canister due to impact or handling.  <u>Further Action Required:</u> None. Supplemental response submitted to NRC to close the item. Awaiting NRC confirmation.

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Table 2.1-1. Status of Site Characterization Analysis Open Items (Continued)

Open Item #	Description of Open Item
<b>QUESTIONS (Continued)</b>	
39	Definition of "unusual process history" of canister.  <u>Further Action Required:</u> Further develop the waste package design.
40	Basis for factor of 2 on borehole liner in comparison to container material.  <u>Further Action Required:</u> Study the effects of water containing liner corrosion products on degradation of the container in accordance with the Metal Barriers Scientific Investigation Plan.
41	Consideration of 10 CFR 60.132 (a) in resolution of Issue 2.4.  <u>Further Action Required:</u> Incorporate regulation 10 CFR 60.132 into the Repository Design Requirements Document (DOE, 1993c). Conduct engineering studies to evaluate throughput requirements.
42	Assumption of stability of vertical emplacement hole.  <u>Further Action Required:</u> Further develop the Advanced Conceptual Design.
44	Basis for assumed numbers of breached assemblies or canisters.  <u>Further Action Required:</u> Develop information on failures of waste forms in multiple locations. Document the waste package corrosion model(s) utilized for TSPA. Further develop the Advanced Conceptual Design and narrow options down to three candidate designs.

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Table 2.1-1. Status of Site Characterization Analysis Open Items (Continued)

Open Item #	Description of Open Item
<b>QUESTIONS (Continued)</b>	
45	Investigation of particulate source terms for waste package, particulate retention factors by containing vessels, or plateout factors for the geologic repository operations area during accident conditions.  <u>Further Action Required:</u> Develop source terms for radionuclide release from breached waste packages during iterative performance assessments.
46	Basis for stricter containment of long half-life isotopes.  <u>Further Action Required:</u> Submit the Engineered Barrier Design Requirements Document (DOE, 1993d) to NRC.
47	Assumption on breaches of waste containers.  <u>Further Action Required:</u> Submit the Engineered Barrier Design Requirements Document (DOE, 1993d) to NRC.
49	Effects of low-temperature oxidation on containers.  <u>Further Action Required:</u> Prepare and issue the Metals Barriers Scientific Investigation Plan. Refine the waste package design down to three options.
51	Design and research criteria for accepting waste from Idaho National Engineering Laboratory and Hanford.  <u>Further Action Required:</u> Prepare a supplemental response and submit it to NRC.

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Table 2.1-1 Status of Site Characterization Analysis Open Items (Continued)

Open Item #	Description of Open Item
<b>QUESTIONS (Continued)</b>	
53	Specification of cooling rate of the glass waste.  <u>Further Action Required:</u> Prepare a supplemental response and submit it to NRC.
55	Interference at the ESF by water storage tanks, septic field, and waste water lagoon.  <u>Further Action Required:</u> Submit the Exploratory Studies Facility Design Requirements Document (DOE, 1993b) to NRC. Conduct an evaluation of the water uses by the ESF on test interference and waste isolation.
56	Basis for 5 cm of fault displacement in waste package environment  <u>Further Action Required:</u> Submit the Exploratory Studies Facility Design Requirements Document (DOE, 1993b) to NRC.
57	Effects of drilling multipurpose boreholes.  <u>Further Action Required:</u> None. Supplemental response submitted to NRC to close the item. Awaiting NRC confirmation.
58	Flexibility of ESF to accommodate in situ testing of waste package.  <u>Further Action Required:</u> Submit the Exploratory Studies Facility Design Requirements Document (DOE, 1993b) to NRC.

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Table 2.1-1 Status of Site Characterization Analysis Open Items (Continued)

Open Item #	Description of Open Item
<b>QUESTIONS (Continued)</b>	
59	Basis for length of in situ thermal tests.  <u>Further Action Required:</u> Prepare and issue Study Plan 8.3.1.15.1.6, "In Situ Thermomechanical Properties."
62	Basis for 30 m separation between ESF and potential waste emplacement panels, and waste emplacement within 500 ft of the ESF.  <u>Further Action Required:</u> Submit the Mined Geologic Disposal System Requirements Document (DOE, 1993e) to NRC.

### 2.1.1.3 Interactions with Advisory Committee on Nuclear Waste

There were five meetings of the Advisory Committee on Nuclear Waste (ACNW) during this reporting period.

On May 19-20, 1993, the 53rd ACNW meeting was held in Bethesda, Maryland. The meeting included a briefing by the Project on site characterization study plans and progress reports. Other topics related to high-level waste included the NRC Systematic Regulatory Analysis, and the Commission's high-level waste research program.

On July 20-22, 1993, the 55th ACNW meeting was held in Bethesda, Maryland. The meeting included an NRC staff discussion on QA in the high-level waste program.

On September 29-30, 1993, the 57th ACNW meeting was held in Bethesda, Maryland. The meeting included committee discussion of a letter from the Department offering suggestions on improving coordination between ACNW and DOE.

#### **2.1.1.4 Interactions with Nuclear Waste Technical Review Board**

During the reporting period DOE participated in the following interactions with the Review Board:

- April 19, 1993 Environment and Public Health and Safety Panel Site Tour. The Department and Project Participants toured the Yucca Mountain environmental reclamation sites.
- April 21-22, 1993 Full Board meeting in Reno, Nevada. The Department and Project Participants made presentations to the Review Board on the process used to resolve difficult issues. Infiltration and the effects of climate change on infiltration was used as an example.
- July 13-14, 1993 Full Board meeting in Denver, Colorado. The Department and Project Participants made presentations to the Review Board to discuss the following thermal-loading issues: natural analogue studies; DOE initiatives to reassess the SCP thermal goals; how the science is applied to engineering and Advanced Conceptual Design; and plans for TSPA 1993.

The Project has also continued its efforts to address many of the Review Board's concerns as a part of the ongoing site characterization activities. Examples of specific efforts include: (1) continued ESF design and construction activities to gain early underground access to Yucca Mountain as recommended in the Review Board's Fourth and Fifth Reports; (2) an ongoing evaluation of thermal strategies as recommended in the Board's Fifth Report; (3) the initiation of limited Advanced Conceptual Design work for the waste package as recommended in the Review Board's Third, Fourth, and Fifth Reports; and (4) planning for a follow-up workshop on engineered barrier system concepts to be held in the Fall of 1993 as recommended in the Review Board's Fourth Report. The Project also welcomed the participation of the Review Board and its staff at various Project meetings, internal workshops, and scientific symposiums.

#### **2.1.1.5 Interactions with National Academy of Sciences**

The Energy Policy Act of 1992 (U.S. Congress, 1992) directed the EPA to contract with NAS (hereinafter referred to as "NAS" or the "Academy") to conduct a study to provide findings and recommendations on reasonable standards for protection of the public health and safety from releases of radioactive materials stored or disposed of in a repository at the Yucca Mountain site. The 1992 law also directed the EPA, based on the recommendations of the Academy, to promulgate public health and safety standards for a repository at the Yucca Mountain site. Furthermore, the Commission was directed to modify its requirements to be consistent with EPA standards and the recommendations of the Academy.

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The Academy formed the Committee on Technical Bases for Yucca Mountain Standards to prepare its recommendations to EPA. The committee held meetings May 27-29, 1993, and August 26-27, 1993. Further meetings have been scheduled for November 9-10, 1993; December 16-17, 1993; February 7-8, 1994; and April 28-29, 1994. A committee report, containing recommendations to EPA, is expected by the end of 1994.

At the request of the Academy, the Department designated a technical liaison representative to the NAS committee. In addition, the Program formed a task force to monitor activities associated with developing a standard for Yucca Mountain, and to provide input to the NAS committee. The Department made presentations to the Academy at the May meeting, identifying key issues related to a Yucca Mountain standard. Several scientists associated with the Project made presentations to the Academy at the August meeting. The Department is currently formulating its position on a standard, as well as the implementing regulations, and the task force anticipates providing this input to the NAS committee in 1994.

### **2.1.2 Issue Resolution**

The Program is continuing an issue resolution process to help in the identification, clarification, and resolution of technical and regulatory issues raised during site characterization. The process has been developed based on the "Issues-Based Approach to Planning Site Characterization" contained in the SCP (p. 8.1-1). Issue resolution is directed toward receiving guidance and comment from NRC staff regarding definition and interpretation of regulatory terms, acceptability of site characterization methodologies, adequacy of site characterization planning and acquired data and analyses as required by 10 CFR Part 60. Although an issue cannot be considered "closed" during this prelicensing period, and any issue can be revisited based on new information, it is important to seek clarification and come to early resolution with NRC staff on as many areas of uncertainty as possible. This clarification will be accomplished by frequent interaction and communication with the Commission. These interactions may include reports sent to NRC staff for review and comment (e.g., topical or technical reports), letters, submittals of the Annotated Outline (see Section 2.1.3), or meetings. In addition, the resolution of the Site Characterization Analysis (NRC, 1989) open items (see Section 2.1.1.2) is being coordinated within the issue resolution process. Issue resolution activities during the reporting period include the following:

- **Volcanism:** A Technical Exchange was held with the Commission on June 9, 1993, to discuss the preliminary draft of the Los Alamos technical report (LA-9325, Volume III) on the status of the Project volcanism studies. The Commission provided written comments on draft LA-9325 to OCRWM in an August 18, 1993, letter. Revisions to Study Plans 8.3.1.8.1.1 and 8.3.1.8.5.1 were submitted to the Commission for review in March 1993.
- **Calcite-Silica:** Technical Report YMP/93-11-R, "Report on the Origin of Calcite-Silica Deposits at Trench 14 and Busted Butte and Methodologies Used to Determine Their Origin" (DOE, 1993f) was completed. The report was transmitted

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to the Commission for information on September 17, 1993, and the information is to be included in a future revision of the Annotated Outline.

- **Seismic Hazards:** A draft topical report, "Methodology to Assess Seismic Hazard at Yucca Mountain" was prepared and internal review has begun. An annotated outline of the proposed topical report was submitted to the Commission on August 18, 1993, in preparation for a DOE-NRC Technical Exchange scheduled for November 17, 1993.
- **Engineered Barrier System Boundary:** A letter report on the definition of the boundary of the engineered barrier system was completed (CRWMS M&O, 1993a). The report documents agreement with the Commission's interpretation that the engineered barrier system boundary does not include a portion of the host rock. This information will be included in a future revision of the Annotated Outline.
- **Substantially Complete Containment:** On August 24, 1993, a DOE-NRC Technical Exchange was held to discuss the methodology for compliance with the substantially complete containment provisions in 10 CFR Part 60. The Department is proposing a qualitative interpretation for compliance demonstration. The methodology is presently being documented as part of the Department's efforts associated with closure of Site Characterization Analysis open items and will be submitted to the Commission for review.

**Forecast:** During the first half of FY 1994, the Project intends to accomplish the following through the issue resolution process: (1) receive a Commission safety evaluation of the topical report entitled "Evaluation of the Potentially Adverse Condition 'Evidence of Extreme Erosion during the Quaternary Period' at Yucca Mountain" (DOE, 1993g) (hereinafter referred to as the "Erosion Topical Report"); (2) transmit, for Commission review, Study Plan 8.3.1.8.5.2, "Characterization of Intrusive Igneous Features" and Study Plan 8.3.1.8.1.2, "Physical Processes of Magmatism and Effects on the Repository;" (3) issue, for Commission review, the Los Alamos final report LA-9325 on the status of volcanic hazards investigations at the proposed Yucca Mountain repository; (4) interact with the Commission in Technical Exchanges on the Commission's preliminary questions on the Erosion Topical Report, on status of work relevant to characterization of the saturated and unsaturated zone flow, and on the methodology for seismic hazard assessment; (5) issue, for Commission review, the topical report entitled, "Methodology to Assess Seismic Hazard of Yucca Mountain;" and (6) continue to resolve additional Site Characterization Analysis open items.

### **2.1.3 License Application Annotated Outline**

The process of developing the MGDS Annotated Outline for Skeleton Text for the License Application (hereinafter referred to as the "Annotated Outline") is a product-oriented management tool that has a key role in the Project's program management and licensing strategies. Specifically, the Annotated Outline process: (1) integrates site characterization, performance assessment, design, and regulatory activities; (2) provides dynamic feedback to



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the site characterization program; (3) implements guidance provided by the Commission in their Draft Regulatory Guide, DG-3003, entitled "Format and Content for the License Application for the High-Level Waste Repository," dated November 1990 (hereinafter referred to as "the Format and Content Reg. Guide"); (4) facilitates focused interactions with the Commission; and (5) provides an instrument for the resolution of technical and regulatory issues. The Annotated Outline is an iterative process that contributes to the development of shared interpretation and understanding of regulations.

During this reporting period, the Annotated Outline, Revision 2 (CRWMS M&O, 1993b), dated May 28, 1993, and consisting of change pages to Chapters 5, 6, and 8, was formally transmitted to the Commission, ACNW, State of Nevada, and Affected Counties. The focus of Revision 2 was setting up the framework and layout for the performance assessment and performance confirmation programs in the Annotated Outline. Revision 2 also included changes resulting from Commission comments on Revisions 0 and 1 (April 17, 1992, and September 30, 1992, respectively).

The Commission's comments on Revision 2 of the Annotated Outline were formally transmitted on July 30, 1993. These comments were directed toward Chapters 6 and 8. Since Revision 3 addresses Chapter 3, the Commission comments will not be addressed in Revision 3, but will await subsequent revision of Chapters 6 and 8.

On July 20, 1993, the Department provided the Commission with a second set of comments (DOE, 1993h) on the Format and Content Reg. Guide. These comments were developed during the Annotated Outline process, and provide the Commission with feedback on the Format and Content Reg. Guide based on its use and annotation by the Department and its Participants. The comments included suggestions for improvement of the text as well as proposed enhancements to the cross-index between the Format and Content Reg. Guide and 10 CFR Part 60 found in the Reg. Guide, Appendix A. The Department had previously provided comments on the Format and Content Reg. Guide to the Commission on September 26, 1991.

In a related activity, a draft letter report entitled "Feedback to the Site Characterization Program" was completed September 30, 1993. The report summarized experience gained during development of Revision 3 of the Annotated Outline and provided feedback to the site characterization program resulting from the attempt to write sections of a potential license application. In effect, the letter report is the mechanism to initiate formal site characterization program change requests to ensure that information needed for licensing is acquired during site characterization. This is the first in a series of reports that will follow each Annotated Outline revision.

**Forecast:** Annotated Outline Revision 3 development continues and consists of extensive changes to Chapter 3, The Natural Systems of the Geologic Setting. Revision 3 is scheduled to be delivered to the Commission on November 30, 1993. The letter report providing feedback to the site characterization program based on Revision 3 will be completed in January 1994.

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Subsequent to Revision 3, revisions to the Annotated Outline are planned to be issued on an annual basis. Revision 4 is, therefore, scheduled to be transmitted to the Commission in November 1994. The letter report providing feedback to the site characterization program based on Annotated Outline Revision 4 will be completed in January 1995.

### 2.1.4 Permits

#### 2.1.4.1 Compliance with Federal Environmental Requirements

The Project uses three Free-Use areas on Bureau of Land Management (hereinafter referred to as "BLM" or "Bureau") land as sources of sand, gravel, and fill material for construction activities. During this reporting period, the Bureau conducted a field inspection of these Free-Use areas. All activities were found to be in compliance with permit requirements.

Consultations continue with Native American tribes and organizations, as specified in the Programmatic Agreement with the Advisory Council on Historic Preservation. One visit to the Yucca Mountain site was conducted for the Native American tribes and organizations.

Quarterly reports on water levels and spring-flow measurements continue to be sent to the National Park Service and the Nevada State Engineer as stipulated in the water appropriation permits.

**Forecast:** Within the next six months, two additional site visits will be conducted for the Native Americans. There is a potential need for another Free-Use permit for the excavation of sand and gravel for use in conjunction with a concrete batch plant for ESF construction activities.

#### 2.1.4.2 Compliance with State Environmental Requirements.

##### Water Quality

A permit request for a potable water supply system for the ESF was submitted to, and approved by, the State of Nevada.

Three temporary water appropriation permits, changing the place of use and allowing for testing and pumping at the C-Well Complex, were issued to the Yucca Mountain Site Characterization Project Office (YMPO) by the State of Nevada. These temporary permits did not request any additional water allocation. The total combined appropriation of these three temporary permits, along with the existing permits for USW VH-1, UE-25 J#12, and UE-25 J#13, will still not exceed the annual limit of  $5.3 \times 10^5 \text{ m}^3$ .

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A request for permit to construct a sewage disposal system for the ESF was also submitted to the State. This request was subsequently put on hold by YMPO because of a change in location of the proposed leachate field.

### Air Quality

Air Quality Permits to Construct and modifications to those permits were issued for air compressors and the following drill rig/dust collector systems: the LM-300, the Failing-500, and the CME-850. Air Quality Permits to Construct were submitted, and are pending, for the ESF Rock Conveyor System and for a Failing Stratmaster Drill Rig/Dust Collection system. The Air Quality Permit to Construct and Operate the Kolburg Plant at the Fortymile Wash borrow area was not renewed. The need to sort material was no longer required at that location. Material will be sorted at Borrow Area #1.

### Drilling and Tracers

Waivers to drill were issued for monitoring wells USW SD-12 and USW SRG-5/USW SD-11. Underground Injection Control tracer permit modifications were received for the C-Well Complex. Approvals were received for the use of tracers in boreholes UE-25 NRG#2b, USW SRG-5/USW SD-11 (phases 1 and 2), UE-25 NRG#7, and USW SD-12.

**Forecast:** The YMP permit applications projected over the next six months include: five air quality permits including a permit for the concrete batch plant, four tracer injection approvals under the Underground Injection Control permit, a sewage disposal permit, and approval for use of a portable holding tank for sewage disposal.

### **2.1.5 Land Acquisition**

The primary land acquisition task during this reporting period has been the processing of Participant requests to initiate site characterization activity. A Participant request to initiate site characterization activity is a prerequisite for the activity and requires Land Acquisition personnel review, processing, and granting of access authorization.

A number of right-of-way applications have been filed with the Bureau for site characterization activities, and an extension application has been filed for N-48602, the largest right-of-way on the Nellis Air Force Range, which expires June 30, 1994.

Twenty-eight Participant requests to initiate site characterization activity were processed during the period. Twenty-five of these requests have been completed and access authorization granted. Of the remaining three requests, one is awaiting the receipt of a right-of-way reservation from the BLM, one is awaiting an operations permit from the Nevada Test Site Office, and one is awaiting additional information from the Participant. Additionally, one Participant request from the last reporting period was completed. This request consisted of five right-of-way applications for seismic stations that were received from the Tonopah

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Resource Area BLM office. Six requests from the last reporting period are awaiting the results of the following actions: one right-of-way application to the Barstow Resource Area BLM office for a surface water monitoring station, two right-of-way applications to the Barstow Resource Area BLM office for seismic stations, a right-of-way application to the Stateline Resource Area BLM office for a seismic reflection program, a casual access determination from both the Barstow and Stateline Resource Area offices for pump tests in 42 existing wells, and two right-of-way reservations from the Caliente Resource Area office for volcanism studies at both Sleeping Butte and Crater Flat.

### **2.1.6 Quality Assurance Program**

#### **2.1.6.1 Program Activity**

During the reporting period, the DOE/Office of Geologic Disposal Yucca Mountain Quality Assurance Division conducted nine audits. The audits were conducted of YMPO, Raytheon Services Nevada (RSN), LLNL, Los Alamos, Reynolds Electrical & Engineering Co., Inc., Sandia National Laboratories, Technical and Management Support Services/Science Applications International Corporation, M&O/TRW Environmental Safety Systems Inc., and U.S. Geological Survey (USGS). The audits evaluated the QA programs for compliance with Program requirements and effectiveness of QA program implementation.

The DOE/Office of Geologic Disposal Yucca Mountain Quality Assurance Division also conducted 24 surveillances. The surveillances were conducted to evaluate specific site characterization related activities and as follow-up to verify corrective actions taken to close open deficiencies.

To ensure that the Commission is kept informed of the status of the QA program, bimonthly QA meetings continue to be held with the Commission. These meetings provide a forum for the NRC, OCRWM, Edison Electric Institute, State of Nevada, local governments, and other affected parties to identify and participate in resolution of QA issues. These meetings also provide information on the status, development, and progress of QA-related actions.

As a result of the issuance of the QARD which more specifically defined the applicability of the QA program, and earlier changes made to the process for developing and maintaining the Q-List and the Quality Activities List, the need for a Project-level Quality Activities List was eliminated; selection of QA controls is now determined based on the importance of the item(s) to which the activity is related. The transition to this methodology, along with the direction established in the Determination of Importance and Grading Enhancement Management Plan that Participants are responsible for performing their own classification analyses, led to the development of the Determination of Importance Evaluation process. This process provides for the evaluation of ESF design elements, including the activities associated with their construction and use, to conclude the importance of the item to radiological safety or waste isolation and provide controls appropriate to these conclusions.

### **2.1.6.2 Management & Operating Contractor Determination of Importance Evaluations**

The philosophy for the Determination of Importance Evaluation program is consistent with the QARD and is derived from NRC guidance found in NUREG-1318 (NRC, 1988) (which defines Q-list items based on permanence) and the methods used to ensure that other Q items and activities are subject to appropriate QA controls.

The Determination of Importance Evaluation program consists of methodology for: the evaluation of permanent (e.g., potential repository) or temporary (e.g., ESF) items relative to their importance to radiological safety or importance to waste isolation; the evaluation of potential impacts of activities on items important to safety or waste isolation; and a method for applying appropriate QA controls to these items and activities. The evaluations are performed in accordance with the M&O Design Analysis procedure, Quality Administrative Procedure-3-9, using the methodology described in the "M&O Plan for Evaluating Items and Activities in the MGDS Program for Importance to Safety and Waste Isolation" (CRWMS M&O, 1992).

Input documentation for Determination of Importance Evaluations is provided by the Site Characterization Group (for Test Interference Evaluations), Performance Assessment Group (for Waste Isolation Evaluations), and ESF Design Organizations (for design configuration packages). The interfaces between these organizations are established in accordance with QA procedures for transmittal of design input. Waste Isolation and Test Interference Evaluations are used as a basis for concluding the importance of items and subsequent controls. Completed evaluations, which document this basis information and provide the controls, are transmitted to the design organization for inclusion of these controls within the Basis for Design document. From the document, these controls flow down into design outputs (specifications and drawings) for implementation by the construction contractor.

Prior to the transition of this function from RSN to the M&O, RSN Classification Analyses were completed for the ESF Topsoil Storage Area and Access Roads. Since that transition (December 1992) eight other design elements have been evaluated:

- ESF North Portal Pad
- ESF Stormwater System
- ESF Rock Storage Area
- ESF Starter Tunnel - Steel Arch Section
- ESF Starter Tunnel - Drill and Blast Section (incorporating the North Ramp Test Alcove #1)
- ESF Switchgear Building

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- ESF Water Supply System
- ESF Water Distribution System

Determination of Importance Evaluations are required prior to implementation of a particular design element. Most of the evaluations listed above were prepared for ESF Package 1A; as a result of the timing of the evaluations, they were prepared, reviewed, and approved after the 1A 90% Design Review. These evaluations were used as justification for removing "To-Be-Verified" indications from the 1A design (these indications were placed to prevent implementation of a given design element prior to completion of its classification analysis or Determination of Importance Evaluation). For subsequent design elements, the evaluations are intended to be presented for review as part of the 50% and 90% design reviews for the associated design packages.

**Forecast:** Work is in progress on revisions to the M&O QA classification procedure (Quality Administrative Procedure-2-3) to allow for its use on the MGDS. This procedure will provide the basis for the M&O QA classification process, which is currently performed according to YMPO procedure Administrative Procedure-6.17Q.

Also anticipated in this fiscal year is a revision to the Determination of Importance Evaluation Plan to incorporate additional evaluation methodologies as they are required and developed to support QA classification analyses. Upon revision, this document will be renamed the QA Classification Methodology Document.

### **2.1.6.3 Q-List and Management Control-List**

The Project Q-List (DOE, 1990a) and Management Control (MC)-List (DOE, 1993i) are used to tabulate permanent items. The Q-List describes those permanent items determined to be important to radiological safety or waste isolation and, therefore, subject to the requirements of the QARD; the MC-List describes those permanent items determined not to be important to radiological safety or waste isolation and subject only to normal management and design controls. Each document describes the basis for the conclusion of a specific item's importance.

An initial evaluation of the natural barriers was performed. This evaluation utilized a systematic approach to provide justifications consistent with the current progress of site characterization. The approach involved evaluating each barrier for its capability to perform one or more potential waste isolation functions, determining the characteristics of that barrier which are needed to perform these functions, and identifying a lateral extent over which these functions would be important to the overall performance of the MGDS. This information was then added to each natural barrier as part of Section 2 of the Q-List. The Q-List will continue to be updated as site characterization data becomes available for use in more detailed performance analyses.

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Both documents reflect the conclusions of Determination of Importance Evaluations performed during this reporting period; the Q-List also still contains items originally placed there by direct inclusion in the original version of the document. Items currently on the Q-List by direct inclusion require documented analysis to warrant their removal. An Assessment Team made up of technical experts from the various Project Participants evaluates recommended changes to the Q-List.

The changes made to the Q- and MC-Lists during this reporting period include:

### Q-List (Revision 1)

- Revision and clarification of the introduction and definitions sections
- Revisions to format for Section 1 (Engineered Items Important to Safety) and Section 2 (Items Important To Waste Isolation)
- Clarification of the importance of specific components of the ESF Starter Tunnel and associated ground support system in response to that item's Determination of Importance Evaluation
- Deletion of Exploratory Shaft Facility and its replacement with Exploratory Studies Facility Optional Access

### Q-List (Revision 2)

- Moved the natural barriers to items important to waste isolation, defined the lateral extent of each barrier, added functions and characteristics to each barrier, and removed alluvium from the Q-List

### MC-List (Revision 0)

- Initial issue

### MC-List (Revision 1)

- Added unconsolidated surficial materials, including alluvium

The revisions to the Q-list were based in part on recommendations for change as a result of the Determination of Importance Evaluations performed during this reporting period. In addition, Revision 2 of the Q-List is currently in review. Recommendations for changes to these lists are evaluated in accordance with Administrative Procedure-6.17Q.

**Forecast:** Acceptance of the M&O Classification procedure (Quality Administrative Procedure-2-3) by OCRWM QA is anticipated in the first half of FY 1994. In-progress Determination of Importance Evaluations for ESF design packages will be completed and development of evaluations for subsequent design packages will continue. The QA

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Classification Methodology Document will be developed for description of subsequent methodologies for supporting analyses.

### 2.1.6.4 Design Control Improvement Plan

During this reporting period the need to evaluate the M&O design control process and procedures was identified. This evaluation was initiated to coordinate and document corrective actions planned in response to QA verification and deficiency documents dated from January 1993 to the present. As part of this evaluation, various areas were identified where process improvement was necessary. The specific evaluation and improvement actions are documented in the "M&O MGDS Design Control Improvement Plan" (CRWMS M&O, 1993c).

The purpose of the improvement plan is to coordinate the implementation of corrective actions to: provide immediate response to open Corrective Action Reports, ensure that conditions immediately adverse to quality (if any) are identified and corrected, and provide for the development of a series of improvements to the design control process to preclude recurrence. The plan was initially issued July 30, 1993. It was revised (Revision 1, September 15, 1993) to incorporate comments from Project and QA representatives as well as other informal comments.

The problems and action items identified in this plan are divided into three areas: near-term or immediate actions; longer-term, broader process improvement actions; and improvement verification or confirmation actions. It is the intent of these action items to provide for a broad review of the entire design control process to identify weaknesses and resolve them in order to prevent future problems. During the reporting period, the majority of the near-term action items were resolved and closed out, the longer-term improvement actions were initiated, and preliminary scope and schedules were developed for verification activities. The status of the action items associated with the improvement plan is as follows:

	Identified	Complete	Pending	Ongoing*
Immediate Actions	33	23	7	3
Process Improvement Actions	16	6	6	4
Verification/Confirmation Actions	5	N/A	3	2

\* Ongoing signifies those actions which will continue indefinitely (e.g., verification of root cause of corrective action requests).

**Forecast:** Completion and close-out of the Design Control Improvement action items, including verification of the actions and evaluation of their effectiveness, is anticipated within FY 1994. Several "ongoing" action items have resulted and will result in permanent changes to the design control process.



## **2.1.7 Document Hierarchy**

### **2.1.7.1 Site Characterization Program Baseline**

The Site Characterization Program Baseline (SCPB) (DOE, 1993a) identifies the baselined site characterization program and provides a means to demonstrate traceability of changes in the objectives of site characterization studies. All revisions to the SCPB are reviewed, approved, and controlled in accordance with approved change control procedures.

#### **SCPB Revision History**

##### **Revision 0, Issued February 22, 1991**

**Revision 1, Issued April 5, 1991:** Updated information related to the ESF in preparation for start of Title II design studies. Incorporated changes to program planning resulting from the "Exploratory Studies Facility Alternatives Study: Final Report" (Dennis, 1991) (hereinafter referred to as "ESF Alternatives Study")

**Revision 2, Issued October 2, 1991:** Documented revised plans for testing in SCP Section 8.3.1.14. Consolidated all of the anticipated studies under Investigation 8.3.1.14 into one Study Plan (8.3.1.14.2, "Soils and Rock Properties").

**Revision 3, Issued February 7, 1992:** Documented changes to the objectives of Activities 1 and 4 in Study Plan 8.3.1.2.1.4, "Regional Hydraulic Synthesis and Modeling" and Activity 4 in Study Plan 8.3.1.2.3.2, "Characterization of the Saturated-Zone Hydrochemistry." Added three drillholes to Study Plan 8.3.1.2.3.1, "Regional Ground-water Flow System." Deleted requirement for tagging surface dust suppression water with chemical tracer. Various editorial changes.

**Revision 4, Issued March 13, 1992:** Incorporated changes in the objectives of Activities 1 and 3 in Study Plan 8.3.1.2.3.2, "Characterization of the Upper Saturated-Zone Hydrochemistry."

**Revision 5, Issued July 15, 1992:** Corrected references to integration of geophysical activities.

**Revision 6, Issued July 15, 1992:** Updated Section 8.4 to be consistent with current ESF concept.

**Revision 7, Issued July 15, 1992:** Deleted Activity 8.3.1.4.2.1.6, "Integration of geophysical activities." Scope was redundant with 8.3.1.4.1.2.

**Revision 8, Issued September 24, 1992:** Reorganized waste package near-field environment program (Section 8.3.4.2.4) to separate the tests addressing the effects of man-made materials from testing in the near-field environment.

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Revision 9, Issued October 2, 1992: Changed scope of SCPB to divide controlled area between SCPB and Study Plans; place parameter tables in separate controlled document; and remove hypothesis testing tables and analyses supporting test control from SCPB. Documented changes made to Activities 8.3.1.2.2.4.6, 8.3.1.5.2.1.2, 8.3.1.5.2.2.1, 8.3.1.5.2.2.2, 8.3.1.5.2.2.3; changes made to Studies 8.3.1.3.7.2, 8.3.1.8.1.1, 8.3.1.8.1.2, 1.10.4.3; and changes made to Investigation 8.3.1.7.1.

Revision 10, Issued January 14, 1993: Documented changes made to Study 8.3.1.2.2.4; Activities 8.3.1.8.5.2.2, 8.3.1.15.2.2, 8.3.1.17.4.3.2, 8.3.1.17.4.4.3; and Section 8.3.5.13.

During this reporting period no revisions to the SCPB were issued. However, several new technical requirements documents were developed and approved. These are discussed in detail later in this section. One of these documents, the Site Design and Test Requirements Document, captures the test requirements for the site characterization program. These requirements are also contained in the SCPB. The Project is in the process of evaluating the scope and content of the SCPB and will likely revise it based on this evaluation.

### **2.1.7.2 Regulatory Controls**

The Program must comply with a large number of requirements imposed upon it by many laws, regulations, orders, and standards. To facilitate compliance with this wide range of requirements, the Project has developed a system of identifying and documenting the requirements in "System Requirements" and "Design Requirements" documents.

The Program had in place an existing suite of documents addressing regulatory controls for the majority of the system prior to the development of the System Requirements and Design Requirements documents. The new hierarchy of requirements documents (Figure 2.1-3) provides a single top level document, the Civilian Radioactive Waste Management System Requirements Document (DOE, 1992a), and rigorously enforces a structured allocation and requirements traceability process for all technical requirements. The new hierarchy also establishes top level interface requirements in the System Requirements documents for each major system element between all other interfacing system elements. An Interface Specification serves to capture and describe interfaces between each of the major system elements.

The Project recently approved five new technical documents in the technical document hierarchy. These Design Requirements Documents are identified on the Document Hierarchy. The Design Requirements Documents are: (1) the Repository Design Requirements Document (DOE, 1993c), (2) the Site Design and Test Requirements Document (DOE, 1993j), (3) the Engineered Barrier Design Requirements Document (DOE, 1993d), (4) the Exploratory Studies Facility Design Requirements Document (DOE, 1993b), and (5) the Surface-Based Testing Facilities Requirements Document (DOE, 1993k).

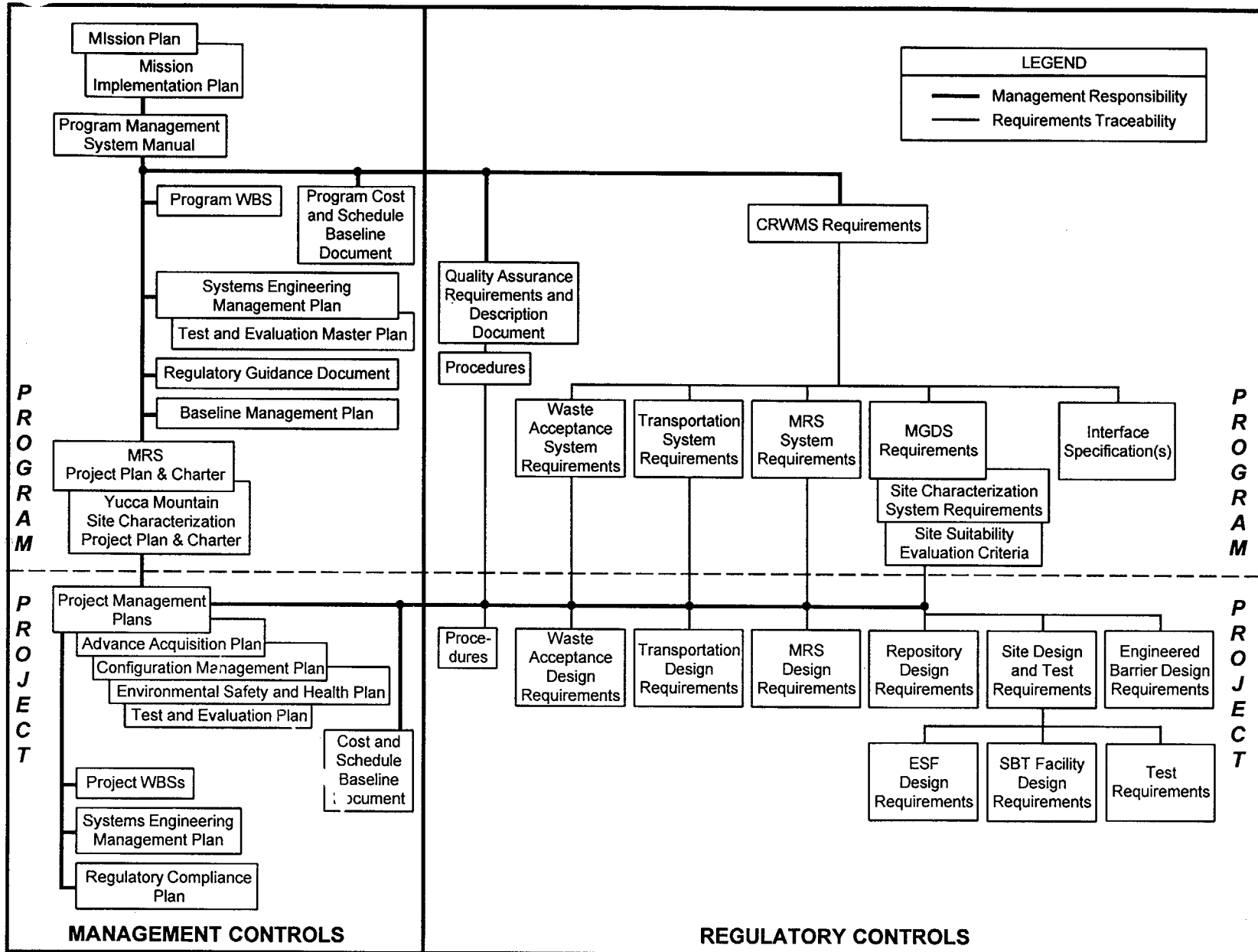


Figure 2.1-3. OCRWM Document Hierarchy

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The Repository, Site Design and Test, and Engineered Barrier Design Requirements Documents derive their requirements from their parent document, the Mined Geologic Disposal System Requirements Document (DOE, 1993e), which was approved by the Change Control Board in January 1993. The Mined Geologic Disposal System Requirements Document derives its requirements in turn from the Civilian Radioactive Waste Management System Requirements Document. The Exploratory Studies Facility Design Requirements Document and the Surface-Based Test Facilities Requirements Document derive their requirements from their parent document, the Site Design and Test Requirements Document. Each Design Requirements Document provides (in Section 6) a matrix that identifies the source of every requirement contained in the document. This section also provides a cross reference for the location of each requirement in the parent document correlated to the location in the Design Requirements Document. Each Design Requirements Document serves a specific purpose in the MGDS.

### Repository Design Requirements Document

This document defines the Project-level requirements for the design of a repository segment consistent with the Mined Geologic Disposal System Requirements Document. These requirements include design, operation, and decommissioning requirements to the extent that they impact the physical design and development of the repository. The document also presents an overall description of the repository segment and its functions (derived using the functional analysis documented by the Mined Geologic Disposal System Requirements Document as a starting point). In addition, the Project-level interfaces of the repository segment are identified. As such, the Repository Design Requirements Document provides the technical baseline for the design of the repository. While the repository segment may evolve and change through the design process, changes must occur in a controlled manner that ensures the Civilian Radioactive Waste Management System remains integrated. In doing so, the Civilian Radioactive Waste Management System Requirements Document, Mined Geologic Disposal System Requirements Document, and Repository Design Requirements Document will be revised to capture the changes.

The Repository Design Requirements Document captures, as appropriate, all of the requirements from the old hierarchy Repository Design Requirements Document. The retention of the old hierarchy repository design requirements is documented in a horizontal trace matrix which makes up a part of the QA records package for this document.

### Site Design and Test Requirements Document

This document establishes the functional descriptions and performance requirements for all site characterization activities. The document also presents an overall description of the site segment and its functions, based on the functional analysis documented by the Mined Geologic Disposal System Requirements Document. The site characterization program requirements for investigations, studies and activities are established and presented in the form of objectives. Design requirements for test support and other facilities are established in

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this document and are allocated to the ESF in the Exploratory Studies Facility Design Requirements Document and/or the Surface-Based Testing Facilities in the Surface-Based Testing Facilities Requirements Document. The Site Design and Test Requirements Document is also the parent document for the Test Requirements Document. The scope and contents of the Test Requirements Document are to be determined. In addition, the interface requirements of the site segment to engineered barrier segment, and repository segment are defined. These interface requirements are identified and allocated to the site segment in the Mined Geologic Disposal System Requirements Document.

The Site Design and Test Requirements Document captures the testing objectives previously controlled in the SCPB (DOE, 1993a). These objectives include the original SCP section references and are included in a traceability matrix in Section 6 of the Site Design and Test Requirements Document.

### Engineered Barrier Design Requirements Document

This document describes the functions to be performed by and establishes the requirements for the engineered barrier segment. The engineered barrier segment is one of the segments of the MGDS for the permanent disposal of spent nuclear fuel, commercial high-level radioactive waste, and defense high-level radioactive waste. The primary function of the engineered barrier segment is to isolate waste, first by containing waste within the waste package and then, together with the geologic setting, isolating radioactive waste from the accessible environment. The requirements for the engineered barrier segment are derived from the requirements contained in the Mined Geologic Disposal System Requirements Document. The major components of the engineered barrier segment consist of the waste packages, the underground facility, any backfill placed in emplacement drifts, and emplacement hardware used to support and protect the emplaced waste packages. The underground facility portion of the engineered barrier segment has been identified as an interface with the repository segment. The Engineered Barrier Design Requirements Document allocates the requirements from the Mined Geologic Disposal System Requirements Document, expands and interprets those requirements, and defines the segment/component level requirements for the design of the engineered barrier segment. The document also presents a description of the engineered barrier segment, its functions, its components, and the requirements of these components. In addition, the interface requirements of the engineered barrier segment to geologic setting, site segment, repository segment, waste acceptance, and transportation are defined. These interface requirements are identified and contained in the engineered barrier segment in the Mined Geologic Disposal System Requirements Document.

### Exploratory Studies Facility Design Requirements Document

This document establishes the requirements and constraints imposed on the development of the design for the ESF. The purpose of this requirement document is to establish the design requirements for facilities, underground openings, utilities, and services as part of the ESF required to support the subsurface in situ tests specified in the Site Design

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and Test Requirements Document. The Exploratory Studies Facility Design Requirements Document includes requirements for both surface and underground construction, utilities, and services.

This document captures all of the appropriate requirements from the previous Exploratory Studies Facility Design Requirements Document. As with the Repository Design Requirements Document, a horizontal traceability matrix was developed and is included in the QA records package.

The latest revision to this document is Revision 0, which is the version implemented with the new hierarchy. Prior to Revision 0, two Interim Change Notices were issued to Revision 7/2/92.

Interim Change Notice-1 (March 29, 1993) - Removed the requirement for chemical tracers in surface dust suppression water to prevent meteoric precipitation from mobilizing tracers on the ground surface and depositing it elsewhere. This change was made to bring the Exploratory Studies Facility Design Requirements into conformance with the SCPB.

Interim Change Notice-2 (April 30, 1993) - Removed the requirement for chemical tracers in water used for fill compaction and general surface construction and also reinstated the requirements from the California Tunnel Safety Code.

### Surface-Based Testing Facilities Requirements Document

This document establishes the requirements and basic constraints imposed on the development of the surface-based testing facilities in support of site characterization at Yucca Mountain. The surface-based testing activities will include sampling and testing to be carried out from the ground surface. This document identifies requirements for facilities needed to support these activities, as well as any other surface-based activity that may affect the geologic or waste isolation characteristics of the site. The purpose of this document is to capture the requirements from the Site Design and Test Requirements Document and define the subsystem-level requirements for the design of the surface-based testing facilities. This document also presents a description of the surface-based testing facilities, its functions, its subsystems/components, and the requirements contained in the subsystems. In addition, the interface requirements of the surface-based testing facilities are defined.

This document contains the appropriate requirements from the old hierarchy Surface-Based Testing Facilities Requirements document and documents horizontal traceability in a matrix included in the QA records package.

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### **2.1.7.3 Management Controls**

As with the Regulatory Controls area, the Program revised the structure of the management document hierarchy, and the Program-Level Management Controls documents are in the process of being revised or new documents developed to respond to these changes.

The Project is also in the process of revising or developing new documents to respond to the above changes. The Project Plan has been developed and is in review. The Project Management Plan has been revised and is on hold pending approval of the Project Plan. The Advanced Acquisition and Assistance Plan has been revised and is also on hold pending approval of the Project Plan. The Configuration Management Plan is in the process of being revised. The Test and Evaluation Plan (CRWMS M&O, 1993d) was revised and approved. The Systems Engineering Management Plan has been revised and is in the comment resolution process.

The Test and Evaluation Plan defines the controls and process to be used for the planning, implementation, and evaluation of scientific investigations of the Yucca Mountain site.

In accordance with the Test and Evaluation Plan, planning of scientific investigations is achieved by implementing the Test Planning Process, Administrative Procedure-5.32Q.

Likewise, implementation of scientific investigations is achieved through the Field Work Activation Process, Administrative Procedure-5.21Q.

Together these two processes constitute the means by which the first two elements of the Test and Evaluation Plan are achieved. The third element, test evaluation, is performed under the specific procedures of the individual Project Participants responsible for site investigations.

### **2.1.8 Environmental Audit Program**

#### **2.1.8.1 Audits**

In accordance with the requirements of the Environmental Regulatory Compliance Plan (DOE, 1988b) an Environmental Audit program was established. Environmental audit program activities during this reporting period consisted of comprehensive environmental audits of Desert Research Institute (Audit FY93B) June 14-18, 1993, and USGS (Audit FY93C) September 20-24, 1993. The audits were directed by the YMPO Project and Operations Control Branch and conducted by the Technical and Management Support Services Environmental Compliance and Permitting Department. The purpose of the audits is to ensure that Project Participants conduct their activities in an environmentally safe and sound manner.

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The Environmental Compliance Audit Report for Audit FY93A (SAIC, 1993a), conducted last reporting period, was issued on May 13, 1993. Audit findings for the Desert Research Institute Audit have been reported in an Environmental Compliance Audit Report for Audit FY93B (SAC, 1993b) issued July 8, 1992. A Corrective Action Plan (DRI, 1993) prepared by Desert Research Institute has been approved and is currently undergoing implementation. An Environmental Compliance Audit Report which delineates the findings of the USGS Audit is under development.

**Forecast:** Implementation of the Corrective Action Plan for Environmental Audit FY93A, conducted in March 1993, will be completed. Three additional comprehensive environmental audits are scheduled in the next six months. There is also one focused special interest audit planned for this period. Audits FY93A and FY93B are expected to be closed out within six months.

### 2.1.8.2 Surveillances

During this period, approximately 120 environmental surveillances were conducted at the Yucca Mountain site to ensure compliance with environmental, programmatic, and permit requirements. One-third of the surveillances required corrective action and follow-up work; 30 of the follow-up activities were completed.

**Forecast:** The number of environmental surveillances projected over the next six months is 180.

### 2.1.8.3 Preactivity Surveys

During the reporting period, 32 land access and environmental compliance activity reviews were completed. This effort involved a total of 96 radiological, archaeological, and biological preactivity surveys. An additional 28 requests to initiate site activity have been received this period. There are currently 18 "open/active" field activities, for which environmental preactivity surveys are being conducted.

**Forecast:** It is anticipated that approximately 45 land access and environmental compliance activity reviews will be completed in the next six months. This effort will involve an estimated 135 radiological, archaeological, and biological preactivity surveys.

### 2.1.9 Exploratory Studies Facility Design and Construction

The ESF design and construction activities have progressed significantly during this reporting period. The design change from a shaft-based concept to a drift-based concept reported in Progress Report 8 (DOE, 1993m) has been implemented. The Commission sent a letter, dated August 20, 1993, to the Department, identifying four concerns related to ESF design (NRC, 1993). A DOE-NRC Management Meeting was held on September 17, 1993,



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to discuss the ESF design issue and a DOE-NRC Technical Exchange on ESF design has been scheduled for October 5-6, 1993. In the August 20, 1993 letter, NRC requested that DOE identify the latest revision of controlled documents relevant to ESF design and construction. These documents, discussed in this and other sections of this Progress Report are:

1. SCPB (YMP/CM-0011), Revision 10 (DOE, 1993a)
2. ESF Technical Baseline (YMP/CM-0016), Revision 2 (DOE, 1993n)
3. ESF Plan (YMP/93-007), Revision 0 (DOE, 1993o)
4. Plan for Phased Approach to ESF Design, Development and Implementation (YMP/91-13) (DOE, 1991a)
5. ESF Design Requirements Document (YMP/CM-0019), Revision 0 (DOE, 1993b)
6. Site Design and Test Requirements Document (YMP/CM-0021), Revision 0 (DOE, 1993j)

As reported in Progress Report 8, changing the baseline construction logic from four Tunnel Boring Machines to two machines was considered. The sequence of excavation presented in Progress Report 8 has not changed. The plan is to continue excavation down the North Ramp, along the main Topopah Spring level drift and up the South Ramp to daylight.

### **2.1.9.1 Exploratory Studies Facility Design**

Design Activities have been fully transitioned from RSN to the M&O. Design Package 1A was originally developed by RSN, and subsequently transitioned to the M&O, and has been released for construction. Ongoing modifications in the form of Field Change Requests and Change Requests continue to be made against Package 1A. Package 1A consists of the following elements:

- North Portal pad
- Topsoil storage area
- ESF access road
- Sewage collection and treatment system
- North Portal pad water supply system
- Tunnel Boring Machine Starter Tunnel
- Rock storage area
- Switchgear building

The balance of Package 1 was further split into Packages 1B, 1C, and 1D. This subdivision was made in an effort to support construction initiatives. Design Packages 1B, 1C, and 1D have all undergone a 50% design review during this period. At the time of the

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50% review the three Package 1 components were consolidated. Package 1B has also undergone a 90% design review during this period. It is planned for Package 1B to be released during the first quarter of FY 1994. Package 1B consists of the following elements:

- Change house building (contains other services to include portal control)
- Shop building
- Sanitary sewer system
- Power distribution
- Water distribution system
- Subsurface wastewater system
- H-road, site grading and paving

Elements of Package 1B will be constructed in FY 1994.

Package 1C, in design during this reporting period, will also be completed in FY 1994 and consists of the following elements:

- Muck storage area
- Power substation pad
- Site lighting
- Conveyor maintenance access road
- Stand-by power
- Fuel storage
- Compressed air system

Package 1D, in design during this reporting period, will be completed in FY 1995 and consists of the following elements:

- Warehouse
- Covered storage
- Off site communications system
- Operations building
- Steam cleaning system

The M&O initiated the design of Subsurface Package 2, North Ramp, during this reporting period. As with Design Package 1, Package 2 underwent a complete 50% design review and subsequently was divided into three components: Package 2A, 2B, and 2C. Package 2A underwent design and a 90% review during this reporting period and will be issued for construction in the first quarter of FY 1994. Originally, Package 2A consisted of the following elements:

- Starter Tunnel extension to Bow Ridge fault (drill and blast methodology)
- Surface and subsurface conveyor specifications including arrangement drawings
- Electrical switchgear, transformers, and power center procurement specifications
- Tunnel Boring Machine operation specification
- Transportation alternatives study

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Due to projected budget constraints in FY 1994 the Starter Tunnel extension was cancelled.

Package 2B, in design during this period, will undergo a 90% design review in the first quarter of FY 1994 and will subsequently be issued for construction. Package 2B consists of the following elements:

- Concrete foundations for the muck conveyor transfer tower
- Utility analysis
- Tunnel ventilation specification and drawings
- Rail haulage system
- Mapping platform procurement specification
- Excavation, ventilation and muck storage trade studies
- Control system specification and drawings
- Monitoring and warning system specifications

Package 2C, in design during this period, will undergo a 90% design review in the first quarter of FY 1994 and will subsequently be issued for construction. Package 2C consists of the following elements:

- Concrete and structural steel for surface and subsurface conveyors
- North Ramp to Topopah Spring Level excavation specification and drawings
- Remaining utility systems for North Ramp
- Electrical power, lighting, and grounding
- Equipment installation specifications

During this reporting period ESF Title II Design activities included a proposed enhancement of the ESF configuration, studies of the transportation of personnel, studies for the procurement of the Tunnel Boring Machine, and several trade-off studies. Title II design of the temporary 69-kV system was completed during this reporting period and was released for construction.

**Forecast:** It is planned for Package 1B to be released during the first quarter of FY 1994. Package 1C, in design during this reporting period, will also be completed in FY 1994. Package 1D, in design during this reporting period, will be completed in FY 1995. The analysis to demonstrate acceptability and the impacts of the ESF enhancements will be completed and dispositioned by DOE. Package 2A will be issued for construction in the first quarter of FY 1994. Package 2B will undergo a 90% design review in the first quarter of FY 1994 and will subsequently be issued for construction. Package 2C will undergo a 90% design review in the first quarter of FY 1994 and will subsequently be issued for construction.

### 2.1.9.2 Exploratory Studies Facility Construction

The most notable activity during this reporting period was the excavation and completion of the 60-m Starter Tunnel which will be used to launch the Tunnel Boring

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Machine. The excavation started on April 2, 1993, and was completed September 9, 1993. In conjunction with the excavation, the Principal Investigators mapped the tunnel as it progressed.

Other significant construction accomplishments include: the access road base to the North Portal pad, the drainage channel over the tunnel portal, and grading of the North Portal pad. The 69-kV power system work was initiated and is in progress during this period. Power poles and lines have been installed. Power up is planned prior to December 24, 1993.

The contract for the 7.6-m Tunnel Boring Machine was awarded to Construction and Tunneling Services, Inc. of Kent, Washington, on June 4, 1993. Delivery of the Tunnel Boring Machine is on schedule for April 1994.

During this period the underground operating contract was awarded to a joint venture of Peter Kiewit and Parsons Brinckerhoff. The operator is a subcontractor to the Constructor, Reynolds Electrical & Engineering Co., Inc. Peter Kiewit and Parsons Brinckerhoff will perform assembly and operation of the Tunnel Boring Machine as well as some of the other underground construction work.

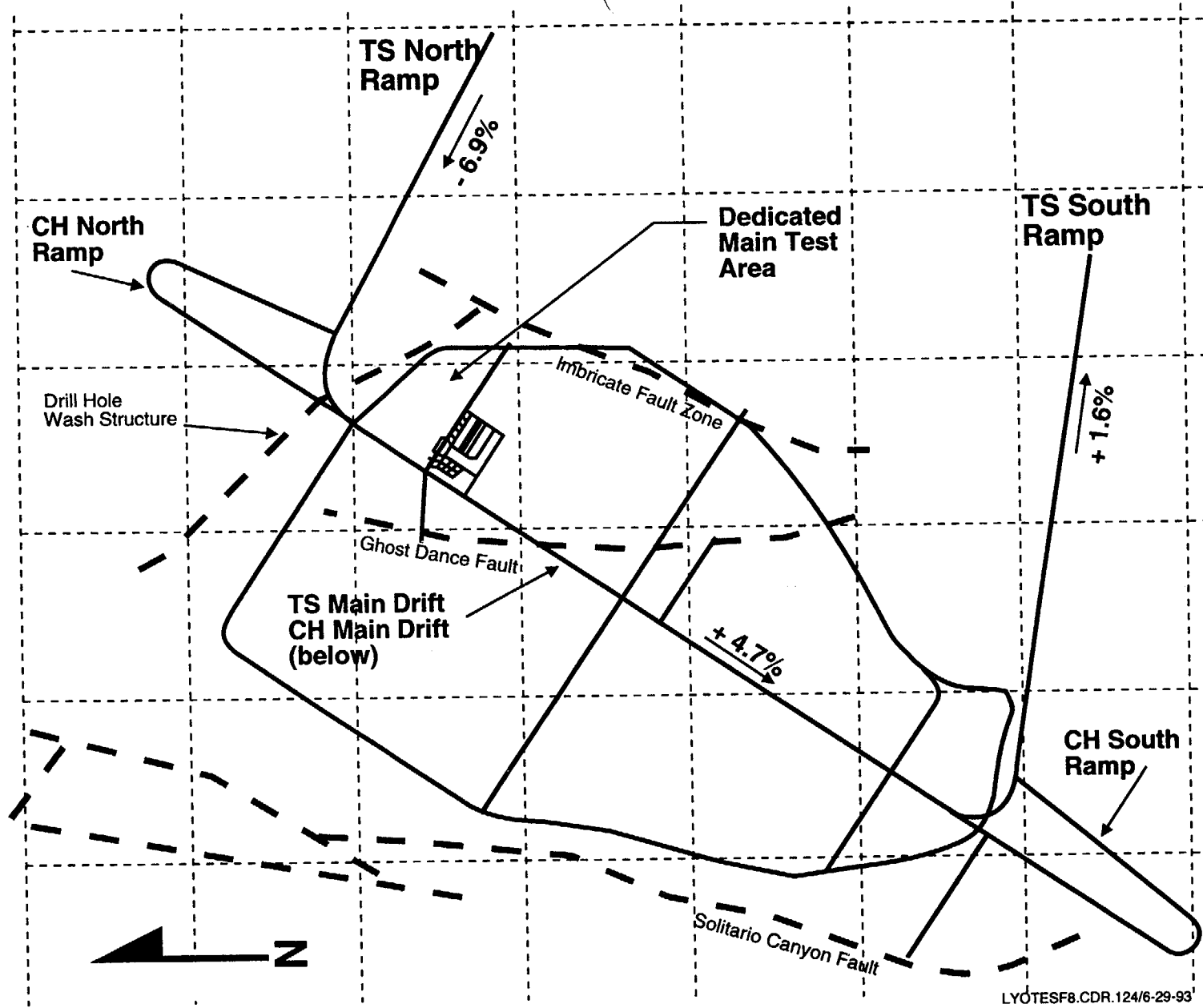
During this period extensive planning was performed for upcoming work. The planning included a comprehensive schedule that will allow installation of adequate site infrastructure to enable assembly and startup of the Tunnel Boring Machine during the next reporting period. Excavation of the first test alcove is in progress and will be completed during the next reporting period. The approximate centerline location of the alcove is 40 m down the Starter Tunnel and the alignment of the alcove is approximately along a northeast to southwest axis.

**Forecast:** Infrastructure to be installed during the next reporting period will include most of the buried utilities on the south side of the portal pad and in the immediate area in front of the portal itself. In addition, the off-pad water system will be developed, as well as temporary office space for all key scientific and engineering personnel. The foundations for the switchgear building will be emplaced as well as the switchgear building and the electrical systems therein. Assembly of the Tunnel Boring Machine is planned for the third quarter of FY 1994. Operations are planned for the end of the fiscal year.

### **2.1.9.3 Proposed Enhancements To The Current Exploratory Studies Facility Configuration**

#### Introduction

The current ESF design is derived from Option 30 of the ESF Alternatives Study (Dennis, 1991). One of its primary features is a main drift connecting the lower ends of the North and South Ramps in the Topopah Spring Level (see Figure 2.1-4). This main drift is oriented at N 34° E, coincident with the alignment of one of the proposed repository main access drifts as shown in the Exploratory Studies Facility Technical Baseline (DOE, 1993n).



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Figure 2.1-4. Baseline ESF Layout

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Recent work on the Advanced Conceptual Design for the potential repository, coupled with concerns on the part of the Review Board and current Project Participants has led to a proposed enhancement to the Option 30-based ESF design. The proposed change would:

- Maintain the portal location and the horizontal alignment of the North Ramp.
- Result in grades less than 3.0 percent in the initial loop formed by the North Ramp - surface to Topopah Spring Level, the main drift, and the South Ramp - Topopah Spring Level to surface. This would allow the use of conventional rail haulage for the excavation in the Topopah Spring Level ramps and main drift, and would preserve the option to use conventional rail haulage in the potential repository.
- Preserve repository layout flexibility to a much greater extent than the current orientation. Flexibility is maintained because:
  - The main drift would cross the repository block at a point stratigraphically higher in the densely welded devitrified lithophysal-poor tuff (TSw2) of the Topopah Spring Member, thereby allowing repository designers to situate drifts below this main drift if future repository design work indicates that the drift is not useful for incorporation into a repository design. This alternative would not have the performance concerns that would result from having a drift situated below potential repository drifts.
  - The main drift would be adjacent to the Ghost Dance fault along much of its length. This portion of the block may be of limited value to the potential repository if it is determined that no waste can be emplaced in the fault zone.
  - Cross drifting within the TSw2 is performed at the ends of the block - not through the center where the arrangement and orientation of potential repository main and emplacement drifts are unknown at this time.
- Better accommodate repository layouts that: (1) have flat grades in emplacement drifts and 2 percent maximum grades in all other "in-block" drifts, (2) do not require emplacement drifts to cross the Ghost Dance fault, and (3) will not eliminate repository concepts identified in the development of Option 30.
- Allow repository emplacement drifts, particularly in the primary block situated west of the Ghost Dance fault, to be placed farther above the water table. (This was identified as a Favorable Feature in the ESF Alternatives Study [Dennis, 1991]; Option 30 previously did not have this feature.)
- Maintain the full scope of site suitability and characterization testing provided in Option 30. In addition, critical characterization of the Ghost Dance fault, at multiple points along the main drift, is easily provided for without compromising potential repository flexibility. The ability to characterize the TSw2, and evaluate potential north-south trending features, is provided at both the north and south ends

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of the block, with added potential to investigate the Solitario Canyon fault within the potential repository horizon via an extension of the North Ramp.

The reoriented ESF layout would result in a longer North Ramp, a shorter South Ramp, and a main drift of about the same length as the current layout (see Figure 2.1-5). The main drift would be oriented approximately north-south and would run subparallel to, and west of, the Ghost Dance fault, with a nominal 122-m offset. The Main Test Area would be located in the same basic area as in the current layout. The initial "loop" would be approximately 7791 m in length, or about 200 m shorter than with the current layout.

### Background of the Development of the Baseline ESF Concept

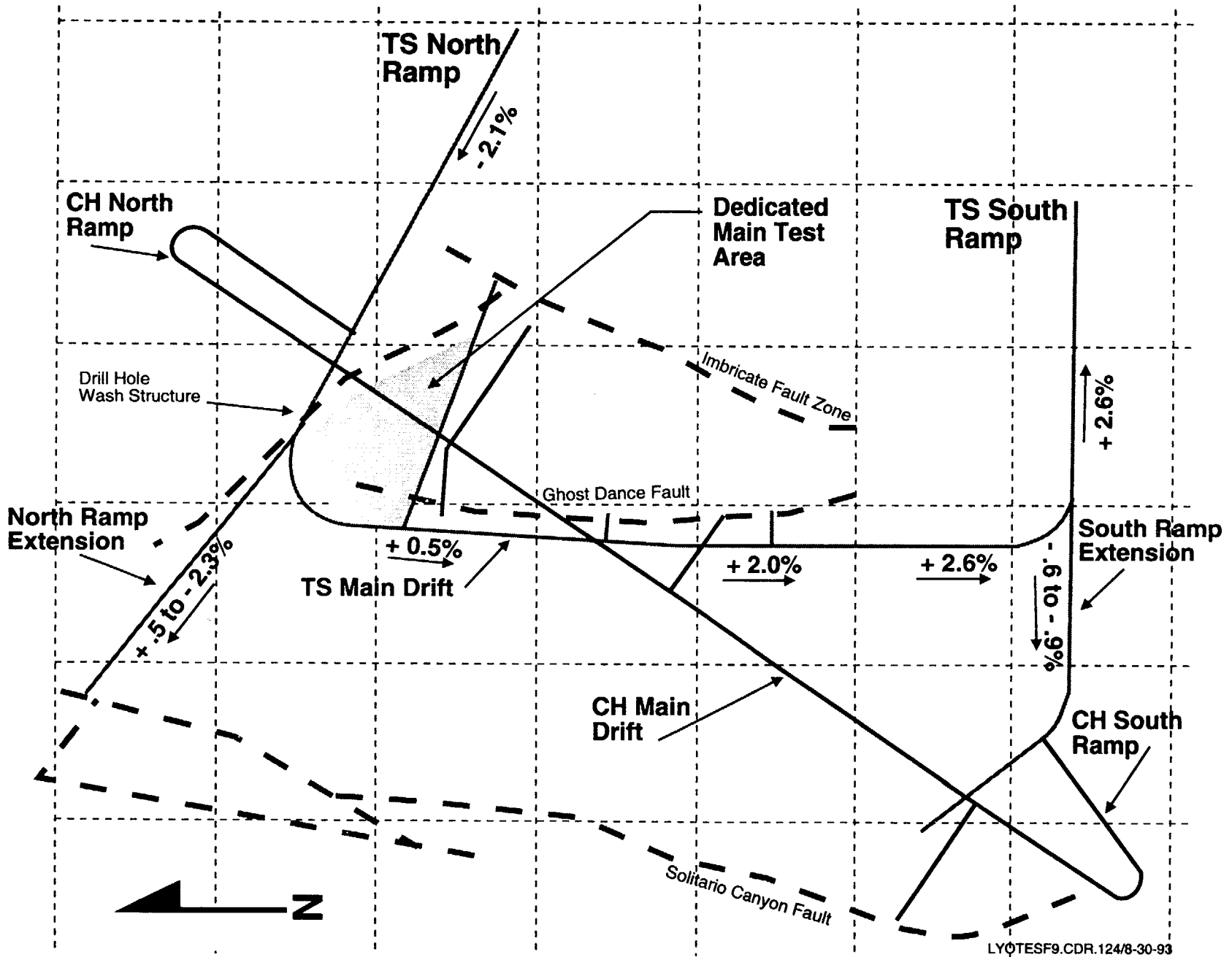
The ESF concept presented in the SCP consisted of two 3.6-m-diameter vertical shafts and approximately 1829 m of drifting in the Topopah Spring level. The drifting was localized in the northeast quadrant of the potential repository block.

Comments from the Commission and the Review Board centered on the excavation method (drill and blast versus mechanical excavation), the Review Board's preference for ramp access over shaft access, and the localized, limited nature of the at-depth drifting.

During 1990, the Project undertook the ESF Alternatives Study to provide a comprehensive assessment of options for development of an ESF, and how those options would fit into a potential repository. Thirty-four options were developed and evaluated. The options included shaft access, ramp access, and combinations of both. Repository concepts were developed for each option to ensure that the requirements of 10 CFR 60.21(c)(1)(ii)(D) were adequately addressed. Option 30 emerged as the highest ranked option at the conclusion of the study. Following the completion of the ESF Alternatives Study, several modifications to Option 30 were made, incorporating features of other highly ranked options. This process is described in "Documentation of the Evaluation of Findings of the ESFAS Used to Develop a Reference Design Concept" (DOE, 1991b). The resulting "Modified Option 30" formed the basis for the start of Title I Design. It is important to note that in this evaluation the following wording was included to prompt exactly the type of enhancements now being proposed:

"Option 30 did not rank high in the favorable feature of showing maximum distance from the waste emplacement level to the water table. The possibility of increasing the distance between the waste emplacement level and the water table will be addressed during the Title II Design. The favorable feature of avoiding emplacement drifts crossing Ghost Dance fault was not marked high for this option; this will be addressed in the repository design."

2.1-56



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Figure 2.1-5. Enhanced ESF Layout



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### Factors Contributing to a Proposed Reorientation

Repository Design Flexibility. The Advanced Conceptual Design of the potential repository began on October 1, 1992. Consideration of various conceptual repository layouts has led to the conclusion that an ESF main drift which runs parallel, and in close proximity to, the Ghost Dance fault would be advantageous from a repository design standpoint. This arrangement would allow the repository designers a large degree of flexibility with respect to alternative layouts, especially those layouts which allow flat (or nearly flat) slopes in the emplacement drifts and accesses, and those which avoid having emplacement drifts cross the fault.

Maintenance of the Conventional Rail Haulage Option. Members of the Review Board have commented frequently, most recently in their "Sixth Report To The U.S. Congress and The U.S. Secretary of Energy," (NWTRB, 1992), that they feel the gradients in the current ESF are too steep, and that steps should be taken to reduce the slopes to those that can accommodate conventional rail haulage.

Availability of New Data on Contact Elevation. The Soil and Rock Properties portion of the surface-based testing program has been under way since early 1992, and results from the drilling of the NRG holes are being incorporated into the Project's data base. Results from the USW NRG-6 hole have been incorporated into the Interactive Graphics Information System geologic model and used to project the contact elevation between the densely welded devitrified lithophysal-rich tuff (TSw1), upper portion, Topopah Spring Member and TSw2. The elevation of this contact in the north end of the potential repository block is an important factor in the underground layout, as it influences the gradient of the North Ramp; the location of repository emplacement and perimeter drifts; and the main Topopah Spring level drift. Recent information suggests that the contact elevation is somewhat higher (15 m) than that used to develop the Title I ESF layout, or a total of approximately 58 m higher than original projections which were available in 1984 when the basic orientation of the main repository access drifts (current Topopah Spring level main drift) was selected.

### Descriptions of the Current Concept and Proposed Modification

Current ESF Description. The ESF design as it currently exists is shown in the Exploratory Studies Facility Technical Baseline (DOE, 1993n). The design consists of two inclined ramps, north and south, from the surface to the potential repository horizon (TSw2). The North Ramp slopes at -6.8 percent while the South Ramp is at -1.8 percent. The bottoms of these two ramps are connected by a main Topopah Spring level drift. This drift is oriented at N 34° E and slopes at +4.7 percent to the south. The Main Test Area is located in the north end of the potential repository block on the east side of the Ghost Dance fault. An exploratory drift is planned which will extend eastward from the Main Test Area to the imbricate fault zone, which is assumed to bound the potential repository block to the northeast. Two cross drifts are planned. The east cross drift will start from the Topopah Spring level main drift, penetrate the Ghost Dance fault, and extend to the eastern limit of the

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potential repository. The west drift will originate in the Topopah Spring level main drift and extend to the west side of the potential repository block.

A second set of excavations is planned for exploration and testing in the underlying Calico Hills unit. These excavations will include two ramps, north and south, which originate in the lower reaches of the North and South Ramps. These two ramps will extend down to the Calico Hills level with a gradient currently planned to be -10 percent. The lower ends of these ramps will be connected by a main drift lying directly under the overlying Topopah Spring level main drift. Four side drifts are planned to be driven off the Calico Hills main drift. The Calico Hills imbricate drift will underlie the Topopah Spring level imbricate drift. Two drifts are planned to intersect the Ghost Dance fault and one drift, located at the extreme southern end of the Calico Hills main drift, will explore the zeolitic-vitric contact in the Calico Hills unit and extend to the Solitario Canyon fault.

Table 2.1-2 shows the approximate lengths of drifting in each segment, the planned cross-sectional dimensions, the approximate tonnage of material to be excavated, and the planned excavation mechanism as it was shown in the Title I design.

Reoriented ESF Description. The reoriented ESF layout is consistent with Option 30 in all important aspects, as will be shown below. It has North and South Ramp accesses to the Topopah Spring level, a main Topopah Spring level drift, cross drifting, North and South Ramps to the Calico Hills, and fault exploratory drifting in the Calico Hills. The currently planned underground testing program can be fully implemented in the revised layout, and in some areas can be significantly enhanced.

The North Ramp, surface to Topopah Spring level, is oriented on the same azimuth as the current layout. The slope of the ramp would be -2.05 percent. The length of the ramp to the beginning of the curve is 2190 m. The length of curve is 610 m, and the radius of curvature is 305 m. The diameter of the Topopah Spring level ramps and main drift is the same as the current layout or 7.62 m. The azimuth of the main Topopah Spring level drift varies from 183.8° to 180°. The main drift will run generally parallel to the Ghost Dance fault in two straight segments connected by a short curve. The northern segment, at an azimuth of 183.8° will be 1410 m in length and the south segment, at an azimuth of 180°, will be approximately 1740 m in length. The main drift is to be located a minimum of 122 m west of the projected location of the Ghost Dance fault. The slope of the main drift will vary from +0.5 to +2.63 percent. The length of curve for the South Ramp is 470 m, with a radius of 305 m, and the distance from the curve to the surface is 1360 m. The slope of the south ramp is -2.63 percent to the west and its orientation is more east-west than the current design. The Main Test Area will be in the same area (northeast quadrant) of the potential repository block as the current layout. The main drift is located higher in the TSw2 than the current layout, so the access drifts from the main drift to the Main Test Area will slope down to the east. The imbricate fault drift will be in the same general area as in the current layout.

The east and west cross drifting in the Topopah Spring level will be arranged as follows. The east cross drift will be replaced by two or more extended alcoves driven off the main drift. These alcoves need only be approximately 200-300 m in length to penetrate the

Table 2.1-2. Summary of Baseline ESF Drifting

COMPONENT	LENGTH (METERS)	GRADIENT (%)	VOLUME (CUBIC METERS)	DRIFT CONFIG. (METERS)	DRIVEN BY
North Ramp, Surface to TSL	1,965	-6.9	89,613	7.62 Round	TBM
South Ramp, Surface to TSL	2,785	-1.6	127,009	7.62 Round	TBM
North Ramp to Calico Hills	2,049	-10/-6	48,441	5.49 Round	TBM
South Ramp to Calico Hills	2,240	-10/16	52,957	5.49 Round	TBM
TSL Main Drift	3,239	4.7	147,714	7.62 Round	TBM
TSL East Drift	981	-2.6	21,874	3.7x6.1	MM
TSL West Drift	1,082	2.1	24,126	3.7x6.1	MM
TSL Imbricate Drift	685	0.5	16,194	5.49 Round	TBM
Main Test Area	2,865	N/A	63,882	3.7x6.1	MM
CH Main Drift	3,462	3.8	81,847	5.49 Round	TBM
CH East Ghost Dance Drift	463	0.5	6,194	2.7x4.9	RH
CH West Ghost Dance Drift	328	0.5	4,388	2.7x4.9	RH
CH Imbricate Drift	658	0.5	8,803	2.7x4.9	RH
CH Solitario Drift	671	8.75/0	8,977	2.7x4.9	RH
<b>TOTALS</b>	23,473		702,020		

TBM: TUNNEL BORING MACHINE

MM: MOBILE MINER

RH: ROADHEADER

2.1-59

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Ghost Dance fault. Additional contacts with the fault are readily available because of the close proximity of the main drift to the fault. Based on available surface fault trace information, this layout has the added advantage of not having to cross the fault zone in the main drift. The west cross drifting will be executed by extending the North and South Topopah Spring level Ramps to the west. The North Ramp extension would be driven to the Solitario Canyon fault located at the west boundary of the potential repository block. The South Ramp extension would be driven 2005 m, skirting the edge of the potential repository block at its southern extremity. This will provide cross drifting to explore for north-south trending structures along the north and south extremities of the block while leaving the main body of the block unencumbered by drifting which would significantly restrict subsequent repository design flexibility. Another important aspect of these ramp extensions is that they will traverse a large percentage of the vertical extent of the TSw2, providing the opportunity to test and evaluate throughout much of the unit. This is an important feature, as almost any repository design concept, including the current baseline layout, will be forced to utilize a large portion of the thickness of the TSw2 due to the dip of the rock unit.

Drifting in the Calico Hills will be almost identical to the current layout. The concerns for restriction of the potential repository layout are not present in the Calico Hills and there is no reason to deviate significantly from the current plan. This orientation serves to transect the potential repository block in such a manner that any major north-south trending structural features not evident from the drifting carried out in the North and South Ramp extensions (described above) should be discovered. Ramp access will be provided to reach the Calico Hills from the north and south. A main Calico Hills drift will connect the ramps and provide the starting point for drifting to the imbricate fault zone, the Solitario Canyon fault, and the Ghost Dance fault. The north Calico Hills ramp would be somewhat longer than in the current layout, while the south Calico Hills ramp would be shorter. See Table 2.1-3 for tabulation of the revised drifting.

### Advantages of the Reorientation

Maximizes the Vertical Distance From Emplacement Drifts to the Water Table. The location of the main Topopah Spring level drift as high as possible in the TSw2 will allow development of flat potential repository concepts which maximize the vertical distance from emplacement areas to the water table while satisfying the 200-m cover limitation. This is especially evident in the primary block west of the Ghost Dance fault. This was Favorable Feature #7 in the ESF Alternatives Study (Dennis, 1991), and was not present in the repository concept which accompanied Option 30 in the ESF Alternatives Study. This feature is desirable because it would maximize the time for ground-water travel from the emplacement area to the water table.

Allows Potential Repository Layouts Which Avoid Having Emplacement Drifts Crossing the Ghost Dance Fault. The orientation of the main Topopah Spring level drift generally parallel to the Ghost Dance fault would allow the development of repository concepts in which no emplacement drift crosses the Ghost Dance fault. This was Favorable Feature #8 in the ESF Alternatives Study, and was lacking in the repository layout which

Table 2.1-3. Enhanced Layout Drifting

COMPONENT	LENGTH (METERS)	GRADIENT (%)	VOLUME (CUBIC METERS)	DRIFT CONFIG. (METERS)	DRIVEN BY
North Ramp, Surface to TSL	2,800	-2.05	127,693	7.62 Round	TBM
South Ramp, Surface to TSL	1,835	-2.63	83,685	7.62 Round	TBM
North Ramp to Calico Hills	2,295	-10/-6	54,257	5.49 Round	TBM
South Ramp to Calico Hills	1,805	-10/-6	42,673	5.49 Round	TBM
TSL Main Drift	3,155	+0.5/2.0/+2.63	143,883	7.62 Round	TBM
TSL North Ramp Extension	1,615	-1.0/+0.5	73,652	7.62 Round	TBM
TSL South Ramp Extension	2,005	-0.89/-0.77	91,438	7.62 Round	TBM
TSL Imbricate Drift	1,275	N/A	30,143	5.49 Round	TBM
TSL Ghost Dance Drifts (2)	420	+0.5	9,365	3.7x6.1	D&B
Main Test Area	2,865	N/A	63,882	3.7x6.1	MM
CH Main Drift	3,415	3.8	80,736	5.49 Round	TBM
CH East Ghost Dance Drift	465	0.5	6,221	2.7x4.9	RH
CH West Ghost Dance Drift	330	0.5	4,415	2.7x4.9	RH
CH Imbricate Drift	655	0.5	8,763	2.7x4.9	RH
CH Solitario	670	8.75/0	8,964	2.7x4.9	RH
<b>TOTALS</b>	25,605		829,768		

TBM: TUNNEL BORING MACHINE    MM: MOBILE MINER    RH: ROADHEADER    D&B: DRILL & BLAST

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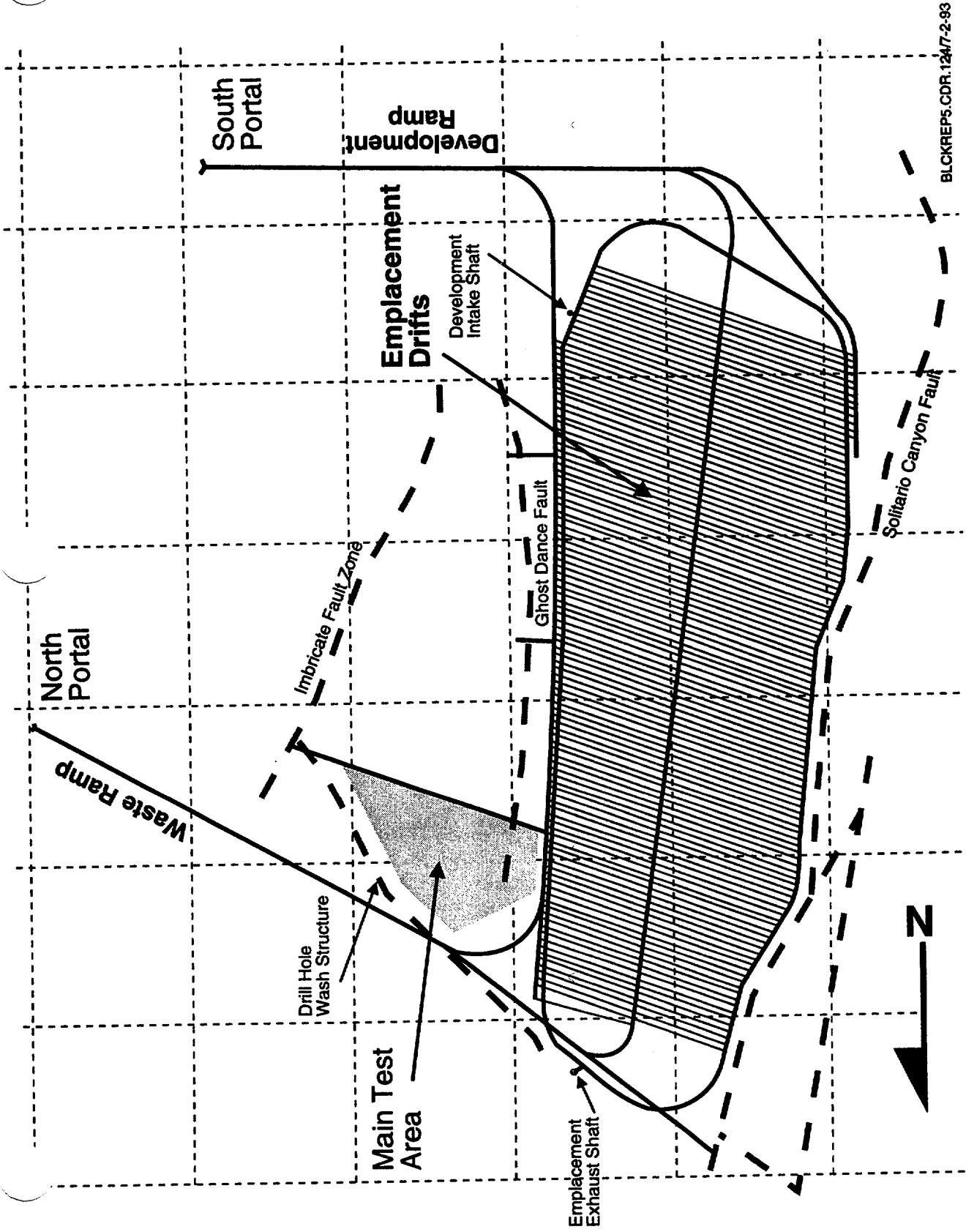
supported Option 30. This feature is desirable because it would minimize the amount of excavation in the fault zone, and would result in less wasted emplacement drift footage, and would negate potential performance concerns which relate to emplacement drifts intersecting one of the more prominent faults in the area.

Preserves the Conventional Rail Haulage Option. The ability to utilize conventional rail haulage in the Topopah Spring level ramps and main drift is a distinct advantage. This would be true during the construction and operation of the ESF, and becomes an even more important consideration in the construction and operation of a potential repository. The important factor is that, by providing tunnels with gradients of less than 3 percent, the ESF would not *preclude* the use of rail haulage. It is not yet known what waste haulage concept will be selected for the potential repository, but, if the construction of ramps and drifts which could become a part of the potential repository is allowed to proceed at the currently designed gradients of 6.9 and 4.7 percent, the conventional rail haulage option will be excluded from consideration. In light of current waste package Advanced Conceptual Design work, which is evaluating very large and heavy package concepts, the use of conventional rail becomes even more appropriate because of the ability of rail to handle heavier loads. Simply stated, the use of flatter grades does not eliminate any type of standard haulage concept while the use of steeper grades does eliminate conventional rail. This idea is stated in the Review Board's Recommendation #5 in its Sixth Report to Congress.

Preserves Potential Repository Design Flexibility. The orientation of the current ESF main drift is a product of earlier potential repository design arrangements in which the main entries bisect the long axis of the block and in which the average slopes of both the main and submain drifts would be approximately the same. This allowed development of emplacement entries or panels of about the same length off each side of the mains, and tended to minimize the total length of main entry footage required. Orientation of the primary and secondary jointing systems was also a factor in the selection of the arrangement. The horizontal location of the TSw2 entry point for the waste ramp and the orientation of the main drifts can be traced back to a study on a phased approach to repository construction which was performed in 1984.

The current repository concept does not consider the Ghost Dance fault to be a constraining factor in the development of the layout. Such a concept requires the Ghost Dance fault to be penetrated at least 50 to 60 times during the construction of a potential repository. In addition to imposing potential performance concerns, the emplacement entry footage in and near the fault would be unusable if emplacement were precluded in fault areas.

A potential repository concept, developed in conjunction with the proposed refinement to the current ESF layout, and which does not require repeated penetrations of the Ghost Dance fault, is shown in Figure 2.1-6. This concept uses the western part of the potential repository block, lying between the Ghost Dance fault and the Solitario Canyon fault, as the primary emplacement area. If the local areal power density ultimately selected for the potential repository equals or exceeds 185 kW/ha (75 kW/acre), this portion of the block should suffice for the entire waste inventory. This compares to a local areal power density of approximately 173 kW/ha (70 kW/acre) in the Site Characterization Plan - Conceptual Design



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Figure 2.1-6. Single Block Repository Concept

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Report (SNL, 1987) layout, and assumes the same 65-MW spent fuel waste stream. If the east portion of the block were needed, it would be developed from main drifts driven from the North and South Ramps along the eastern side of the Ghost Dance fault, as shown in Figure 2.1-7. This two block configuration would accommodate a local areal power density of approximately 148 kW/ha (60 kW/acre). This type of concept has been generally referred to in the Program as a "step block" concept. It minimizes to a great extent the number of penetrations required through the fault, can be developed at grades which would allow conventional rail haulage, and allows the emplacement drifts to be constructed absolutely horizontal, or at whatever slope is determined to be advantageous for drainage.

An important point to consider is that the reoriented ESF layout does not preclude any known repository layout, haulage concept, or the implementation of any currently planned ESF testing activities. Conversely, the current layout does make conventional rail haulage unfeasible, it limits the ability to lay out a potential repository which avoids the Ghost Dance fault to the maximum extent, and it constrains development of potential repository layouts utilizing flat emplacement drifts, unless a large portion of the block (i.e., the area crossed by the current main Topopah Spring level drift and west cross drift) is removed from consideration.

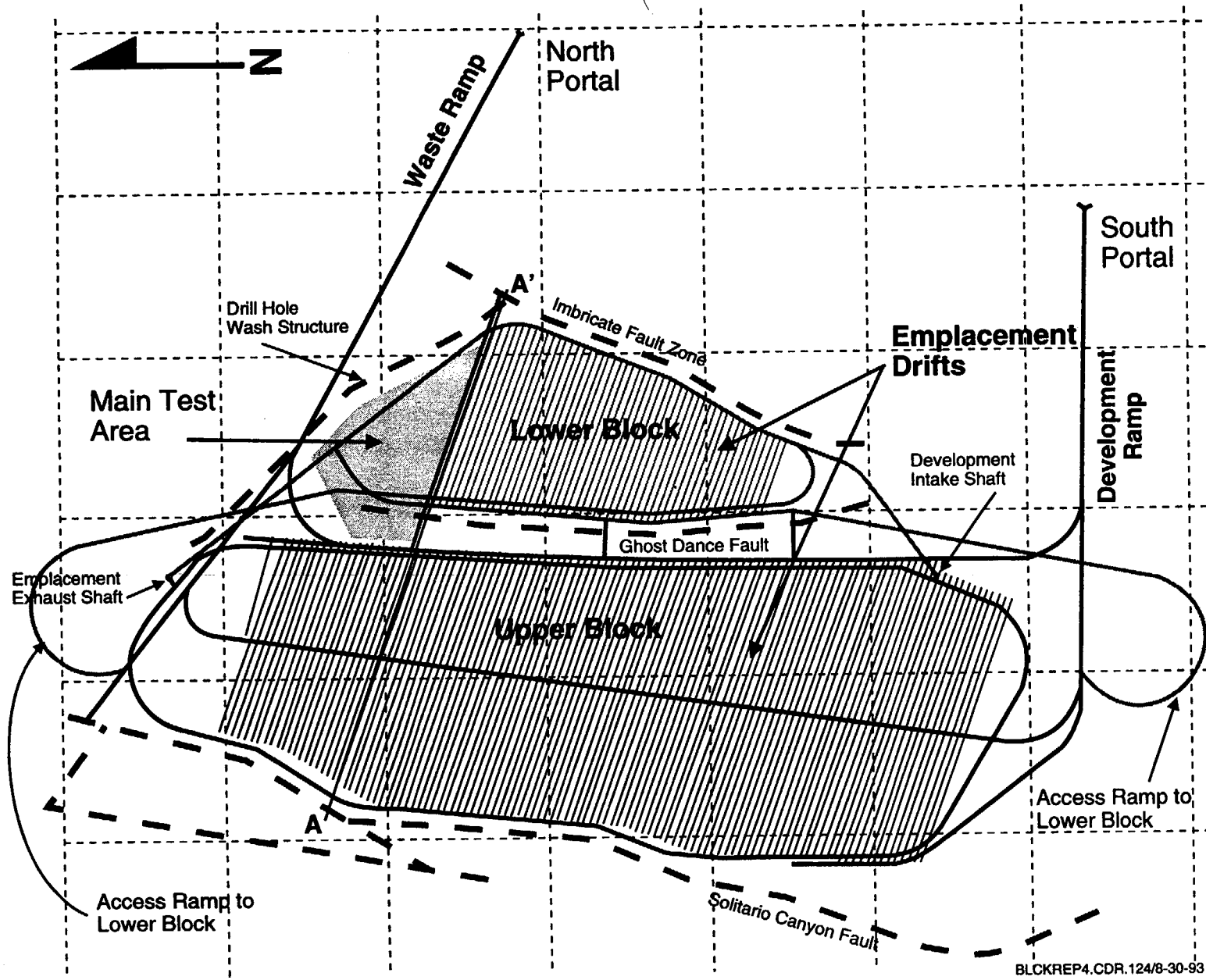
### Conclusions And Recommendations

The proposed enhancements to the layout will result in an ESF which possesses all the favorable features embodied by Option 30, plus the two features which Option 30 did not have. In addition, the primary Topopah Spring level "loop" will be arranged at grades that will allow the use of conventional rail haulage for construction and operation in the ESF, and that preserve the rail option for a potential repository. It should also be noted that the overwhelming majority of Tunnel Boring Machine-driven tunnels utilize conventional rail haulage for transport of men and materials between the surface and the working face. The enhanced layout would have approximately 9 percent more excavation footage.

In light of the added flexibility that this configuration provides for potential repository layout and haulage system selection, it has been recommended that the new layout be adopted and be added to the ESF Technical Baseline, superseding the existing arrangement. Affected documents would include the ESF Technical Baseline (DOE, 1993n), the ESF Plan (DOE, 1993o), the SCPB (DOE, 1993a), and the Plan for Phased Approach to ESF Design, Development, and Implementation (DOE, 1991a).

This change will require some replanning of the surface-based drilling program related to the ESF. A critical early need will be a borehole, roughly in the center of the proposed repository block, to acquire geotechnical data and information on the TSw1-TSw2 contact in close proximity to the Ghost Dance fault. This hole should also yield information on the suitability of the 122-m offset from the fault. Also required will be a borehole near the proposed entry point location at the end of the curve of the North Ramp to verify the TSw1-TSw2 contact in this area. The TSw1-TSw2 contact information is also needed near





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Figure 2.1-7. Two Block Repository Concept

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the south end of the main Topopah Spring level drift where the drift exits the potential repository block.

**Forecast:** At the end of this reporting period, the proposal for formally modifying the ESF design had not yet been acted upon by the Change Control Board but action is expected in early FY 1994. If the proposed change is accepted, the baseline ESF configuration will be changed during FY 1994.

### **2.1.10 Initiatives in Surface-Based and Underground Testing**

#### **2.1.10.1 Site Investigations Annual Plan**

The Project, with assistance from the M&O Site Characterization Group developed a draft "Fiscal Year 1994 Annual Plan for Site Characterization." A preliminary draft plan was reviewed by Project managers, Participants, and the M&O to identify activities that address current Project goals, and that are consistent with the long-range plan. Activities proposed for implementation in FY 1994 were screened according to Project priorities and budget constraints to produce an integrated site investigations plan. Appendices to the plan summarize work scopes, budgets, schedules, logistical concerns, and expected deliverables for each activity. The status of FY 1993 activities is also summarized; incomplete FY 1993 milestones and deliverables are tracked into FY 1994 until finished.

**Forecast:** The Annual Plan for 1994 is expected to be issued in early FY 1994. The Site Investigations Annual Plan will be revised yearly.

#### **2.1.10.2 Integrated Test Evaluation**

The Integrated Test Evaluation (ITE) is an effort to produce a logical methodology to be used as a tool in prioritizing the testing program during site characterization. The evaluation framework is designed to be used iteratively as test results become available, costs are revised, and Department priorities change.

During this reporting period, the ITE continued its efforts to aid in the prioritization of the testing program. Initial efforts on the ITE-92 effort concentrated on evaluating the ability of tests to address the criteria of suitability of site, regulatory performance objectives, scientific consensus of the general scientific community, and cost of the tests. The ITE-93 effort has centered on adding the criterion of design, updating test costs, and adding Scientific Investigation Plans to the analysis. Costs associated with drilling were assigned to the primary tests requesting the drilling in both ITE-92 and ITE-93. In the FY 1993 effort, the cost of alcove construction in the ESF was allocated to the primary tests requesting alcoves.

Preliminary results of ITE-93 are that the design decisions that will benefit most from specific data provided by the testing program include the thermal loading and waste package decisions. Eight tests have shown to be of clear value because of the cost savings to the

decision making process versus the cost of conducting the test. However, the overall ranking of tests established during ITE-92 is not significantly affected by adding the criterion of design.

**Forecast:** The final report "Integrated Test Evaluation Framework to Prioritize Tests for the Yucca Mountain Site Characterization Project" is expected to be issued in October 1993.

### **2.1.10.3 Test Interference and Waste Isolation Evaluations**

As part of the planning process for testing and construction activity, test interference and waste isolation evaluations are carried out. These evaluations address the potential of site characterization activities to interfere with ongoing or planned tests, and to affect the ability of the site to isolate waste. The evaluations serve as input to the appropriate Test Planning Package or to the QA classification process through Determination of Importance Evaluations. Potential test interference or waste isolation concerns are addressed through imposition of controls on testing, design, construction, or operations activities.

During the current reporting period, 26 evaluations were carried out.

### **2.1.10.4 Technical Assessment of the Exploratory Studies Facility Seismic Design**

A Technical Assessment team was assembled to evaluate the Exploratory Shaft Facility Seismic Design Working Group Report (Subramanian et al., 1990) with respect to its applicability to the current ESF configuration. The recommended seismic design basis in the Working Group Report is being assessed relative to the enhanced ESF configuration, and in light of advances in knowledge on the seismotectonic framework in the vicinity of Yucca Mountain. While the technical assessment is being carried out, a temporary conservative design basis was put in place.

**Forecast:** The Technical Assessment will be completed and a seismic design basis for the ESF will be recommended.

### **2.1.11 Planning for Site Suitability Evaluation**

The response to the three NRC comments and two questions on the Early Site Suitability Evaluation report (Younker et al., 1992) was issued in June, 1993. In addition to the response to NRC, a response package was prepared for comments received from the U.S. Department of the Interior, the State of Nevada, and all affected units of local government.

**Forecast:** During FY 1994, DOE will be initiating two activities that are related to the process of determining site suitability. The first activity is an evaluation of the DOE Siting

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Guidelines that are codified in 10 CFR Part 960 to address changes that have occurred in the Program over the past several years. The second activity will address the methodology to be used for the determination of site suitability, and will be consistent with the results of the evaluation of 10 CFR Part 960. The first of these activities will be conducted by a team that is being formed by DOE in the first quarter of FY 1994, and which may include participation from the State of Nevada and the affected units of local government.

### **2.1.12 Technical Data Parameter Dictionary**

In compliance with QA requirements and good scientific and engineering practices, the M&O is compiling a list of data needs in support of design, performance assessment, and licensing activities. This necessary data is being identified and defined in the Technical Data Parameter Dictionary (CRWMS M&O, 1993e). The data identification process utilizes the prescribed data needs contained in the SCPB with reviews by each Participant organization to factor in the knowledge gained since the SCPB publication.

**Forecast:** The Parameter Dictionary will be used to identify necessary data needs on a schedule to support the site suitability determination and the License Application development processes. It will be published in early FY 1994.

### **2.1.13 Energy Policy Act of 1992, Section 803 Report**

The U.S. Congress, in the Energy Policy Act of 1992 (U.S. Congress, 1992), instructed DOE to evaluate whether its current programs and plans for management of nuclear waste were adequate to deal with volumes or categories that might be generated through new nuclear power plants. The Congress also asked the Secretary to report on additional transportation, interim storage, and geologic repositories needed for these new wastes.

The Department was given one year to perform this study, to write an analysis, and to present its findings to the public for review and comment.

An annotated outline was developed and distributed among interested parties for comment and discussion at a public meeting held in February 1993.

The Department evaluated existing plans, as specified in the Nuclear Waste Policy Act (NWPA, 1983) and ensuing regulations, and wrote the report based on scenarios that included amounts of waste higher than expected in various cases. A reference case was developed and compared with high estimates to ensure that programs and plans could handle extreme estimates over a wide range of conditions.

In addition to waste that may be generated by new nuclear power plants, the report included waste from other sources, including spent nuclear fuel and high-level radioactive waste from both commercial and defense sources.

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The analysis resulted in the conclusion that programs and plans are adequate to handle waste management into the future, based on three findings:

- Radioactive materials from new nuclear power plants, and most other radioactive materials not managed as part of the current waste management system, will not be generated until well into the future.
- Flexibility has been built into the current program and plans.
- Development of the waste management system is at an early stage, and there is ample opportunity to accommodate changing needs.

In June 1993, a draft report on "Adequacy of Management Plans for the Future Generation of Spent Nuclear Fuel and High-Level Radioactive Waste" was released for public comment. The draft followed an evaluation process that invited substantive public involvement at various stages.

Drafts of the report were discussed in two public hearings, one held in Las Vegas, Nevada, on July 20, 1993, and a second held in Washington, D.C. on July 29, 1993.

The NRC and the EPA were consulted in producing the report, as Congress had specified. Those two agencies elected not to comment on the final version of the report. Their earlier comments were incorporated or addressed in response documents.

Responses to all people who commented either at a public meeting, a hearing, or a letter to the Department were addressed in the final report, which is currently being reviewed by DOE Headquarters.

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### SECTION 2.2 SITE PROGRAMS

The site characterization effort for the Yucca Mountain site consists of a number of component programs. These programs, a reference to the section providing a summary of the progress during this reporting period, and a summary of the activity are as follows:

- **Geohydrology (Section 2.2.1)** - investigates surface and subsurface hydrology on both site and regional scales, with ground-water flow system characterization and modeling for both the unsaturated zone and saturated zone (Site Characterization Plan (SCP) Section 8.3.1.2).
- **Geochemistry (Section 2.2.2)** - investigates and models rock chemistry and mineralogy, ground-water chemistry, and geochemical behavior of materials along potential radionuclide transport pathways (SCP Section 8.3.1.3).
- **Rock Characteristics (Section 2.2.3)** - characterizes and models rock stratigraphic and structural features and distributions within the site area, and integrates geophysical and drilling activities to obtain subsurface stratigraphic and structural data (SCP Section 8.3.1.4).
- **Climate (Section 2.2.4)** - analyzes paleoclimate, paleohydrology, and paleo-environment, and characterizes modern climate, future climate, and future hydrology (SCP Section 8.3.1.5).
- **Erosion (Section 2.2.5)** - characterizes modern and past erosion and evaluates the potential effects of future climate and tectonics on erosion (SCP Section 8.3.1.6).
- **Postclosure Tectonics (Section 2.2.6)** - characterizes tectonic features such as igneous activity and fault and fold deformation in the Yucca Mountain vicinity, with emphasis on volcanic activity, and analyzes the potential effects of tectonic processes on a potential repository and the site ground-water system (SCP Section 8.3.1.8).
- **Human Interference (Section 2.2.7)** - evaluates the known and potential natural resources in the site area, and the potential for future human intrusion into the site area in search of such resources (SCP Section 8.3.1.9).
- **Meteorology (Section 2.2.8)** - characterizes the site and regional meteorological conditions of the Yucca Mountain vicinity (SCP Section 8.3.1.12).
- **Offsite Installations and Operations (Section 2.2.9)** - determines the presence of offsite industrial, transportation, and military installations and operations in the Yucca Mountain vicinity, and the potential impacts of these installations and operations on the site area (SCP Section 8.3.1.13).

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- Surface and Subsurface Access Characteristics (Section 2.2.10) - characterizes the properties of surficial soil and rock materials and topographic characteristics in the site area (SCP Section 8.3.1.14).
- Thermal and Mechanical Rock Properties (Section 2.2.11) - determines rock thermal and mechanical properties from laboratory and in situ investigations and characterizes thermal and mechanical stress conditions at the site (SCP Section 8.3.1.15).
- Preclosure Hydrology (Section 2.2.12) - characterizes the potential for flooding and determines location of an adequate water supply for repository construction and operation and preclosure hydrologic conditions in the unsaturated zone at Yucca Mountain (SCP Section 8.3.1.16).
- Preclosure Tectonics (Section 2.2.13) - characterizes faults, seismicity and tectonic stress field, and evaluates the potential for faulting, ground motion, and volcanic ash fall in the site vicinity (SCP Section 8.3.1.17).

These programs are discussed in detail in the referenced sections.

### **2.2.1 Geohydrology (SCP Section 8.3.1.2)**

#### **2.2.1.1 Study 8.3.1.2.1.1 - Characterization of the Meteorology for Regional Hydrology**

The study plan received U.S. Nuclear Regulatory Commission (NRC) acceptance on October 21, 1991.

Activity 8.3.1.2.1.1.1 - Precipitation and meteorological monitoring. Data collection continued during the reporting period. Site meteorological data from five weather stations plus two remote tipping-bucket rain gauge locations were downloaded, reviewed, and archived weekly. Additional precipitation data were collected from the network of 134 nonrecording (storage) rain gauges deployed on and around Yucca Mountain. This network expands the automated network and fills in gaps. Three types of storage gauges were deployed: plastic wedges, 4-in-diameter plastic canisters, and 8-in-diameter National Weather Service gauges. Mineral oil was used in these gauges to minimize evaporation. During the reporting period, there were only five distinct precipitation events affecting Yucca Mountain, resulting in a relatively dry spring and summer following a very wet winter. The exception was an anomalous storm June 5-6, 1993, that quadrupled the mean monthly rainfall and was the largest of the spring and summer. This storm was unusual in that June is typically the driest month of the year in southern Nevada. A thunderstorm struck the southern half of Yucca Mountain on August 27, 1993. Meteoric water samples were taken from the storage gauge network, when possible, for stable isotope analysis.

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Collection and archival of satellite and lightning data continued. Synoptic weather charts were also received and analyzed daily. The daily synoptic weather patterns were cataloged according to the five major weather types. Time-lapse video data of Yucca Mountain weather continued to be collected.

Statistical analysis of precipitation data obtained from the tipping-bucket gauges for the period 1990 through 1993 was initiated. These data are important for characterizing the temporal distribution of precipitation events, including the probability of storm occurrence, storm duration, and storm intensity. The preliminary analysis included a comparison of the tipping-bucket data with daily accumulations obtained using the storage gauge network. Lightning strike data, meteorological data (wind, air temperature, humidity), satellite data (cloud cover and storm type), and the video record were all used to more accurately characterize daily and seasonal storm types. Results of this work are needed to characterize natural infiltration at Yucca Mountain using rainfall-runoff models.

Work continued on a U.S. Geological Survey (USGS) Open-File Report entitled "Precipitation Data from the USGS Storage Gage Network at Yucca Mountain, Nevada, 1992-93" (Ambos). Work continued to reformat weather station data into daily files and summaries of daily precipitation.

**Forecast:** Continue to collect and analyze data from the precipitation networks. Complete the 1992-93 data report.

### **2.2.1.2 Study 8.3.1.2.1.2 - Characterization of Runoff and Streamflow**

The study plan received NRC acceptance on May 14, 1991.

Activity 8.3.1.2.1.2.1 - Surface-water runoff monitoring. Monitoring activities continued at 11 continuous-recording stream gauges, 12 peak-flow sites, and 26 storage-type precipitation gauges. In August and September, new continuous-recording streamflow gauges were installed on the Amargosa River near the California-Nevada state line, on Upper Split Wash in Yucca Mountain, and on Split Wash between Antler Ridge and Live Yucca Ridge. Data collected from these sites will be used to support studies associated with the Unsaturated Zone Infiltration Study and other regional hydrologic activities. Peak-flow gauges for documenting cross-sectional, high-water profiles at these new gauges were also installed. Reference marks were established at the three new sites and verified at other selected sites.

A report entitled "Streamflow and Selected Precipitation Data for Yucca Mountain and Vicinity, Nye County, Nevada, Water Years 1983-85" (Pabst et al., 1993) was approved for publication as a USGS Open-File Report. A draft report entitled "Streamflow and Selected Precipitation Data for Yucca Mountain Region, Southern Nevada, and Eastern California, Water Years 1986-90" (Kane et al.) has been technically reviewed and submitted for approval.



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Intermittent precipitation events occurred within southern Nevada during the reporting period resulting in minor flows at some regional and Yucca Mountain monitoring gauges. Reduction of the surface-water and precipitation records for water years 1991-93 continued.

Activity 8.3.1.2.1.2.2 - Transport of debris by severe runoff. No progress during the reporting period; this was an unfunded activity.

**Forecast:** Monitoring will continue at 14 continuous-recording stream gauges, 12 peak-flow sites, and 29 storage-type precipitation gauges. Two to three additional continuous-recording gauges will be installed at selected drainages along the eastern slope of Yucca Mountain to support the Unsaturated Zone Infiltration Study. Peak-flow gauges will also be installed to supplement data collected at these and other selected continuous-recording sites. Reports documenting runoff and precipitation data for Yucca Mountain and vicinity for 1986-90 and 1991-93 will be completed.

### 2.2.1.3 Study 8.3.1.2.1.3 - Characterization of the Regional Ground-Water Flow System

The State of Nevada sent 58 comments on the study plan to the Office of Civilian Radioactive Waste Management (OCRWM) on March 16, 1993. Responses to these comments were returned to the State on September 22, 1993.

Activity 8.3.1.2.1.3.1 - Assessment of regional hydrologic data needs in the saturated zone. This activity was evaluated during the completion of the study plan, in which prioritization of Project data needs was largely completed. It was determined that as new Project data become available, data needs may change based on previously unrecognized hydrologic conditions. The current data uncertainty was used to prioritize data collection needs, as documented in the study plan.

Activity 8.3.1.2.1.3.2 - Regional potentiometric-level distribution and hydrogeologic framework studies. Hydrochemical sampling was performed in three deep 2-in-diameter piezometers in the central Amargosa Desert using a pump jack assembly. Installation of the pump was accomplished through the use of a modular tripod and electric truck winch, permitting installation depths as great as 213 m. Additional samples were obtained from five piezometers which were bailed. These piezometers were constructed to permit sampling and water-level monitoring of the uppermost saturated zone, for subsequent comparison with deeper screened intervals in adjacent piezometers within the same boreholes. Gas bubbles were observed during the removal of the pump jack tubing, which led to resampling of two deep boreholes using a thief sampler so that the gas could be kept in solution long enough to be captured and analyzed.

Several wells in the northwest Amargosa Desert that are being monitored by LAC Bullfrog Mine, Beatty, Nevada, were visited. Discussions with LAC personnel took place and water-level records for 12 monitoring wells obtained. LAC records indicated that elevation surveys were made for all 12 wells. Quarterly water-level data from these 12 wells were

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obtained from National Park Service personnel. Measurements are planned by Project staff to corroborate values obtained by LAC personnel. Plans are in process to obtain water samples from various LAC wells and from the underground workings of the LAC Bullfrog Mine.

A report entitled "Lithologic and Geophysical Logs of Drill Holes Felderhoff Federal 5-1 and 25-1, Amargosa Desert, Nye County, Nevada" (Carr et al.) was submitted for internal USGS review.

An abstract entitled "Spreadsheets for Field Analyses of Hydrochemical Samples" (Czarnecki et al.) was prepared for inclusion at the Fall Meeting of the American Geophysical Union in San Francisco, California, December 6-10, 1993. The abstract discusses two computer spreadsheets used to evaluate the representativeness of a hydrochemical sample and to calculate the field alkalinity through incremental acid titration.

Hydraulic testing and hydrochemical sampling were conducted at drillhole USW UZ-14 at Yucca Mountain. A datalogger program was developed for storing selected water-level data obtained by using a pressure transducer. The program stores these data based on a specified change between current and previously stored values of pressure. The program (HYDTEST) was supplied to Site Saturated-Zone Studies personnel for evaluation and testing. Also, hydraulic test results for a 25-hour hydraulic test of USW UZ-14 were analyzed to estimate transmissivity.

Activity 8.3.1.2.1.3.3 - Fortymile Wash recharge study. Soil-moisture measurements and depth-to-water measurements were made in upper Fortymile Wash on a regular basis. Ground-water levels and unsaturated-zone soil moisture continued to decline following a period of recharge in January-March, 1993.

A draft report entitled "Selected Hydrologic Data from Fortymile Wash in the Yucca Mountain Area, Nevada, Water Year 1992" (Savard) was prepared. Precipitation, streamflow, unsaturated-zone, and saturated-zone data were compiled in the report to document ground-water recharge in Fortymile Canyon during 1992.

Precipitation, streamflow, unsaturated-zone, and saturated-zone data for the Water Years 1992 and 1993 were compiled for inclusion in an extended summary which was submitted for inclusion at the 1994 International High-Level Radioactive Waste Management Conference in Las Vegas, Nevada, May 22-27, 1994. The objectives of the summary were to document ground-water recharge in Fortymile Canyon and to describe water movement through unsaturated volcanic and alluvial strata.

Results of a study that applied chaos theory to time series of streamflow data were presented in an all-day seminar at USGS Headquarters in Reston, Virginia. These results and their possible significance for Yucca Mountain hydrology were discussed with other participants in the seminar, which focussed on the application of nonlinear theory to hydrologic investigations.

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Activity 8.3.1.2.1.3.4 - Evapotranspiration studies. A CR-10 datalogger routine for running Bowen-ratio equipment was modified to incorporate regression equations for pairs of humidity and temperature sensors. The program and equipment were deployed at the Central Site at Franklin Lake Playa for further testing and evapotranspiration estimation. Initial data analyses indicated a possible reversal in equipment wiring which required a site visit to verify. Further analyses indicated variations in dew-point sensor response.

Two data dumps were made on a trial setup of Bowen station equipment designed to estimate evapotranspiration at a central site on Franklin Lake Playa. Humidity sensors were placed side by side to determine if the sensors were capable of producing comparable results over a 20-day period.

**Forecast:** Hydrochemical sampling will continue in deep wells in the Amargosa Desert using a small-diameter jack pump. Water levels will be measured in several strategic wells throughout the flow system. Recharge data from Fortymile Wash will be compiled and prepared as a draft report. Hydrologic and hydrochemical testing of USW G-2 will occur. Implementation of a 2-arm aspirated chilled mirror/thermocouple system will be incorporated into a Bowen-ratio station for deployment at Franklin Lake Playa. Further testing of a dew-cell Bowen ratio station will also continue.

### **2.2.1.4 Study 8.3.1.2.1.4 - Regional Hydrologic System Synthesis and Modeling**

The NRC completed a detailed technical review of the study plan on April 6, 1993, and sent three comments and two questions to OCRWM. The USGS was asked on April 16, 1993, to assess the impact on the study. The OCRWM responded to NRC comments and questions on August 30, 1993. The State of Nevada sent 18 comments to OCRWM on January 22, 1993. OCRWM responded to the State's comments on April 2, 1993.

Activity 8.3.1.2.1.4.1 - Conceptualization of regional hydrologic flow models. Seminars on characterization of the regional ground-water flow system of Yucca Mountain and vicinity were presented at the USGS District Office in Boston and in the Water Resources Department of the Department of Civil Engineering at the Massachusetts Institute of Technology. Discussions were held with personnel from each group regarding various strategies for site characterization. A paper entitled "Conceptual Models of Regional Ground-Water Flow and Planned Studies at Yucca Mountain, Nevada" (Czarnecki and Wilson, 1993) has been published.

Project staff discussed sampling of carbonate and hydrogenic deposits with USGS Geologic Studies Program staff and attended a meeting to discuss hydrogenic deposits at Site 199 in Crater Flat. A follow-up visit to look at hand specimens resulted in agreement that hydrogenic deposits west of Stateline, Nevada, in the Amargosa Desert were very similar to those at Site 199.

Activity 8.3.1.2.1.4.2 - Subregional two-dimensional areal hydrologic modeling.

Activity staff continued to run simulations which examined the removal of the barrier to ground-water flow responsible for representing the large-hydraulic gradient north of Yucca Mountain on the SUN computer. Initial hydraulic head was set to 20,000-year 15x-increased-recharge conditions. Mass balances were typically five to six orders of magnitude smaller than the maximum specified fluxes within the model indicating excellent mass balance. A breakthrough was made in automatic plotting of head-difference contours for each reported time step.

Refinements to a two-dimensional finite element mesh of the subregional flow system were made using the Grid Builder software package. A refined mesh was produced around the Yucca Mountain site with adjusted nodal locations corresponding to actual well locations. A disk file of this mesh was developed for incorporation into the regional Geoscientific Information System data base for establishing land-surface elevations and hydrogeologic properties at the nodal locations.

Personnel from USGS and the M&O met to discuss interfacing a subregional two-dimensional finite-element model domain and hydrogeologic property designations with a two-dimensional boundary-element model being developed for performance assessment by the M&O. A map of the finite-element nodal locations and node numbers and a key for going from local coordinates to central Nevada coordinates was provided to the M&O.

Project staff met to discuss the priority of water table holes that may be selected by Nye County for construction of adjacent monitor wells to be used during the hydraulic testing/sampling of the water table holes. USW WT-1 was considered to be the most desirable of these.

An abstract entitled "Automatic Editing and Graphical Postprocessing of Output from the MODular Finite Element (MODFE) Model" (Czarnecki) was written for the 7th National Computer Technology Meeting of USGS to be held in New Orleans, Louisiana in April 1994.

Activity 8.3.1.2.1.4.3 - Subregional two-dimensional cross-sectional hydrologic modeling. No progress during the reporting period; this was an out-year activity.

Activity 8.3.1.2.1.4.4 - Regional three-dimensional hydrologic modeling. Development of a three-dimensional hydrogeologic framework model of the regional flow system at Yucca Mountain continued. Digital point files describing locations of hydrogeologic units and faults were developed from three-dimensional cross sections. Digital grids of each of the ten hydrogeologic units were developed using major regional faults as discontinuities. These faulted surfaces were visualized as two-dimensional cross sections to evaluate validity and then edited. From these gridded surfaces, preliminary three-dimensional models of the area were developed in both Intergraph's Modular Geographic Information System Environment Voxel Analyst and Dynamic Graphics' Earth Vision software. These preliminary visualizations indicated that some of the regional data would need to be simplified to be used effectively in current three-dimensional modeling software. As a result, modifications were made to refine and simplify cross-section data. Arrangements were made to visualize refined

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data sets in LYNX Geosystem's Geologic Modeling System and Stratamodel's Stratigraphic Geocellular Modeling and Geocellular Template Modeling software. A paper entitled "Geoscientific Information Systems and 3-D Hydrogeologic Framework Models for the Yucca Mountain Area, Southern Nevada and California, USA" has been published (Faunt et al., 1993).

A paper entitled "Hydrogeologic Characterization of Structural Discontinuities in the Death Valley Region, Nevada and California" (Faunt, 1993) was modified as a result of further work on the analysis of structural control of regional ground-water flow. Earthquake epicenters, regional discharge areas, and regional spring discharge locations were incorporated into the data sets for this task. Data were analyzed with the stress and fault data, areas where structural control was evident were delineated, and final maps and figures were prepared.

A report entitled "Preliminary Digital Geologic Maps of the Mariposa, Kingman, Trona, and Death Valley Sheets, California" (Faunt et al.), which includes data used to construct the hydrogeologic map for the study, was completed and began USGS internal review.

A series of Geographic Information System maps was developed by synthesizing and interpreting much of the regional hydrogeologic data of the Death Valley region. Map coverages were used to develop numerical arrays for the three-dimensional MODFLOW model. A vegetation map of the regional model area from Thematic Mapper satellite images was developed. Field verification was conducted and used to enhance accuracy of the map. Water use estimates were developed for the study area based on earlier investigations and additional data from the Nevada State Engineer. A map showing location, type, and estimated volume of ground-water withdrawal was developed.

Present-day discharge areas and previously estimated flux rates were analyzed. This task, conducted in conjunction with the Past Discharge Activity, resulted in the development of a map of areas showing discharge from free-water, bare soils, wetlands/marshes, and phreatophyte areas. Comparisons were made with historical estimates and published models. Discrete discharge from regional springs was also examined. This included analyzing spring discharge rates, temperature and chemistry to determine if a spring was, indeed, a regional discharge component. Additional spring localities in the northern portion of Death Valley were located. A map showing regional springs location, temperature, and discharge rate was developed to be used as a three-dimensional MODFLOW model array for ground-water discharge.

A regional potentiometric-surface map of the regional model area using well, spring, and surface hydrography data was developed. The map was compared to other published maps and topographic data. Additional changes will be made through the end of fiscal year (FY) 1994. Preparation of a USGS report entitled "A Regional Potentiometric-Surface Map of the Death Valley Region, Nevada and California" (D'Agnese) will be deferred until FY 1995 because of lack of funds. Previous ground-water recharge estimates based on the Eakin "first approximation" method were modified. The estimate was the second of three refinements to regional recharge estimation.

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A report summarizing all the work on hydrologic conceptualization for modeling purposes entitled "Hydrology of the Death Valley Region, Nevada and California" (D'Agnese et al.) was begun. However, preparation of this report will be deferred until FY 1995 because of lack of funds.

In conjunction with the Regional Hydrochemistry Activity, regional water chemistry data were sorted by lithology, and basic statistics were run for each lithologic group. Piper plots were made for each lithologic group. The data set was then analyzed in Statistical Analysis System using the method of cluster analysis. Cluster analyses of the chemical data were reviewed and interpreted. The clusters were compared with spatial and geologic information. Preliminary t-tests were run to test for separation of the nine cluster groups that were defined. These clusters were interpreted for hydrochemical significance.

A paper entitled "Using GIS for Three-Dimensional Ground-Water Flow Modeling, Death Valley Region, Nevada and California" (D'Agnese et al.) was presented at a Conference/Workshop on Integrating the Geographic Information System and Environmental Modeling, in Breckenridge, Colorado, on September 28, 1993. The paper discussed the utility and efficiency of using the Geoscientific Information System for regional ground-water modeling.

**Forecast:** No subregional two-dimensional areal or cross-sectional modeling will be done in FY 1994. Planned work will include finishing modifications to the three-dimensional Hydrogeologic Framework Model and completing preliminary runs of the three-dimensional MODFLOW model.

### 2.2.1.5 Study 8.3.1.2.2.1 - Characterization of Unsaturated-Zone Infiltration

Revision 2 of the study plan was sent to the Commission on April 5, 1993.

#### Activity 8.3.1.2.2.1.1 - Characterization of hydrologic properties of surficial materials.

To determine the surface flux at Yucca Mountain, characterization of the hydrologic and physical properties of the surficial materials was performed. Monthly surficial grab samples, tensiometer transects, mapping programs, and geophysical logging programs were used in an effort to measure temporal and spatial changes in hydrologic and physical properties of unconsolidated sediments.

A monthly surficial sampling project, which collected grab samples of the surface materials near each neutron hole, was continued. The samples were sieved in the field and only the less-than-2-mm fraction was used for determination of soil moisture potential and gravimetric moisture content. All the moisture data have been placed into a data base. Preliminary analysis of the data showed that surficial moisture potentials ranged from 2000 bars to 0 bars and gravimetric moisture contents ranged from 0.02 to 0.20 g/g.

Preliminary map unit descriptions for geomorphic surfaces, depth to bedrock, and soil classification have been defined and evaluated in the field. A preliminary landscape position

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map for WT-2 Wash and most of Split Wash has been completed. A first attempt to determine what information will be placed in the Geographic Information System data base has been carried out. The Geographic Information System will serve as the central data base for all characterization data and mapping information. This information, combined with the surficial sampling data, will be used to create a first order surface moisture flux map.

Three transects of tensiometers (60 tensiometers total) were installed in WT-2 Wash. The tensiometers were installed at two depths (15 and 30 cm) at each of the sampling locations. Samples for gravimetric water content, volumetric water content, and soil moisture potential were collected once a month at selected locations along the transects. Bulk samples from each of the tensiometer sites have been sieved into two fractions (<2 mm and >2 mm). Determination of the different size separates of each sample has been completed.

Calibration techniques have been developed for all of the probes used with the geophysical logging van. The calibration techniques are consistent and repeatable for each of the given tools. Software was developed that allowed for time-based logging and proper sensor alignment for each of the tools. The geophysical logging van (neutron, natural gamma, and density tools) has been used in three neutron access holes and at USW UZ-14 and UE-25 UZ#16. The natural gamma and density logs differentiated the caliche and boulder layers found in the alluvial profiles. This permitted determination of layers that may inhibit or control the downward movement of water.

Activity 8.3.1.2.2.1.2. - Evaluation of natural infiltration. Numerical modeling of a small scale watershed, water content and water potential measurements in boreholes and from surface samples, water balance studies, and evaluation of shallow/deep infiltration processes were used to characterize the net present-day infiltration at Yucca Mountain.

The water contents in the existing 99 neutron-access boreholes were monitored on a monthly basis with a neutron probe. All the collected neutron probe data from July 1984 through September 1993, were organized into a functional PARADOX data base with 431,992 measurements. The data have been validated to assure that the data are consistent with the borehole measurement depths. The standard ten counts taken before field measurements indicate that the neutron probes were working properly. Work was begun organizing the measured gravimetric water contents from the drilling of the neutron calibration boreholes. Laboratory analysis of the cores from the last neutron probe boreholes was started. These data will be combined with the initial neutron probe measurements to provide data for calibration. The lithology for each neutron probe measurement depth of the boreholes drilled before November 1991 was identified and organized.

Borehole UE-25 UZN#39 was drilled through 18 m of alluvium in Jackass Flats. Drive core samples were continuously collected for the entire depth. Cuttings were collected at 60 cm intervals for eventual analysis of  $^{36}\text{Cl}$ . This borehole completed the planned boreholes for this activity.

Tensiometer and chilled mirror psychrometer measurements of the surface water potential and gravimetric surface water content measurements were made to evaluate natural

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infiltration and surface boundary conditions. Surface water potentials ranged from -10 to -200,000 kPa and surface water contents ranged from 0.01 to 0.15 g/g. Detailed radiation load modeling of WT-2 Wash accounting for slope, aspect and blocking ridges showed average monthly radiation loads ranging from 12.7 mJ/m<sup>2</sup>/d in December to 32.8 mJ/m<sup>2</sup>/d in June. Preliminary analysis of the Bowen ratio data suggests reasonable agreement with Priestley-Taylor calculations.

Preliminary conceptual models of natural infiltration at Yucca Mountain suggest that models should incorporate four potential topographic positions: ridgetop, sideslope, alluvial terrace, and active channel. Preliminary topographic, geologic, and meteorologic factors influencing infiltration at Yucca Mountain were also identified. Measured water content profiles suggest natural infiltration and percolation of water into bedrock primarily occurs through the shallow alluvium covering the slopes and ridgetops rather than through the deep alluvium at the bottom of washes, except during extreme runoff conditions.

Modeling of the measured water content profile at UE-25 UZ#16 from the surface to the water table suggested the importance of using correct lithology. Hydraulic properties measured on outcrop samples were adequate for this modeling.

Activity 8.3.1.2.2.1.3 - Evaluation of artificial infiltration. Measurements of in situ hydrologic properties and water movement in the surficial materials of Yucca Mountain was performed. Infiltrometer measurements, large scale ponding experiments, and time domain reflectometry were all used to determine, under controlled conditions, the soil water flux in the near surface environment.

Neutron logs of water movement at the UE-25 UZN#85 prototype ponding infiltration experiment continued. The periodic readings showed that internal drainage was proceeding, but at a very slow rate. Bulk density and moisture content samples were taken at each of the time domain reflectometry probe locations. These measurements were used to refine the time domain reflectometry moisture calibration for soils containing carbonate materials. Particle size analysis (<2 mm and >2 mm fractions) were completed for each of the individual stratigraphic units. These data are being used to model the saturated hydraulic conductivity ( $K_{sat}$ ) for each of these stratigraphic units.

A survey of potential field sites for infiltrometer measurements was completed. Sites were chosen that represented the greatest range in potential infiltration rates for various surficial materials. Measurements of infiltration rates were taken in selected wash locations. The double ring infiltrometer measurements of  $K_{sat}$  ranged from 2 to 20 cm/h.

Because the double ring infiltrometer may only be used on flat surfaces, work was started to develop a tension infiltrometer that may be used on sloping surfaces. Several small prototype units were developed and tested on a variety of different soil materials. Use of the tension infiltrometer, in association with the double ring infiltrometer, will allow for controlled measurements of the surface water flux for consolidated and unconsolidated surficial materials.



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A large scale time domain reflectometry calibration experiment was completed at the UE-25 UZN#14 site. A 6 x 3 block (18 blocks total), with each block containing three probe sets, was used to calibrate the time domain reflectometry at various moisture levels. Probe sets were wetted with approximately 4 L of water. At selected intervals, following the wetting, bulk density and water potential samples were collected from the material surrounding each of the probe sets. The bulk density was uniform across the site ( $1.33 \text{ g/cm}^3 \pm 0.2 \text{ g/cm}^3$ ). An R value of 0.72 was obtained from a regression of the measured volumetric water contents vs. Topp's equation. Variability in the measured values were related to a field feature and were not a function of Topp's equation. The field feature affecting Topp's equation is most likely coarse fragment content. Analysis of the particle size fractions (including coarse fragment content) for each of the bulk density samples has been completed. This information will be used to improve Topp's equations fit of the time domain reflectometry data.

**Forecast:** Characterization of hydrologic properties of surficial materials: Borehole geophysical logging will be conducted in boreholes that are completed in FY 1994 to obtain in situ information prior to stemming or casing. Similar borehole geophysical logging will be conducted in the neutron-access boreholes. More intensive logging will be conducted on the 24 boreholes that were completed within the last two years. The geohydrologic/surficial/infiltration/runoff map will be refined based upon the results of field studies and the laboratory analysis of several hundred surficial-materials samples and a preliminary map will be produced.

Evaluation of natural infiltration: Logging the 99 neutron-access boreholes for the detection of changes in water content will continue as an ongoing activity. Water balance studies will continue at selected water shed basins at Yucca Mountain. Irretrievable data such as field water retention, surface-water contents, and evapotranspiration will be collected at field sites. Water-balance data collected in FY 1993 will be reviewed and organized for Technical Data Information Form submittal. Shallow and deep infiltration data, including FY 1992 and FY 1993 neutron-access borehole logging data, will be reviewed and organized. Papers will be written for presentation at the 1994 High-Level Waste Conference.

Evaluation of artificial infiltration: This activity received no funding for FY 1994, therefore no activity is planned.

### 2.2.1.6 Study 8.3.1.2.2.2 - Water Movement Test

Revision 1 of the study plan was submitted to the Commission for a Phase I review on February 18, 1993. It was accepted on April 8, 1993, with no comments.

Activity 8.3.1.2.2.2.1 - Chloride and chlorine-36 measurements of percolation at Yucca Mountain. Analyses of  $^{36}\text{Cl}$  were performed on twenty samples from UE-25 UZ#16 and from several additional samples from neutron-access boreholes USW UZN-11, USW UZN-37, USW UZN-53 and USW UZN-54. These data were analyzed and a talk entitled "Distribution of Chlorine-36 in the Unsaturated Zone at Yucca Mountain: An Indicator of Fast Transport

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Paths" (Fabryka-Martin et al., 1993) was presented at the Focus '93 meeting in Las Vegas, Nevada, September 26-29, 1993. The report discussed how the  $^{36}\text{Cl}/\text{Cl}$  ratios for chloride extracted from soil and ream-bit cuttings were used to provide information on characteristics of water movement through the unsaturated zone at Yucca Mountain. Bomb-pulse  $^{36}\text{Cl}$  was found in the alluvium in two holes down to depths <20 ft; below that depth, bomb-pulse  $^{36}\text{Cl}$  was present in the alluvium only at background levels, providing evidence for the role of deep alluvium and associated vegetation in attenuating infiltration. Elevated levels of  $^{36}\text{Cl}$  in the underlying Paintbrush nonwelded unit were detected in three of five boreholes; this may indicate that fast transport of water via fractures through the Tiva Canyon welded unit is possible. A proceedings paper describing this work was in the Project approval process.

**Forecast:** Data will be collected from surface soil samples, soil profiles from pits, and cuttings from neutron access boreholes and the Exploratory Studies Facility (ESF) to determine the prebomb meteoric  $^{36}\text{Cl}$  ratio; assess the variability in meteoric  $\text{Cl}/\text{Br}$  and  $^{37}\text{Cl}/^{35}\text{Cl}$  ratios; and estimate present-day shallow infiltration.

Cuttings from deep surface-based holes in the unsaturated zone at Yucca Mountain will be collected and analyzed to determine the depth to which bomb-pulse  $^{36}\text{Cl}$  has penetrated, and to correlate such distribution with lithology and structural features, and estimate the average residence time of infiltrating water as a function of depth.

A progress report on  $^{36}\text{Cl}$  analysis will be prepared.

### **2.2.1.7 Study 8.3.1.2.2.3 - Characterization of Percolation in the Unsaturated Zone-- Surface-Based Study**

The study plan received NRC acceptance on March 26, 1992.

Activity 8.3.1.2.2.3.1. - Matrix hydrologic properties testing. Core samples processed for porosity, bulk density, particle density and water content included all preserved samples from neutron holes USW UZN-31 and USW UZN-32, as well as UE-25 UZ#16. The first samples processed from UE-25 UZ#16 were those close to the water table, providing data needed to interpret the various water table levels and bailing information obtained during the final drilling cycles. The processing of all core was expedited by the receipt of a large capacity relative humidity oven.

Rock physical properties were determined for all remaining surface outcrop transect samples (total 1006 samples) and a composite data set of 45 samples was developed that represents all lithologic units to be encountered in UE-25 UZ#16. These samples included additional measurements of saturated conductivity, moisture retention, and sorptivity. This data set, plus all core data from USW UZN-55, USW UZN-54 and USW UZN-53, was provided to INTRAVAL participants for development of models to predict UE-25 UZ#16 water contents. Final UE-25 UZ#16 core data were eventually provided as a validation exercise. Two reports, "Physical and Hydrologic Properties of Rock Outcrop Samples at

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Yucca Mountain, Nevada" (Flint et al.), and "Physical and Hydrologic Properties of a Two-Dimensional Transect of the Shardy Base Microstratigraphic Unit at Yucca Mountain, Nevada" (Rautman et al.), are in draft form for the transect sample data. A paper on the modeled predictions of UE-25 UZ#16 water contents was presented at the INTRAVAL international meeting in Sweden. The data set was also used for inputs in the site scale model and a two-dimensional model investigating lateral infiltration into the Paintbrush nonwelded tuff.

Over 300 samples in a series of 26 vertical transects (3000 ft [914 m] horizontal by 35 ft [10.6 m] vertical) were collected in the nonwelded shardy base of the Tiva Canyon, and were used to examine horizontal and vertical spatial variability. This particular unit exhibits strong vertical deterministic trends based on the volcanic depositional processes, while on a site scale there are few lateral differences. A paper entitled "Spatial Variability in Hydrologic Properties of a Volcanic Tuff" (Istok et al.) was submitted for Ground Water journal review.

Samples collected from UE-25 UZ#16 were received and processing began to prepare plugs for measurement of saturated hydraulic conductivity, air permeability, and particle density using the gas pycnometer, sorptivity at relative humidity dryness, moisture retention and eventually thermal conductivity and unsaturated conductivity. Unsaturated conductivity will be measured using the steady state ultra centrifuge currently in the procurement system. About 20 percent of all samples have saturated flow properties too slow to be measured in the existing permeameter. Necessary arrangements were made to construct a low flow/high pressure permeameter.

Methodology was developed using the CX-2 chilled-mirror psychrometer to measure water potential of the preserved samples from UE-25 UZ#16 samples. The instrument was used to determine moisture retention curves which were done for the 45 samples from the composite data set. Curves were fitted to all data to provide van Genuchten hydraulic parameters for estimation of unsaturated conductivity and exercises were conducted to determine the appropriate number of parameters to best estimate the data.

Another approach to estimating hydraulic parameters is through the use of an analytical solution which uses sorptivity measured at various water contents. This method, presented at the 1993 High-Level Waste Conference, assumes a linear relationship of sorptivity with initial water content and is solved analytically to predict moisture retention and unsaturated conductivity. An apparatus was designed which will provide detailed measurements of imbibition with time for up to eight samples simultaneously to provide the data for the calculation of sorptivity. Two papers entitled "Characterization of Rock Hydrologic Properties Using Model Verification" (Flint et al., 1993) and "Use of a Submersible Pressure Outflow Cell for Determination of Moisture Characteristic Curves on Rock Core" (Flint and Flint, 1993), presented in 1991, have been published.

Activity 8.3.1.2.2.3.2 - Site vertical borehole studies. A criteria letter for instrumenting the existing small diameter UZ boreholes (UE-25 UZ#4, UE-25 UZ#5, USW UZ-13, USW UZ-6s, USW UZ-7, and USW NRG-6) was prepared and submitted to the Yucca Mountain Site Characterization Project Office (YMPO) in July. Most materials and supplies

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to instrument these boreholes were acquired. Arrangements were made to fabricate 15 instrument shelters that will be needed for the unsaturated zone borehole instrumentation program. Work on these shelters will begin in October 1993. Testing of the first instrument shelter that was delivered in December 1992, was conducted throughout the reporting period. This unit appears to be functioning satisfactorily. Arrangements were also made to refurbish two instrument shelters that were fabricated in 1989/1990. These shelters will be used on the small diameter borehole sites (USW NRG-6 and UE-25 UZ#4 and UE-25 UZ#5).

All UE-25 UZ#16 fracture data were compiled and a completion report is presently in preparation.

Two reports entitled "Borehole and Geohydrologic Data for Test Hole USW UZ-6, Yucca Mountain, Nevada" (Whitfield et al., 1993) and "Proposed Algorithm for Determining the Delta Intercept of a Thermocouple Psychrometer Curve" (Kurzmack, 1993) have been published.

### Vertical Seismic Profiling

Velocity measurements (P- and S-wave) of 50 core samples from UE-25 UZ#16 were completed in July. A zero offset and vertical seismic profiling walkaway survey was conducted at the UE-25 UZ#16 borehole site in mid-August. The purpose of this survey was to confirm the feasibility of conducting vertical seismic profiling surveys in the unsaturated zone at Yucca Mountain using a multigeophone string. A single wall-locking geophone was used in the preliminary tests at UE-25 UZ#16. The walkaway survey confirmed that surface seismic energy sources could be detected in the borehole from distances as great as 1219 m, well within the range of offset needed to image the Ghost Dance fault. Data from these tests are being evaluated, with a final report of results due in December 1993.

A presentation was made to NRC in Las Vegas, Nevada, that provided an overview of the purpose, scope, and objectives of the vertical seismic profiling program at UE-25 UZ#16; and a talk, "Multi Mode Reverse Time VSP Migration Overcomplex Structures at Yucca Mountain, Nye County, Nevada" (Balch) was presented.

### Integrated-Data-Acquisition System

Project staff completed the transition to a personal computer-based system. The new system performs four main functions (data acquisition, data transfer to Denver, data translation, and data display/analysis). The data acquisition function is performed by three programs (HDAS, SETHDAS, and HBASE), and was installed at the Hydrologic Research Facility borehole facility in May. An additional data acquisition system was installed in the instrument shelter at the Hydrologic Research Facility building, and is currently monitoring for testing purposes.

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Data transfer is currently handled manually using a remote control program and high speed modems. Data translation is done by a program called ICONVERT, and allows the raw data to be stored in a compact file structure. The display function is handled by the IDISPLAY program which was nearly completed.

Evaluation of data from the Hydrologic Research Facility boreholes continued throughout the reporting period. Sensors in these boreholes have been in operation for a period of 24 months and continue to provide reliable data. Sensors in the second borehole will be pulled in early FY 1994 and recalibrated.

### Surface-Based Air-Permeability Testing

Construction or modification of the surface-based air-permeability testing support trailer was completed. Following reinforcement of the boom, the trailer was successfully load tested with 10,000 lbs. Staff also completed construction of the packer-assembly. The support trailer and packer assembly was field tested at the C-hole complex. Testing included: assembly of the packers, attachment of the packers to the pneumatic tubes and electrical cables, lowering the packers down borehole UE-25 c#1, and inflation of the packers. All testing was successful and the field staff received the training necessary for the operation of this equipment.

The Hydrologic Research Facility calibration lab was modified for the calibration of air-permeability instruments. Calibration of the thermistors, pressure transducers, and mass flow controllers was completed. These will be used for the air-permeability testing in UE-25 UZ#16.

The data acquisition and storage system was assembled. This system consists of power sources, data loggers, switching boxes, and a field personal computer. All instruments that require certification were sent out for calibration. The programs for activation and data collection from the data gathering instruments have been written and tested. The surface-based air-permeability testing activity is fully operational and ready to begin testing in UE-25 UZ#16.

### USW UZ-14 Support

Drilling of USW UZ-14 began in mid-April 1993. As of September 30, 1993, this borehole had been dry-drilled and cored to a total depth of 396 m. In late July, water was encountered at a depth of 383 m, with a standing water level of 381 m. Drilling was temporarily suspended in early-August 1993, to test the hydraulic characteristics of the "perched water zone." Three bail-down and recovery tests were conducted as the borehole was advanced in stages to a total depth of 391 m. Four pumping tests (drawdown and recovery) were conducted after advancing the borehole to the top of the Topopah Spring basal vitrophyre. Water samples were taken to determine if the source of the water encountered could be attributed solely to fluid losses from the drilling of USW G-1 in 1980, or to

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contamination of a naturally occurring perched water zone by these drilling fluids. Analysis of these samples is still in progress. In late September, grout was injected into the perched water zone in an attempt to seal off inflow into the borehole before drilling deeper. The target depth for USW UZ-14 is approximately 610 m.

In May 1993, a talk entitled "Recent Advances in the Practical Utilization of Thermocouple Psychrometers" (Rousseau) was presented at the Fourth Technology Information Exchange Conference hosted by the U.S. Department of Energy (DOE) in Knoxville, Tennessee.

Six abstracts were prepared and submitted for presentation at the 1994 High-Level Waste Conference in Las Vegas. The titles of these papers are as follows:

1. "Evaluation of a 6-wire Thermocouple Psychrometer for Determination of In-Situ Water Potentials" - (Loskot et al.)
2. "A Gas Sampling System for Withdrawing Nearly Vapor-Saturated Gases from Deep Boreholes" - (Thordarson et al.)
3. "A Borehole Instrumentation Program for Characterization of Unsaturated-Zone Percolation" - (Kume and Rousseau)
4. "Results of Prototype Borehole Instrumentation at the Hydrologic Research Facility, Area 25" - (Rousseau et al.)
5. "Results of Air-Permeability Testing in Vertical Boreholes at Yucca Mountain" - (LeCain and Walker)
6. "Applications of Multi-Mode Imaging to Multiple Offset VSP Data" - (Balch et al.)

Activity 8.3.1.2.2.3.3 - Solitario Canyon horizontal borehole study. No progress during the reporting period; this was an out-year activity.

**Forecast: Surface-Based Borehole Studies:** The drilling of Unsaturated Zone and Systematic Drilling boreholes will continue to be monitored for adherence to the drilling requirements of this activity. Sensors will be calibrated for use in the instrumentation of boreholes. Boreholes USW NRG-6, USW UZ-7, and UE-25 UZ#16 are scheduled for instrumentation in FY 1994. A second gas sampling apparatus, designed to prevent vapor condensation during gas sampling, will be assembled and tested. Downhole Instrument Station Apparatuses for instrumenting boreholes in FY 1994 will be procured, assembled, and tested. The instrumentation and stemming plan for USW NRG-6, USW UZ-7, and UE-25 UZ#16 will be completed. The UE-25 UZ#16 completion report will be completed. Papers will be written for presentation at the 1994 High-Level Waste Conference.

**Vertical Seismic Profiling:** Zero offset and walkaway data acquired at UE-25 UZ#16 will be analyzed and processed and a report will be written on the results. The geophone

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string will be installed in UE-25 UZ#16. Plans will be made for collection of the vertical seismic profiling data. The detailed survey will be conducted at UE-25 UZ#16 involving several hundred source offsets in multiple directions from the borehole. Special effort will be made to cover the Ghost Dance fault and other features of hydrogeologic importance. Data collected from the vertical seismic profiling production survey will be processed and interpreted. A report on the results of this work will be prepared. Cross-hole vertical seismic profiling data collected at the Colorado School of Mines experimental mine will be evaluated and reported on. Papers will be written for presentation at the 1994 High-Level Waste Conference.

Hydrologic Data Acquisition System: A program to verify the proper operation of in situ borehole sensors will be developed, coded, and tested. The Hydrologic Data Acquisition System will be installed at boreholes USW NRG-6 and USW UZ-7 for the monitoring instruments and collection and storing acquired data. Instrumentation in the Hydrologic Research Facility boreholes will be monitored in FY 1994. Data from these boreholes will be analyzed to assess the performance of the Hydrologic Data Acquisition System. Reports detailing the results of gas sampling software and the Downhole Instrument Station Apparatus Test program will be written.

Air-K & Gaseous-Tracer-Testing: Staff will prepare for surface-based air permeability testing of UE-25 UZ#16 by ensuring that all equipment is available and calibrated, all planning and quality assurance (QA) documents are in place, and reviewing hydrogeologic conditions in the borehole. Staff will conduct air-permeability testing in borehole USW SD-12, and smaller diameter boreholes, provided that equipment is available to accommodate testing in these boreholes. A second borehole packer-testing system will be constructed and tested. A report on the air-permeability testing of UE-25 UZ#16 will be written.

Matrix Hydrologic-Properties Testing: Laboratory measurements of soil and rock physical properties will be conducted on as many as 2000 surface, borehole, and ESF samples. Water potential will be determined for specially preserved samples. This activity supports many different SCP activities including the Unsaturated Zone Infiltration Study, the Unsaturated Zone Percolation Study, and the Unsaturated Zone ESF Study. Moisture characteristic curves will be determined for about 500 samples. Matrix permeability tests will be conducted on about 1000 samples to define the hydrogeologic units in the unsaturated zone for use in hydrologic models. A report on the current understanding of matrix hydrologic and physical properties based on laboratory results from core samples from seven surface transects will be prepared.

USW UZ-14 Support: Sliding screen assemblies and radio modems will be procured for instrumentation of USW UZ-14. Staff will calibrate in situ instruments for the borehole; assemble, mount sensors, and test Downhole Instrument Station Apparatuses for use in instrumenting the borehole; monitor the drilling of the borehole for adherence to drilling criteria for unsaturated-zone boreholes; conduct detailed fracture logging of core from the borehole; and conduct unsaturated-zone hydrochemistry, gaseous-phase circulation, and air-permeability testing in the borehole. The borehole will be instrumented with 16 instrument

stations, each containing two pressure transducers, two thermistors, two thermocouple psychrometers, and gas sampling tubing. Core samples collected from the borehole will be tested in the Hydrologic Research Facility and the Unsaturated Zone Hydrochemistry Laboratory.

**2.2.1.8 Study 8.3.1.2.2.4 - Characterization of the Yucca Mountain Unsaturated Zone in the Exploratory Studies Facility**

Revision 2 of the study plan (adding Activity 8.3.1.2.2.4.10) was submitted to the Project for verification of comment resolution on October 1, 1993.

Activity 8.3.1.2.2.4.1 - Intact-fracture test in the Exploratory Studies Facility.

Fabrication of a low-pressure vessel to test single fracture rock cores was completed. The vessel was assembled and tested for leaks and will be torn down to start connecting the monitoring instruments. The linear variable differential transducer calibration stand was modified and delivered in late-July 1993, and the mounts were completed and delivered in September 1993. A "blank sample" is currently being fabricated and delivery is expected in October 1993.

Activity staff continued to provide support for prototype testing of the Percolation test in the Exploratory Studies Facility (Activity 8.3.1.2.2.4.2). Support included the following: documenting day-to-day events concerning the Block E, core 13B, and imbibition tests and data collection; air-permeability testing of boreholes in Block E; recalibration of thermocouple psychrometers used for Block E test; coring of samples from Block E trimmings for imbibition tests (included set up for wet-drilling, glove box refurbished and two stations set up for these tests); and preparation of a draft of a technical procedure for thermocouple psychrometer calibrations.

Activity 8.3.1.2.2.4.2 - Percolation tests in the Exploratory Studies Facility. The ponding test on a large fractured welded tuff block from the Tiva Canyon columnar unit was restarted in September 1993. The block dimensions are 54.3 cm long x 47.5 cm wide x 80.6 cm high. Originally, the test was terminated, and data collection stopped in January 1993. In July 1993, and following gas injection into the fractures, the ponded water that was left on top of the block started flowing slowly into the block. Most of the remaining water drained over a three-day period. Following the gas injection in July, it was verified that the fractures were open and continuous from top to bottom of the block. Entrapped air and/or bacterial growth were suspected to have caused the water to stop flowing during the original testing period prior to January 1993. Based on the latest events, entrapped air seems to be the major mechanism that interferes with water flow in fractures. After restarting the test, water started to continuously flow through the block. Measurements are still under way.

Measurements of water-flow rates through a naturally fractured core were made at unsaturated conditions. The core dimensions were 7.0 cm long x 4.2 cm in diameter, and the fracture was axial. The measurements were made at different boundary pressures, and lasted for four weeks. A significant variability was observed in flow rates made at the same



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boundary pressures. The variability was attributed to entrapped air and bacterial growth. Both entrapped air and bacteria do occur in natural systems and may cause similar variability in the natural environment.

Two summary papers entitled "Laboratory Measurements of Water Infiltration Rates into a Block of Fractured Tuff" (Thamir et al.), and "Laboratory Measurements of Unsaturated Flow Through a Fractured Core" (Thamir et al.), were sent for consideration for presentation at the 1994 High-Level Waste Conference.

Activity 8.3.1.2.2.4.3 - Bulk permeability tests in the Exploratory Studies Facility. No progress during the reporting period; this was an unfunded activity.

Activity 8.3.1.2.2.4.4 - Radial borehole tests in the Exploratory Studies Facility. Plans to use the SEAMIST borehole liner system for air-permeability testing and gas sampling in the radial boreholes were altered. The cost of the SEAMIST system was significantly greater than allocated and therefore pneumatic packers will be used. The packers will be designed and constructed by USGS staff. The system will consist of an injection string and several monitor strings. The injection string will consist of one injection interval capable of injecting 500 standard L per minute. The monitor strings will consist of 15 monitor intervals, 0.3 m in length, separated by 1.7-m packed-off intervals. Each monitor interval will be connected to the alcove with 3/8 in Teflon tubing that will be used to monitor the pressure in the interval and/or obtain gas samples.

The Apache Leap Tuff Site prototype cross-hole air-permeability testing report, "Pneumatic Testing in 45-degree Inclined Boreholes in Fractured Volcanic Tuff near Superior, Arizona," (LeCain) has been submitted for editing.

Activity 8.3.1.2.2.4.5 - Excavation effects test in the Exploratory Studies Facility. Several technical procedures from Sandia National Laboratories (SNL), Waste Isolation Pilot Plant site, were reviewed with the possibility of using them for the ESF test. The procedures discussed two types of instruments that will be used for the ESF test—hydraulic pressure cells for measuring changes in rock pressure, and extensimeters for measuring rock deformation. The SNL procedures were developed with Department funds and were subject to a QA program similar to the one being followed for this project.

Activity 8.3.1.2.2.4.6 - Calico Hills testing in the Exploratory Studies Facility. This activity was deleted from the study plan in Revision 9 of the Site Characterization Program Baseline. Testing in the Calico Hills unit will be described in revisions to ESF study plans.

Activity 8.3.1.2.2.4.7 - Perched-water test in the Exploratory Studies Facility. Monitoring for perched water in the ESF starter tunnel was performed. Supplies and equipment were purchased and prepared for use if needed. A trailer was obtained and will be set up on the ESF pad for potential perched water handling. A design of potential perched water sampling and analysis systems has been ongoing.

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Activity 8.3.1.2.2.4.8 - Hydrochemistry tests in the Exploratory Studies Facility. A scientific notebook was prepared for horizontal borehole instrumentation work in the ESF and was implemented. The location of the first alcove was determined (42.7 m) using available geologic information. A short borehole packer was designed, built and tested in a borehole installed in the right rib at 42.7 m. Gas samples ( $\text{CO}_2$ ,  $\text{SF}_6$ ,  $\text{CH}_4$ ,  $^{14}\text{C}$ ,  $^{13/12}\text{C}$ ) were collected from this short borehole. Staff began the design of a packer system and evaluation of which, if any, of the borehole liner systems will be purchased.

Activity 8.3.1.2.2.4.9 - Multipurpose-borehole testing. This activity was intentionally deleted from the study plan in Revision 9 of the Site Characterization Program Baseline. Under the current ESF design with two ramps, testing is no longer planned in a scientific shaft. This activity was originally planned to monitor hydrologic and engineering interference effects from construction of Exploratory Shafts 1 and 2 on tests in these shafts and interference effects between tests in the shafts.

**Forecast:** The perched water trailer will be set up and the equipment and supplies will be installed in the trailer. A report on perched water equipment will be prepared. Monitoring for perched water will resume as soon as additional construction occurs. Hydrochemistry testing will start early and will consist of collecting samples from boreholes for gaseous and aqueous geochemical analysis. Collecting rock samples throughout the ESF to determine matrix hydrologic properties in the laboratory will start when mining begins. The packer equipment to conduct the radial borehole and major faults tests has been identified and will be procured. Procurement of equipment to support the excavation effects test has been identified, but has not been procured because this test will not be conducted until FY 1995.

Several short boreholes will be sampled during the construction of Alcove #1. Three boreholes will be drilled at the end of the alcove. Traced drilling air from the borehole construction will be evacuated and the boreholes will be monitored for temperature, humidity, moisture content, pressure conditions, air flow and gas chemistry. A packer and/or borehole liner systems will be designed, constructed and tested and used to sample gas and water chemistry from these boreholes.

### **2.2.1.9 Study 8.3.1.2.2.5 - Diffusion tests in the Exploratory Studies Facility**

Activity 8.3.1.2.2.5.1 - Diffusion tests in the Exploratory Studies Facility. No progress during the reporting period; this was an out-year activity.

### **2.2.1.10 Study 8.3.1.2.2.6 - Characterization of Gaseous-Phase Movement in the Unsaturated Zone**

Revision 1 of the study plan was submitted for Project review on April 6, 1993. The Project comments were sent to USGS for response on June 8, 1993. All comments were resolved on September 21, 1993, and the approved study plan was prepared for transmittal to the Commission.

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**Activity 8.3.1.2.2.6.1 - Gaseous-phase circulation study.** Gas sampling for gas chromatographic analysis ( $\text{CO}_2$ ,  $\text{CH}_4$ ,  $\text{SF}_6$ ) and for isotopic analysis ( $^{14}\text{C}$ ,  $^{13/12}\text{C}$ ,  $^3\text{H}$ ,  $^{18/16}\text{O}$ ) was conducted in boreholes USW UZ-6, USW UZ-6s, USW UZ-13 and selected neutron access boreholes. Stable isotope,  $^{14}\text{C}$ ,  $^{13}\text{C}$ , and  $^3\text{H}$  results were received from the Southern Methodist University radiocarbon lab, the USGS Reston Isotope lab, and the Hydrologic Investigation Program Unsaturated Zone Hydrochemistry lab, respectively. Gas sampling for chlorofluorocarbon ( $^{11}\text{F}$  and  $^{12}\text{F}$ ) were conducted in USW UZ-6s. Results were received from the USGS, National Research Program laboratory. Background gas samples for  $\text{CO}_2$ ,  $\text{CH}_4$ ,  $\text{SF}_6$ ,  $\text{CBrCl}_2\text{F}$ , and  $^{13/12}\text{C}$  were collected from 13 Hilti holes (small diameter, shallow boreholes) near the crest of Yucca Mountain and from USW UZ-6s on several occasions, in preparation for conducting the divergent tracer tests at those locations.

A standpipe for measuring air flow direction was designed, constructed and installed at USW UZ-6s. Flow velocity, temperature, and relative humidity data were collected using the new instrument configuration. A flow survey was conducted downhole in UE-25 UZ#16, using an anemometer, to determine the zones of origin of the gas flow. A shut-in pressure test was conducted in four isolated intervals in UE-25 UZ#16 to determine the pressure response of various lithologic units. Two papers, "The Composition  $\text{CO}_2$  Carbon Isotope Signature of Gases from Borehole USW UZ-6, Yucca Mountain, Nevada," (Thorstenson, 1993) and "Does the Wind Blow Through Yucca Mountain?" (Weeks, 1993) were presented at a 1991 Commission meeting and have been published.

Preparation of data and interpretive reports of the physical and chemical data collected from USW UZ-6, USW UZ-6s, and select neutron holes has begun. A meeting was held with University of Nevada, Las Vegas staff to discuss lab tests needed to ascertain the tracer potential properties of various gasses proposed for use as gas tracers. Discussions were held with the M&O and other Project Participants to determine the need for an additional gas flow model for ESF test interference study and the additional data that will be needed to feed that modeling effort. Gas phase circulation model development continued. Various hydrologic procedures were prepared and updated to allow collection of temperature, humidity, pressure, flow and gas phase chemistry data.

**Forecast:** Periodic ongoing testing, sampling, and monitoring activities at boreholes USW UZ-6, USW UZ-6s, and selected neutron-access boreholes will continue in FY 1994. Selected boreholes completed in 1993 will be instrumented and monitored to establish baseline conditions for gaseous-phase circulation in the unsaturated zone. Boreholes along the alignment of the North Ramp, South Ramp, and Main Test Level drift will be tested as part of this study. This includes numerous North Ramp Geologic boreholes, a hole in the systematic drilling program, unsaturated zone boreholes, and existing boreholes. There will be a significant increase in the amount of samples collected and analyzed. The amount of in situ data collected and analyzed will also increase significantly.

**2.2.1.11 Study 8.3.1.2.2.7- Hydrochemical Characterization of the Unsaturated Zone.**

Revision 1 of the study plan was submitted to the Project for review on November 24, 1992. The USGS received Project comments on the revision on February 8, 1993. The Department approved the study plan on September 10, 1993, and it was sent to the Commission on September 17, 1993.

Activity 8.3.1.2.2.7.1 - Gaseous-phase chemical investigations. An evaluation of existing transport models for gaseous  $^{14}\text{C}$  in carbon dioxide showed that calculation of the partitioning of  $^{13}\text{C}$  and  $^{14}\text{C}$  between the gaseous, aqueous, and solid phases, even in a one-dimensional transport model, is not something that can be accomplished by incorporating a simple set of chemical equations into a transport model, nor by simple modifications of existing geochemical modeling codes. Discussions on how to proceed were held with USGS National Research Program personnel. An attempt was made to formulate equations for the distribution of  $^{14}\text{C}$  in aqueous and solid phases. No practical solution to this problem was found. The current approach being tested involves precalculating reactions with PHREEQE and using these numerical results in the transport modeling. A manuscript entitled "Interpretation of Gaseous-Phase Isotopic and Chemical-Composition Data from Test Hole USW UZ-1" (Yang et al.) is in final stages of preparation for publication.

Laboratory analyses of gas samples included: methane, carbon dioxide, and carbon-isotopic concentrations from USW UZ-1; tritium analysis of water vapor samples from USW UZ-1; analysis for carbon dioxide concentrations in gas extracted from UE-25 UZ#16 tuff cores by one-dimensional compression; analyses for carbon dioxide, methane, and  $\text{SF}_6$  concentrations from five depths in the open borehole UE-25 UZ#16. In addition, USW UZ-1 was monitored on five occasions for  $\text{SF}_6$  concentrations and on one occasion for carbon dioxide concentrations to determine if concentrations changed during the drilling of USW UZ-14, which is approximately 30.5 m to the west of USW UZ-1. This was done to evaluate any fracture connection between the two boreholes.

The  $\text{SF}_6$  tracer injection in various boreholes (USW UZ-14, UE-25 NRG#2a, UE-25 NRG#2b, UE-25 NRG#4, and UE-25 NRG#5) and sampling and monitoring of tracer concentrations in those holes continued. Drilling-air samples were collected for tracer-concentration analysis at least twice a day or whenever there was a significant change in the volume of drilling air being injected. A paper entitled "Field Testing the Effectiveness of Removing Sulfur Hexafluoride Traced Drilling Air from a Prototype Borehole near Superior, Arizona" (Peters et al., 1993) has been published.

The insertion of a lightweight, plastic, wire-rope-strung, non-rigid, eight packer string was attempted to a depth of 366 m in borehole UE-25 UZ#16. The packer handling system experienced some problems during the insertion. Due to these insertion problems, only four of the eight packers were inserted, and only to a depth of 183 m. Modifications to the packer handling system will be made in an attempt to alleviate the insertion problems. Gas samples for carbon dioxide, methane, sulfur hexafluoride, and carbon isotopic concentrations were collected from the four packed intervals. Carbon dioxide data indicate that concentration levels at UE-25 UZ#16 are similar to those in other unsaturated zone boreholes at the Nevada

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Test Site, and that concentrations of sulfur hexafluoride have decreased to near background levels.

The adsorption of carbon dioxide gas onto mineral surfaces in Yucca Mountain tuffs, especially the bedded tuff, is known to occur. The extent of adsorption onto various units of Yucca Mountain tuff under various water saturations (with alkalinity similar to the unsaturated-zone) has been investigated. These experiments are important in determining the gas-phase release of  $^{14}\text{C}$  to the accessible environment.

Activity 8.3.1.2.2.7.2 - Aqueous-phase chemical investigations. Additional core from borehole UE-25 UZ#16 and 33 cores from USW UZ-14 were obtained for pore-water extraction by one-dimensional compression and distillation for water analysis of the pore waters. Pore-water extraction tests by one-dimensional compression were completed on 13 core samples (mostly from the Calico Hills unit) from UE-25 UZ#16. Another twenty eight core samples from UE-25 UZ#16 were prepared for one-dimensional pore-water extraction in 1994. Pore-water samples extracted from UE-25 UZ#16 core were sent for cation and anion analyses, and selected samples for  $^{14}\text{C}$  determinations.

Pore-water extraction by distillation was accomplished on over 90 cores from USW UZN-55, UE-25 UZ#16, UE-25 UZ#4, and UE-25 UZ#5 boreholes. Selected water samples from these distillations and one-dimensional compression tests were analyzed for  $^3\text{H}$ ,  $^{18}\text{O}$ , and  $^2\text{H}/\text{H}$  ratio. Water samples from USW UZ-14 perched waters, and UE-25 UZN#2 precipitation waters were prepared and sent for analyses of  $^3\text{H}$ ,  $^2\text{H}$ ,  $^{18/16}\text{O}$ ,  $^{87/86}\text{Sr}$ ,  $^{36}\text{Cl}$ ,  $^{14}\text{C}$ ,  $^{13/12}\text{C}$ , rare earth elements, cations and anions.

Preliminary results for the USW UZ-14 perched-water chemical analyses indicated that a polymer drilling fluid component from G-1 drilling was present in USW UZ-14. Concentrations of inorganic constituents of the three perched water samples indicated that two of them were similar to the UE-25 J#13 water, and one was orders of magnitude higher than the UE-25 J#13 water compositions. The  $^3\text{H}$  concentrations were near background level (i.e., greater than 100 year-old water). Results for other  $^{14}\text{C}$ ,  $^{13/12}\text{C}$ ,  $^{18/16}\text{O}$ ,  $^{87/86}\text{Sr}$ , and  $^2\text{H}/\text{H}$  ratios have not been completed.

A manuscript entitled "Pore-Water Extraction from Unsaturated Tuff by Triaxial and One-Dimensional Compression Methods, Nevada Test Site, Nevada" (Mower et al.) was approved by the USGS for release as a Water-Resources Investigations Report. Two additional manuscripts, a journal paper, "Development of the One-Dimensional Compression Method for Extraction of Pore-Water from Unsaturated Tuff" (Higgins et al.), and a USGS Open-File Report documenting the chemistry of pore-water extracted by compression methods, are in preparation.

**Forecast:** Tracer injection, monitoring, and gas-sample analyses will be completed for USW UZ-14. Tracer gas injection and monitoring activities will be conducted at boreholes UE-25 NRG#5 and USW SD-12. Core samples from the existing boreholes (mostly USW UZ-14) will be compressed and distilled for pore-water extraction. Extracted water will be analyzed for cations, anions, and isotopic content. The USGS Water Resources

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Investigation Report, "Pore-Water Extraction from Unsaturated Tuff by Triaxial and One-Dimensional Compression Methods, Nevada Test Site, Nevada" (Mower et al.) will be published. Three manuscripts, "Interpretation of Gaseous-Phase Isotopic and Chemical-Composition Data from Test Hole USW UZ-1" (Yang et al.), "Development of the One-Dimensional Compression Method for Extraction of Pore-Water from Unsaturated Tuff" (Higgins et al.), and a USGS Open-File Report on pore-water chemistry, are planned for completion.

### 2.2.1.12 Study 8.3.1.2.2.8 - Fluid Flow in Unsaturated, Fractured Rock

Revision 0 of the study plan was submitted to the Commission on September 1, 1992, and the Phase I review was completed January 28, 1993. The Commission provided two comments and requested references cited in the study plan. The OCRWM responded in a letter dated May 27, 1993. Revision 1 is now in Project review.

Activity 8.3.1.2.2.8.1 - Development of conceptual and numerical models of fluid flow in unsaturated, fractured rock. Preliminary work testing the feasibility of deriving fracture porosity from acoustic properties of fractured core was completed. The technique was tested on data from boreholes UE-25 a#4, UE-25 a#5, UE-25 a#6, and UE-25 a#7 located in or near Drillhole Wash. Preliminary results show that core from fractured Topopah Spring partially welded tuff has an average calculated fracture porosity that is high but not unreasonable considering the wash is thought to be fault controlled. A search was started to acquire additional data from varying geologic and structural settings.

Transformation of the large volume of data from the large block percolation experiment (Activity 8.3.1.2.2.4.2) as input for numerical modeling was begun as well as formulation of modeling strategies.

Golder Associates Inc. assisted the USGS staff in adapting a fracture network model, FracMan, to unsaturated zone flow. As part of the conceptual design of this activity, fracture orientations, dip, frequency, density, size, orientation and flow rates in differential stress regimes, and fracture characterization at different scales continue to be compiled from borehole, pavement, and tunnel sources. This information will be used in the formulation of fracture networks and fracture network flow and transport models.

Meetings were held with Geologic Studies Program staff to discuss preliminary results of fracture mapping in the ESF starter tunnel, the UE-25 NRG#1 borehole, and the pavement study near UE-25 NRG#1. The data from the fracture mapping will be incorporated into developing fracture networks.

A report entitled "Numerical Investigation of Steady Liquid Flow in a Variably Saturated Fracture Network" (Kwicklis and Healy) was accepted for publication in Water Resources Research. This report examines the fundamental behavior of unsaturated fracture systems using numerical experiments. Analyses and compilation of existing fracture data from the site are under way and will continue as new information becomes available. A

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report entitled "Numerical and Laboratory Investigations of Transient and Steady-State Flow in a Fractured Core" (Kwicklis et al., 1993) was published. Additional data that were collected to help resolve uncertainties described in this report are being processed, but not yet available for modeling.

About 80 percent of the report/user's guide for the semi-analytical dual-porosity code has been written by Lawrence Berkeley Laboratory (LBL) staff. It contains discussions of dual-porosity models, fracture/matrix interaction equations, shape factors and equilibration times for matrix blocks. It also contains sample problems illustrating the use of the new code. The report has five appendices covering the following topics: numerical solutions to the Richards equation, sorptive lengths and imbibition equilibration times for matrix blocks, grid discretization, comparison between Brooks-Corey and van Genuchten sorptives, and the effect of air on the infiltration of water into matrix blocks. The LBL staff presented simulation results using the dual-porosity code at the unsaturated zone modeling meeting held in Berkeley, August 11-12, 1993.

An approximate expression for the Warren-Root alpha parameter, which governs the fracture/matrix interflow rate and equilibration time, was developed. The approximation utilizes the hydrologic parameters and surface/volume ratio of the matrix block, and seems to be more accurate than previous bounds and estimates. Several papers addressing the effect of block-size distribution, in the context of saturated flow or solute transport, have been collected from the literature and studied. Recent work was focused on developing an approach for approximating the behavior of a *distribution* of block sizes by an *equivalent* matrix block. Using both a Warren-Root and a more exact treatment of fracture/matrix interactions, the equivalent shape factors will be determined in terms of the moments of the block-size distribution function.

Roughly 50 percent of the report on semi-analytical methods, which will use previously developed LBL models to predict permeability from aperture data, has been written. Various sets of published data on aperture distributions and permeabilities of fractures were collected from the literature to use in testing the models. Preliminary results indicate that reasonable estimates of the permeability can be made based on measurements of the mean and standard deviation of the aperture distribution.

Activity 8.3.1.2.2.8.2 - Validation of conceptual and numerical models of fluid flow through unsaturated, fractured rock. No progress during the reporting period; this was an out-year activity.

**Forecast:** No activity is planned for FY 1994; this study is unfunded.

### 2.2.1.13 Study 8.3.1.2.2.9 - Site Unsaturated-Zone Modeling and Synthesis

The study plan was revised extensively during Project review to supply additional detail concerning numerical codes and modeling strategy to be employed by the study. The study

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plan was resubmitted on December 10, 1992, received Project approval on July 2, 1993, and was sent to the Commission on July 14, 1993.

### Activity 8.3.1.2.2.9.1 - Conceptualization of the unsaturated-zone hydrogeologic system.

A report entitled "Estimation of Unsaturated Zone Liquid Water Flux at Boreholes UE-25 UZ#4, UE-25 UZ#5, USW UZ-7 and USW UZ-13, Yucca Mountain, Nevada, from Saturation and Water Potential Profiles" (Kwicklis et al.) was written and will be published in the Proceedings of Focus '93, Site Characterization and Model Validation. The report presents saturation profiles for the four named unsaturated zone boreholes, derives correlations between important unsaturated zone hydrologic parameters, and uses these correlations to calculate flux profiles at the four holes. Hydrologic interpretations made on the basis of this analysis compared favorably with interpretations made using isotope data. Shortcomings in various data used in the analysis were also discussed.

Building on the work described in the report named above, one-dimensional numerical simulations were done which attempted to reproduce the observed saturation and water potential profiles at UE-25 UZ#4 and UE-25 UZ#5 in Pagany Wash. Fair agreement between the observed and simulated profiles was obtained for UE-25 UZ#5 using a time-varying infiltration rate. The one-dimensional simulations were done as a necessary prelude to two-dimensional simulations which will examine the importance of lateral flow. A summary of this work has been submitted for acceptance to the 1994 High-Level Waste Conference.

A presentation on comparison of dual-porosity and effective continuum approaches to thermal modeling was made by Kwicklis and Bodvarsson at the Performance Assessment Thermal Modeling Meeting, June 29, 1993, in Las Vegas. The work presented demonstrated that even at high thermal loads, the relatively simple and efficient composite porosity approach to modeling fracture-matrix systems is an excellent approximation to a more complex, computationally demanding dual-porosity model.

Activity 8.3.1.2.2.9.2 - Selection, development, and testing of hydrologic-modeling computer codes. The decoupled TOUGH code has been successfully tested against the original TOUGH code for various problems of different complexity. For all of the cases tested, the decoupled code gave accurate results.

Activity 8.3.1.2.2.9.3 - Simulation of the natural hydrogeologic system. A report entitled "Development of a 3-D Site Scale Model of Yucca Mountain, Nevada" (Wittwer et al.) on moisture flow is in review at LBL and will be revised according to reviewer comments.

A study was performed addressing the accuracy of the three-dimensional site-scale model with respect to the grid spacing used. A numerical grid for one of the cross sections of the three-dimensional site scale model was developed by halving the vertical and horizontal dimensions of all elements, resulting in four times as many elements. Simulations were run to compare the results with the coarse grid. New moisture tension permeability and porosity data were received from other unsaturated zone activities. A number of reports were received from the participants and generally reviewed for relevance to the site-scale model. After



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reviewing papers on gas flow at Yucca Mountain, the existing unsaturated zone model was modified to include the gas component. In this model, the gas phase consists of both air and water vapor and has both pressure and diffusion as driving mechanism for its transport. A literature search to study the effects of alternate and more realistic surface boundary conditions was begun. Both one-dimensional and two-dimensional simulations of the effects of gas movement due to pressure gradient and diffusion on moisture flow were performed. Some of the parameters and model geometries used in the three-dimensional site-scale model were also used in a study of lateral flow in the Paintbrush unit. A paper entitled "Computer Simulation of Lateral Infiltration into the Paintbrush Unit at Yucca Mountain, Nevada" (McGraw et al., 1993) summarizing this work was accepted for presentation at Focus '93.

Activity 8.3.1.2.2.9.4 - Stochastic modeling and uncertainty analysis. No progress during the reporting period; this was an out-year activity.

Activity 8.3.1.2.2.9.5 - Site unsaturated zone integration and synthesis. No progress during the reporting period; this was an out-year activity.

**Forecast:** Staff at LBL will continue to develop the three-dimensional site-scale model. New geological, hydrological, and geochemical data will continuously be incorporated into the model as they become available. Three-dimensional moisture flow within Yucca Mountain will be evaluated using the site-scale model. Areas of Yucca Mountain with different flow complexity will be identified. For example, areas of the mountain where moisture flow is mostly one-dimensional vertical will be identified. Conversely, other areas of the mountain where two- or three-dimensional complex flow is occurring, perhaps lateral flow in the bedded units, or flow within or near faults and offsets will also be identified. The initial moisture flow report describing the development of the three-dimensional site-scale model will be completed and published. Data on spatial and temporal distributions of infiltration will be incorporated into the model and the results evaluated. Gas effects will be studied using submodels, and then incorporated into the site-scale model. Effects of the ESF on moisture and gas flow in the nearby rock masses will be evaluated using the site-scale model.

### **2.2.1.14 Study 8.3.1.2.3.1 - Characterization of the Site Saturated-Zone Ground-Water Flow System**

The study plan completed the NRC Phase I review on December 6, 1991.

Activity 8.3.1.2.3.1.1 - Solitario Canyon fault study in the saturated zone. No progress during the reporting period; this was an out-year activity.

Activity 8.3.1.2.3.1.2 - Site potentiometric-level evaluation. Monitoring of water levels in the saturated zone at Yucca Mountain continued. Monthly water-level measurements were made in 18 wells. Hourly water-level data were collected from 17 zones in 12 wells, and continuous data were obtained in 4 zones in 2 wells. Thirty-six transducer calibrations were performed in support of the hourly monitored wells. Additional water-level measurements

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were made in support of other activities at the C-Well complex, Well UE-25 UZ#16, and Well USW UZ-14. Evaluation of the 1990-91 water-level data was completed, and a draft of a report entitled "Water Levels in the Yucca Mountain Area, Nevada, 1990-91" (Tucci et al.) documenting water levels for that period was completed. Reduction and evaluation of the 1992 water-level data were completed, and work has begun on a report entitled "Water Levels in the Yucca Mountain Area, Nevada, 1991-92" (Tucci and O'Brien). Evaluation of 1993 water-level data has begun and is continuing. Water levels have essentially remained stable during the reporting period.

Four zones in two wells were monitored continuously to detect water-level fluctuations caused by earthquakes. The region remains seismically active. Water-level fluctuations associated with earthquakes in southern California, May 17-19, 1993, were very minor and transient. All water levels returned to pre-earthquake levels within one to two hours.

Work was begun on plans for drilling two new wells, USW WT-23 and USW WT-24. The sites for these two wells were located in the field in June. Plans for cleaning, reconfiguring, and hydraulic testing of three WT-series wells were completed, as were plans for hydraulic testing of Well USW G-2.

Three reports were published during the reporting period: "Water Levels in Continuously Monitored Wells in the Yucca Mountain Area, Nevada, 1985-88" (Luckey et al., 1993); "Earthquake-Induced Water-Level Fluctuations at Yucca Mountain, Nevada, June 1992" (O'Brien, 1993); and "Hydrologic Responses to Earthquakes, June 28-29, 1992 at Yucca Mountain, Nevada" (O'Brien and Tucci, 1993).

Two reports, "Precision and Accuracy of Manual Water-Level Measurements Taken in the Yucca Mountain Area, Nye County, Nevada, 1988-90" (Boucher) and "Water Levels in Continuously Monitored Wells in the Yucca Mountain Area, Nevada, 1989" (Luckey et al.), have received USGS approval and are being processed for publication.

Activity 8.3.1.2.3.1.3 - Analysis of single- and multiple-well hydraulic-stress tests. A report entitled "Results and Interpretation of Preliminary Aquifer Tests in Boreholes UE-25 c#1, UE-25 c#2, and UE-25 c#3, Yucca Mountain, Nye County, Nevada" (Geldon) was sent out for technical review. Past C-holes test data were analyzed by using manual graphical matching techniques and are included in this report. A paper entitled "Analysis of Aquifer Tests in Miocene Tuffaceous Rocks with Layered Fracture and Matrix Permeability, Yucca Mountain, Nevada" (Geldon) was submitted to the Geological Society of America Annual Meeting in Boston, Massachusetts, October 24-29, 1993.

During June 1993, Wells UE-25 c#1, UE-25 c#2, and UE-25 c#3 were instrumented with transducers in an open-hole configuration to collect atmospheric-loading data. These data will be analyzed to obtain a barometric efficiency correction factor and hydraulic diffusivity.

Activity 8.3.1.2.3.1.4 - Multiple-well interference testing. The USGS Heat and Solute Transport three-dimensional code, written by USGS National Research Program personnel, is

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being used to develop a three-dimensional porous-medium-equivalent model of the C-hole complex (the model can be used for cross-hole test design and analysis of the eventual cross-hole test results). A preliminary run of the Heat and Solute Transport code was successfully completed, using an input file representing a geohydrologic model of the cross-section between UE-25 c#1 and UE-25 c#3.

The Department issued a "Temporary Deferral of Selected Activities" to the USGS covering all pumping activities at the C-holes until the pump power cable issue is resolved. A Department Order required the power cable to be a four-conductor cable, with one of the conductors a ground wire, and all the pump-related equipment be Underwriters' Laboratories, Inc.-listed. This requirement exceeds the National Electric Code. A formal memorandum responding to the deferral order was sent to the Department after an extensive and exhaustive market search, involving all major pump and pump cable companies, in search of a way to resolve the four-conductor/Underwriters' Laboratories, Inc.-listing dilemma.

An interim plan was developed to conduct non-pumping tests at the C-holes until the discharge pipeline is completed, and the power cable issue is resolved. The interim plan involves monitoring for hydraulic effects of barometric pressure changes with open holes and for the hydraulic effects of earth tides and seismic strain with packer-string-instrumented holes.

Activity 8.3.1.2.3.1.5 - Testing of the C-hole sites with conservative tracers. A tracer mixing tank will be required on the surface at the C-holes complex during the tracer tests at the C-holes. The tank design was discussed with Klaus Stetzenbach, Professor of Chemistry at the University of Nevada, Las Vegas, who will be preparing the tracer at the Hydrologic Research Facility, prior to placing it in the tracer tank. Topics discussed included the possibility of any harmful vapors emanating from the tank, necessity of mixing the tracer in the tank, necessity of a mixing pump in the tank, and the availability of prefabricated tanks made from specially resistant materials. Work continued on design refinement and purchasing of materials for the downhole tracer injection system.

**Forecast:** Routine monthly, hourly, and continuous water-level monitoring will continue with the present network. Plans will be formulated for cleaning, reconfiguring, and hydraulic testing for all WT-series wells, as well as several other wells. Specifications for the drilling of Well USW WT-23 will be completed. The 1990-91 water-level data report will be submitted for approval, and a draft of the report on the 1992 water levels will be completed. Water-level data evaluation for 1993 will continue.

Phase I of work at the C-holes will be conducted, and will involve: (1) running a "dummy packer" down the three C-holes to total depth to identify any problems that may arise when the actual packer strings are lowered; (2) lowering the pump shroud (with no pump) to the location where it would eventually be placed in Well UE-25 c#3 (this well has the worst borehole constriction problems among the three), to identify any problems that may arise when the pump and shroud unit are eventually lowered; and (3) installing the packer strings in the three C-holes with three packers in each hole, allowing for four individual zones to be tested. Actual pumping from the C-holes cannot be done until the pump power cable

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grounding issue is resolved, and the discharge pipeline and discharge pond are constructed. It is anticipated that Phase II of work at the C-holes (the pumping phase) may commence in January or February of 1994, allowing for a month or two of cross-hole testing to be done within the forecast period. The collection of data during these tests will be controlled by a computerized data acquisition system that has been developed specifically for these tests.

Activity 8.3.1.2.3.1.6 - Well testing with conservative tracers throughout the site. No progress this reporting period; this was an out-year activity.

Activity 8.3.1.2.3.1.7 - Testing of the C-hole sites with reactive tracers. Data collection was completed on the suite of batch sorption experiments for lithium bromide; the results were analyzed, and two reports describing this characterization work were prepared. In a report entitled "Lithium Batch Experiments" (Newman et al.), the authors discussed sorption isotherms (surface concentration versus fluid concentration) obtained using tuff from Well UE-25 c#2 in the Bullfrog Member. The second report entitled "The Influence of Temperature and the Solid-Liquid Ratio on the Adsorption of Lithium in a J-13 Well Water and a C-2 Bullfrog Tuff System" (Polzer et al.) presented information on the influence of temperature and rock-water ratio on sorption.

Tracer tests were conducted using iodide and polystyrene microsphere tracers in a natural fracture in Bandelier Tuff, in preparation for similar tests in two C-Wells fracture specimens. In preparation for field tests at the C-Wells, several sizes and types of microspheres were tested.

Software documentation and QA efforts continued for the FEHMN application, a three-dimensional, multi-phase heat and mass transfer code.

Two papers were approved by the Project, and accepted for publication by the Journal of Radioactive Waste Management: "A Strategy for Validating a Conceptual Model for Radionuclide Migration in the Saturated Zone Beneath Yucca Mountain" (Robinson) and "The Use of Selectivity Coefficients to Estimate Modified Langmuir Isotherm Parameters as a Function of Experimental Conditions" (Polzer and Essington).

B. Robinson compiled all documentation for the computer code SORBEQ and prepared a paper entitled "SORBEQ—A One-Dimensional Model for Simulating Column Transport Experiments," which was approved by the Project. The model simulates one-dimensional transport governed by the convective-dispersion equation, with equilibrium sorption. It is designed to be used to simulate column sorption data to obtain the best-fit parameter values. This paper also includes all requirements, design, verification, and user information; it will be published as a Los Alamos National Laboratory (Los Alamos) report.

Activity 8.3.1.2.3.1.8 - Well testing with reactive tracers throughout the site. No progress during the reporting period; this was an out-year activity.

**Forecast:** To ensure confidence that field experiments will yield usable results (i.e., a breakthrough curve in an interwell tracer test), Los Alamos staff plans to demonstrate, using

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laboratory-scale specimens, that microspheres transport through fractures; these tests will determine which particle sizes and what quantities will be used in field tests. Staff will also determine, by comparing to dissolved tracer breakthrough curves, whether transport behavior is controlled by hydrologic mechanisms or interactions with the rock surface. All details of the design of C-Wells experiments will be developed. The choice of well and flow rates of circulation will be determined. Using numerical solutions, the test duration, injection amount, concentration and duration of tracer injection, and sampling frequency will be set. The appropriate detailed technical procedures will be written.

### **2.2.1.15 Study 8.3.1.2.3.2 - Characterization of the Saturated-Zone Hydrochemistry**

The study plan was accepted by the Commission in a Phase 1 review letter January 4, 1993, with no comments but with a request for references. The requested references were sent to the Commission on April 20, 1993..

Activity 8.3.1.2.3.2.1 - Assessment of saturated-zone hydrochemical data availability and needs. Using lithologic data from a Geographic Information System retrieval, the previously constructed set of 2203 balanced (<10 percent) analyses was sorted by lithologic type. Basic statistics were calculated for the chemical analyses for each lithologic group. The calculated results were not reasonable, necessitating examination of the process. On finding that many retrieved data were incorrectly associated with well and spring locations, they were retrieved again, verified, the data set re-sorted, and the statistics recalculated. A set of means data calculated using this data set was subsequently used for Statistical Analysis System cluster analysis. Nine distinct clusters were defined by the analysis, which used normalized-Euclidean-distance, farthest-neighbor examination of a log-transformed and pre-clustered version of the means data set. Preliminary interpretation of relative mean concentrations and the results of basic statistics for the populations of each cluster revealed relations between water chemistry, lithology, and geologic structure. In the course of preparation of a draft report for release of the data base it was determined that some location data were incorrect. These location errors were corrected. A report, "Regional Groundwater Chemistry Data, Death Valley Region, Southwestern United States" (Perfect et al.), is in preparation.

Activity 8.3.1.2.3.2.2 - Hydrochemical characterization of water in the upper part of the saturated zone. Planning for construction of a mobile laboratory included examination of extant USGS equipment in Boulder, Colorado, maintenance of analytical equipment (ion chromatograph system) purchased for inclusion in a laboratory, and examination of a currently idle Environmental Protection Agency mobile laboratory in Las Vegas. The availability of the equipment is being pursued by staff as a possible cost- and time-saving opportunity.

Contact has been maintained with possible suppliers of equipment that will be used to discretize saturated intervals of boreholes that will, perhaps, be sampled as part of saturated zone hydrochemistry characterization efforts. The only effort toward development of a downhole data and sample collection system was contact with the manufacturer of a fiber-

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optic-based dissolved oxygen meter for consideration of inclusion in the system to be obtained when funding is allocated.

Field data and a suite of samples were collected in late August during construction of USW UZ-14. The fluid sampled is, at least in part, drilling fluid lost during construction of USW G-1. The complete set of resultant analytical data likely will be available no earlier than December 1, 1993.

Input was provided in preparation of plans to clean out selected water-table holes at the site.

Activity 8.3.1.2.3.2.3 - Regional hydrochemical tests and analyses. Samples and field data were collected at additional springs within Death Valley National Monument to provide a hydrochemical and isotopic means of evaluating the extent to which Death Valley is a boundary of the regional geohydrologic system of which Yucca Mountain area is a part. Precise locations of discrete discharges were determined and site identifications established for all sites sampled to date. A water-treatment system was installed in USGS facilities in Area 25 at the Nevada Test Site to support these and subsequent data- and sample-collection efforts. A paper entitled "Hydrochemical Monitoring Through a Thick Unsaturated Zone at Yucca Mountain, Nevada, USA" (Steinkampf, 1993) describing hydrochemical monitoring at Yucca Mountain has been published.

Activity 8.3.1.2.3.2.4 - Synthesis of saturated-zone hydrochemistry. No progress during the reporting period; this was an out-year activity.

**Forecast:** The report documenting the compilation and assessment of extant hydrochemical data will be reviewed and approved for release. Preparations to conduct detailed hydrochemical characterization at and in the vicinity of Yucca Mountain will continue, but the continuing deferral of capital funding will delay the start of collection of defensible data and samples until about March of 1996. Plans to collect preliminary data and samples during the cleaning of perhaps three water-table holes will be finalized.

### **2.2.1.16 Study 8.3.1.2.3.3 - Saturated-Zone Hydrologic System Synthesis and Modeling**

The study plan was sent to the Commission on January 28, 1993. The Commission accepted the study plan on June 16, 1993, and requested six references cited in it. The references were sent on October 25, 1993.

Activity 8.3.1.2.3.3.1 - Conceptualization of saturated-zone flow models within the boundaries of the accessible environment. Twenty-one outcrop samples were collected, using a portable 1-in-diameter drill, from the Crater Flat Tuff outcrop east of Little Skull Mountain in the Bullfrog Member. The samples were collected and analyzed for the following physical properties: bulk density, porosity, and particle density. Two methods of drying, relative humidity drying and hard drying, were used during processing of the samples. The data will

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be used for scoping calculation for preliminary ground-water modeling of the site area at Yucca Mountain.

Activity 8.3.1.2.3.3.2 - Development of fracture network model. A study on the effects of censoring on fracture data from theoretical pavement maps was done by LBL staff. A report entitled "A Forward Simulation of Pavement Maps and Censoring Effects on Determining Fracture Size Distribution" (Najita) is now in LBL review. A user's manual and tutorial for the fracture flow and transport code TRINET is in review at LBL. The largest fracture flow simulation ever run using TRINET, 250,000 elements on a Sun work station, was successfully carried out. An inversion algorithm called cluster annealing that combines variable aperture fracture to match well hydraulic test data worked successfully and converged much faster than a single element on-off annealing on a synthetic case. A journal paper entitled "Using the Jackknife, the Bootstrap, and Cross-Validation with Spatially Dependent Data" (Mauldon et al.) is in review.

A report presenting fracture data collected from outcrops, "Fracture Data from Outcrops of the Bullfrog Member of the Crater Flat Tuff near Yucca Mountain, Nevada" (Ervin and Chornack), is in the USGS review process. Data include fracture orientation, length and height dimensions, spacing, mineral fill or coating, type of fracture, and qualitative categories for expression, shape, and roughness. The data are organized in table form, and orientation data are plotted on stereonet and in rose diagrams. The data will be used to constrain the numerical fracture-network model discussed above.

Activity investigators are developing a summary of possible conceptual models for fracture flow at the C-hole complex. The model(s) will be the basis for developing the fracture-flow model at the multiple-well complex.

Activity 8.3.1.2.3.3.3 - Calculation of flow paths, fluxes, and velocities within the saturated zone to the accessible environment. No progress during the reporting period; this was an out-year activity.

**Forecast:** A conceptual model for ground-water flow at Yucca Mountain on the site scale (tens of kilometers in x-y space) will be developed in 1994. Preliminary numerical modeling will be done to test the site-scale conceptual model. The conceptual and numerical fracture-network models that will be used to interpret results of hydraulic tests at the C-hole complex will be refined. A report containing data on fracture networks in the Bullfrog Member of the Crater Flat Tuff will be completed. Approximately 20 samples of fracture fill material from outcrops of the Crater Flat Tuff will be collected. The results of the C-hole hydraulic tests also will be examined employing both the inverse technique using the inversion scheme to calculate aquifer properties and by the forward process using the spatially correlated model to predict hydrologic results. Studies of effects of permeable matrix on flow and transport in fractured rocks will be conducted. Results of cross-hole hydraulic and tracer tests at the C-hole complex will be examined to investigate the effects of the tuff matrix. Studies on scale effects will be carried out to understand whether, and how, the findings at the well test scale can be extrapolated to larger scales. Results of cross-hole hydraulic and tracer tests at the C-hole complex will be examined to investigate scale effects.

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### **2.2.2 Geochemistry (SCP Section 8.3.1.3)**

#### **2.2.2.1 Study 8.3.1.3.1.1 - Ground-Water Chemistry Model**

Review comments on the study plan were received in May 1992 and were being addressed during this reporting period.

Data collection on geochemical modeling of Yucca Mountain ground waters in support of the "most active ground-water" model were completed, and a letter report describing the results was in preparation. A summary report of pH and Eh conditions at Yucca Mountain was in progress.

**Forecast:** Staff will address additional comments to the study plan, participate in the October DOE-NRC Technical Exchange, and complete the paper on pH and Eh at Yucca Mountain.

#### **2.2.2.2 Study 8.3.1.3.2.1 - Mineralogy, Petrology, and Chemistry of Transport Pathways**

The study plan was being revised during the reporting period.

Activity 8.3.1.3.2.1.1. - Petrologic stratigraphy of the Topopah Spring Member. There was little progress in this activity because efforts were deferred until samples became available from new drill core and from the ESF. New UE-25 UZ#16 samples have been received; a letter report was prepared summarizing preliminary quantitative x-ray diffraction analyses on the upper portions of the UE-25 UZ#16 core, emphasizing shallow, potentially transmissive zones. However, analysis of the remainder of the UE-25 UZ#16 core, including the Topopah Spring Member host rock, will be completed in FY 1994.

Preliminary data collection on the chemical composition of fracture calcites at Yucca Mountain was completed. A paper on this subject entitled "Combined Quantitative-XRD and Chemical Evaluation of Soil Formation at Yucca Mountain, Nevada" (Vaniman et al., 1993) was published. The results indicated that with the exception of drill core USW G-4, there is a common composition for most unsaturated-zone calcites at Yucca Mountain that is distinct from most calcites in the saturated zone.

Activity 8.3.1.3.2.1.2. - Mineral distributions between the host rock and the accessible environment. Thirty samples from five different major rock groups at Yucca Mountain were prepared for microautoradiography analysis.

Data collection was completed on instrumental neutron activation analyses of calcites from a variety of boreholes. A paper summarizing the results, "Calcite Deposits in Drill Cores USW G-2 and USW GU-3/G-3 at Yucca Mountain, Nevada" (Vaniman), was approved for publication by the Project and will be published as a Los Alamos report.



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An invited talk entitled "Applications of Advanced X-ray Powder Diffraction Methods to Natural Zeolites" (Bish, 1993a) was presented at the International Conference on Applied Mineralogy in Fremantle, Australia, May 30 to June 4, 1993. The talk emphasized the large amount of quantitative information available in the x-ray diffraction patterns of natural zeolites and used numerous examples from Yucca Mountain studies, ranging from studies of the erionite content of tuffs to the hydration/dehydration behavior of zeolites. An abstract of this talk was approved by the Project and published in the conference program.

An invited talk entitled "The Importance Of Zeolites in the Potential High-level Radioactive Waste Repository at Yucca Mountain, Nevada" (Vaniman and Bish, 1993) was presented at the 4th International Conference on the Occurrence, Properties, and Utilization of Natural Zeolites (Zeolite '93) in Boise, Idaho, June 20-28, 1993. The abstract of this talk was published in the conference program. Vaniman evaluated the role of zeolites in waste retardation, site thermal loading, and site hydrology. In particular, the paper considers the details of zeolite-radionuclide interactions in light of recent sorption data. A paper was completed for the conference proceedings volume and was in the Project approval process.

A poster entitled "Equilibrium Modeling of the Formation of Zeolites in Fractures at Yucca Mountain, Nevada" (Chipera et al., 1993) was presented at Zeolite '93. The abstract of this talk was published in the conference program. Equilibrium thermodynamic modeling was used to explain the present-day mineral assemblages at Yucca Mountain, with emphasis on the zeolitic assemblages. The model calculations suggested that silica activity is an important variable in determining the zeolite mineralogy. In addition, it was found that temperature and the dominant alkali or alkaline earth cation exert some control on the stable zeolite assemblage. A full paper was completed for the conference proceedings volume and was in the Project approval process.

Collection of x-ray diffraction and chemical analyses of unweathered tuffs grading into soil horizons was completed. A talk based on this work entitled "Combined Quantitative X-ray Diffraction and Chemical Evaluation of Soil Formation at Yucca Mountain, Nevada" (Vaniman et al., 1993) was presented at the 1993 Clay Minerals Society Meeting in San Diego, September 25-30, 1993. The abstract was approved by YMPO and published in the conference program. This study was designed to examine sources of materials and their modes of transportation, focusing on sources of silica that may be transported downward into the unsaturated zone and the effects of weathering on mafic minerals.

Data collection was completed on the effects of varying humidity on the calibration data obtained for clays and zeolites occurring at Yucca Mountain, and a talk on this subject entitled "Effects of Humidity on Clay and Zeolite Quantitative XRD Analyses" (Chipera and Bish, 1993) was presented at the 1993 Clay Minerals Society Meeting. The abstract was approved by the Project and published in the conference program.

Dust samples were collected from natural dust traps at and near Yucca Mountain and from the cyclone on the drilling rig at UE-25 UZ#16, and the samples were characterized using x-ray diffraction and scanning electron microscopy to define natural background dust levels in the Yucca Mountain area.

Activity 8.3.1.3.2.1.3. - Fracture mineralogy. A paper entitled "Fracture-Lining Manganese Oxide Minerals in Silicic Tuff, Yucca Mountain, Nevada" (Carlos et al., 1993a) was published in Chemical Geology. The authors indicated that Mn-oxide mineralogy appears to be controlled by both stratigraphy and relationship to the static water level (water table). In fractures below the water table, Mn- and Fe-oxides are potentially the most significant minerals for retardation of some radionuclides, particularly the actinides, and the Mn-oxide minerals may form an important barrier to radionuclide migration in a waste repository. Because of the ease with which the Mn in these minerals is reduced, their contribution to sustaining oxidizing ground-water conditions should be considered.

A poster entitled "Distribution of Fracture-Lining Zeolites at Yucca Mountain, Nevada" (Carlos et al., 1993b) was presented at Zeolite '93. The author presented information on the variation in mineralogy and chemistry of fracture-lining zeolites across Yucca Mountain. An abstract of this poster was approved by the Project and published in the conference program. A full paper was completed for the conference proceedings volume and was in the Project approval process.

**Forecast:** The fracture mineralogy of drillholes USW UZ-14 and UE-25 UZ#16 will be determined, and these data, along with previously collected data on fracture mineralogy, will be included in a report summarizing all fracture-mineralogy studies at Yucca Mountain. The study of respirable minerals at and around Yucca Mountain, and at USW UZ-14 and ESF-related excavations will continue. Trace minerals such as Fe-Ti oxides, which may have significantly greater sorption or surface complexation potential than the bulk rock, will be quantified. The mineralogy and chemistry of calcite in fractures at Yucca Mountain will be studied to determine the origin of calcite-depositing fluids and to identify paleotransport pathways for these fluids. Using x-ray diffraction, x-ray fluorescence, scanning electron microscopy, and optical petrography, the mineralogy of rock units above and below the potential repository horizon using core from UE-25 UZ#16 will be determined. This work will focus on ties between mineralogy, unsaturated-zone hydrology, and thermal loading. Quantitative x-ray diffraction analytical methods, incorporating the effects of changing humidity on hydrous minerals and possibly incorporating compositional information will continue to be improved.

#### **2.2.2.3 Study 8.3.1.3.2.2 - History of Mineralogical and Geochemical Alteration of Yucca Mountain**

The study plan was completed by NRC in a Phase I review on April 27, 1992.

Activity 8.3.1.3.2.2.1 - History of mineralogic and geochemical alteration of Yucca Mountain. Sample collection in the ESF North Ramp Starter Tunnel began.

K/Ar studies of secondary minerals using the electron microprobe and scanning electron microscope continued. Zeolites from altered volcanic ashes at Barstow and Lake Tecopa were examined.

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Data collection was completed on dating zeolites from existing Yucca Mountain drillholes and from other locations in the southwest, and an invited talk on this subject entitled "K/Ar Dating of Clinoptilolites: Methods and Preliminary Results" (WoldeGabriel, 1993) was approved by YMPO and presented at Zeolite '93. An abstract of this work was published in the conference program. A full proceedings paper was also completed and approved by YMPO.

A paper entitled "Paleogeothermal and Paleohydrologic Conditions in Silicic Tuff from Yucca Mountain, Nevada" (Bish and Aronson, 1993) was approved by YMPO and published in the journal Clay and Clay Minerals. The authors used results of illite/smectite studies of clays from Yucca Mountain drill cores and K/Ar dates for some of these clays to reconstruct the paleogeothermal gradients along Yucca Mountain as they existed approximately 11 million years ago. The effects of both deep hydrothermal circulation and "rain-curtain" meteoric recharge may be discernible in the gradients.

A paper entitled "ESR Dating of Quartz from Exile Hill, Nevada" (Cowan et al., 1993) was published in Applied Radiation and Isotopes. Drusy quartz from the Tiva Canyon tuff in Trench 14 was dated using a technique that measured the gradual accumulation of paramagnetic defects produced by alpha recoil in the quartz. The calculated age of  $8.7 \pm 2.6$  million years has a large uncertainty, but is clearly not a Quaternary age.

Data collection was completed on altered rock at Busted Butte and Yucca Mountain, and a paper entitled "Surface-Discharging Hydrothermal Systems at Yucca Mountain—Examining the Evidence" (Levy, 1993) was approved by YMPO and published in the proceedings of the Materials Research Society. The paper describes exposures of altered rock at Busted Butte and Yucca Mountain that were thought to have been formed by recent discharges of water from depth; they were examined to address a concern about hydrothermal processes that could compromise the isolation capability of a potential waste repository. Levy found that the deposits are most likely the products of hydrothermal processes engendered by infiltration of water into newly deposited and still-hot pyroclastic flows that occurred more than 12 million years ago. Data collection on petrographic analysis for an expanded study on this subject was completed, and a paper on this subject entitled "Studies of Altered and Fractured Rocks Exposed around Yucca Mountain, Nevada" (Levy) was being prepared for approval by YMPO.

Preliminary plans were completed for natural self-analog studies of alteration in the Topopah Spring tuff, in conjunction with numerical modeling, as a means of understanding potential repository hydrothermal effects. The plans were summarized in a talk entitled "Natural Alteration in the Cooling Topopah Spring Tuff, Yucca Mountain, Nevada, as an Analog to a Waste-Repository Hydrothermal Regime" (Levy and Valentine, 1993) which was presented at Focus '93. A proceedings paper on this subject was prepared and submitted for Project approval.

Activity 8.3.1.3.2.2.2 - Smectite, zeolite, manganese minerals, glass dehydration, and transformation. Long-term steam-heating experiments, which were begun one year ago, continued. The materials under investigation include devitrified tuff, vitric nonwelded tuff,

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vitrophyre, smectite-rich altered tuff, zeolitic altered nonwelded tuff, cation-exchanged clays, opal-CT, and two standard clinoptilolites.

A talk entitled "Alteration History of Yucca Mountain due to Thermal Effects: Analog for a Hot Repository?" (Bish) was presented to the Nuclear Waste Technical Review Board. The presentation highlighted the following: (1) three kinds of natural alteration at Yucca Mountain that provide insight into the thermal stability of zeolites and clays under saturated conditions; (2) the variability associated with fracture-dominated hydrothermal alteration in the unsaturated zone; and (3) changes in hydrologic properties associated with zeolitization of glassy nonwelded tuffs.

An effort to model the evolution of water from zeolitic tuffs at controlled temperatures and water vapor pressures was begun. The data will help predict the behavior of zeolitic tuffs under repository-induced thermal conditions.

Data collection on the effects of heating on zeolite crystal-lattice dimensions was completed and a talk entitled "Thermal Behavior of Natural Zeolites" (Bish, 1993b) was presented at Zeolite '93. An abstract of this talk was published in the conference program; a proceedings paper was completed and was in the YMPO approval process.

**Forecast:** The report on history of chemical alteration at Yucca Mountain will be supported. Textural, mineralogical, and chemical analyses of core containing alteration features, with emphasis on faults and breccia zones, transport-related features, and natural gels will be collected. Laboratory tests to collect new K/Ar data will be conducted. Using surface and subsurface samples, relationships between mineral alteration and hydrologic history, emphasizing the identification of past preferential ground-water pathways will be studied. Mineralogical and geochemical studies of Trench 14 will be completed. Short-term experiments on pure minerals to determine dehydration/rehydration behavior and volume changes will be performed. The stability of clinoptilolite, smectite, hematite, devitrified, vitric, and zeolitic tuffs, vitrophyre, and opal-CT will be determined in heated dry, steam, and saturated atmospheres over long periods. Studies will be done on the thermodynamics of water adsorption and desorption from zeolites to predict the chemical and mineralogical effects on tuffs in the vicinity of the heated repository under different thermal loading scenarios.

### **2.2.2.4 Study 8.3.1.3.3.1 - Natural Analog of Hydrothermal Systems in Tuff**

No progress during the reporting period; this was an out-year activity.

**Forecast:** No activity is planned for FY 1994.

### **2.2.2.5 Study 8.3.1.3.3.2 - Kinetics and Thermodynamics of Mineral Evolution**

The draft study plan is being revised by Los Alamos staff prior to YMPO review.

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Activity 8.3.1.3.3.2.1 - Kinetic studies of zeolite and related framework silicates. No progress during the reporting period; this was an unfunded activity.

Activity 8.3.1.3.3.2.2 - Determination of end-member free energies for clinoptilolite-heulandite, albite, and analcime. No progress during the reporting period; this was an unfunded activity.

Activity 8.3.1.3.3.2.3 - Solid solution descriptions of clinoptilolite-heulandite and analcime. No progress during the reporting period; this was an unfunded activity.

**Forecast:** The study plan will be revised. The solubilities of mordenite, clinoptilolite, and analcime to derive improved estimates of  $\Delta H_f^\circ$  for use in improving the design of kinetic experiments and for defining their equilibrium states when modeling the response of the potential repository rocks to heating will be measured and evaluated. This activity will focus on the measurement and evaluation of reaction rate constants and associated activation energies for: (1) the dissolution and precipitation of cristobalite; (2) the dissolution and precipitation of mordenite, clinoptilolite, and analcime; (3) reactions between and among mordenite, clinoptilolite, and analcime; and (4) the reaction of smectite to illite. These studies will be carried out from H3OR to 25ORC as functions of: (1) the activity of water; (2) silica activity; (3) aluminum activity; and (4) the ratio of  $H^+/Na^+/K^+/Ca^{2+}$ .

### 2.2.2.6 Study 8.3.1.3.3.3 - Conceptual Model of Mineral Evolution

No progress during the reporting period; this was an unfunded study.

**Forecast:** No activity is planned for FY 1994; this is an unfunded study.

### 2.2.2.7 Study 8.3.1.3.4.1 - Batch Sorption Studies

A draft of the study plan, which combines studies 8.3.1.3.4.1 and 8.3.1.3.4.3, was submitted to YMPO on October 28, 1992. Review comments on the study plan were returned to Los Alamos in February 1993. They were being addressed during this reporting period.

Activity 8.3.1.3.4.1.1 - Batch sorption measurements as a function of solid phase composition. Data collection was completed on the study of uranyl interactions in the goethite/solution interface. A report on this subject entitled "Uranyl Interactions in the Goethite/Solution Interphase Region: Formation of Binary and Ternary Surface Complexes" (Kohler, Honeyman, and Leckie) was being prepared. This report focuses on the development of an empirical data base leading to the derivation of binding constants for uranium adsorption onto goethite in the presence of  $CO_2$  and ethylene-diamine tetraacetate using the triple-layer model to provide the necessary parameters for equilibrium models.

Data collection was completed and a paper entitled "Neptunium Retardation with Tuffs and Ground-waters from Yucca Mountain (3040)" (Triay et al., 1993a) on the role that trace

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minerals in tuff play in Np retardation was published. The results of these studies indicated that sorption of Np does not appear to correlate with the quantity of trace metal oxides in the tuff.

Data collection was completed on a study of radionuclide sorption as it relates to sample grinding, surface area, and water composition, and a paper entitled "Dependence of Radionuclide Sorption on Sample Grinding, Surface Area, and Water Composition" (Rogers and Meijer, 1993) was published. The results of this study indicated that particle grinding does not influence the sorption behavior of the tuff samples until the particle size becomes smaller than about 38  $\mu\text{m}$ .

Activity 8.3.1.3.4.1.2 - Sorption as a function of sorbing element concentrations (isotherms). Data collection was completed on the study of the sorption of  $^{237}\text{Np}$ ,  $^{137}\text{Cs}$ ,  $^{133}\text{Ba}$ , and  $^{85}\text{Sr}$  onto tuffs from the Topopah Spring Member; from zeolitic and vitric Calico Hills; and from the following pure minerals: calcite, hematite, montmorillonite, clinoptilolite, and quartz. Sorption of these tuffs and minerals was studied as a function of radionuclide concentration and temperature (25°, 60°, and 80°C).

Activity 8.3.1.3.4.1.3 - Sorption as a function of ground-water composition. Staff studied sorption of Np onto tuffs and pure minerals (See Section 8.3.1.3.4.1.2.) as a function of ground water (UE-25 J#13, UE-25 p#1, and synthetic) and temperature (25°, 60°, and 80°C). The experimental results will be reported by Triay et al. in a report entitled "Summary Report on Np Transport through Yucca Mountain Tuffs."

The paper by Rogers and Meijer (1993) (see Activity 8.3.1.3.4.1.1 above) reported the results of studies in which devitrified and zeolitized tuffs were pretreated with a synthetic water (with a Paleozoic-rock-aquifer-type water chemical composition) and following this, the sorption experiments were performed with normal UE-25 J#13 ground water. The pretreatment step was undertaken to simulate a situation in which ground water similar to UE-25 J#13 leaked from the repository and contacted deeper layers of tuff that had been previously saturated with a Paleozoic-type ground water. The results indicated that in devitrified tuffs, where sorption is dominated by surface reactions, the sorption of Np is insensitive to adsorption of calcium and magnesium during the pretreatment step. In the case of zeolitic tuffs, the sorption coefficient decreases by a factor of three for the pretreated tuffs. This behavior might be the result of competition for Np exchange sites by the divalent cations in a Paleozoic-type water.

Activity 8.3.1.3.4.1.4 - Sorption on particulates and colloids. No progress during the reporting period; this was an unfunded activity.

Activity 8.3.1.3.4.1.5 - Statistical analysis of sorption data. No progress during the reporting period; this was an unfunded activity.

Activity 8.3.1.3.4.3 - Development of sorption models - (See comment in Section 2.2.2.9.) Staff studied reactions of goethite mineral surfaces with water using atomic force

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microscopy. Certain surfaces were observed to react very quickly with water, producing significantly increased surface roughness.

Data collection on atomic force microscopy images of goethite and hematite surfaces was completed and a report entitled "Atomic Force Microscopy Studies of Natural Mineral Surfaces" (Rogers), which discusses experimentally observed surface reactions with water as a function of surface structure and orientation, was being prepared.

**Forecast:** The following activities will be performed:

1. Whole-rock experiments to determine the effect of organic coatings on radionuclide sorption onto tuffs (with emphasis on Np and U) will be conducted. Spectroscopic techniques to determine the mechanism of radionuclide sorption onto organic coatings will be used.
2. The sorption of U and Pu as a function of radionuclide concentration using tuff samples will be determined. The effect of T on the sorption of U and Pu onto tuff at 25°, 60° and 90°C will be determined.
3. Sorption measurements will be made on U and Pu as a function of ground-water chemistry (using UE-25 J#13, UE-25 p#1, and NaHCO<sub>3</sub> waters) at pH 6, 7, and 8.5. Carbon dioxide overpressures will be utilized to attain the specified pH values.
4. Experiments on pure separates of the minerals found in Yucca Mountain tuffs in various solutions using all of the important radionuclides will be conducted and the results used to interpret and extrapolate the whole-rock K<sub>d</sub> data.

Priorities will be set using Los Alamos sorption strategy. The study of Np and focus on other radionuclides such as Pu and U will be completed. Progress reports and a final report on sorption of radionuclides by single minerals will be produced. To identify the sorbing phases (in tuff) for U and Pu, sorption experiments using pure mineral separates will be conducted, and the identity of surface layers absorbed or precipitated on minerals from Yucca Mountain and their influence on sorption properties will be determined. The validity of the surface complexation model and the validity of parameters obtained from single mineral studies for predicting surface adsorption of Np and U on devitrified tuffs will be tested.

### **2.2.2.8 Study 8.3.1.3.4.2 - Biological Sorption and Transport**

A package of references requested by the Commission in a Phase I review on March 25, 1993, was sent by OCRWM on August 5, 1993.

The principal investigator was on sabbatical leave at the University of California, Berkeley from September 15, 1992 to September 15, 1993, studying microbially enhanced mineral dissolution (goethite and hematite).

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A paper entitled "The Role of Siderophores in the Transport of Radionuclides" (Hersman et al., 1993) was published. The results indicated that actinide elements, which normally exhibit quite low solubilities in near-neutral solutions, can be complexed by carbonate ligands and form solutions of higher actinide ion concentration. The results of this study bear significantly on the transport of radioactive wastes through a soil/rock system because it is possible that siderophores produced by soil microorganisms could complex with actinide/carbonate complexes, thereby altering the transport rate of the elements.

**Forecast:** This task is unfunded in FY 1994.

### **2.2.2.9 Study 8.3.1.3.4.3 - Development of Sorption Models**

This study has been combined with Study 8.3.1.3.4.1. A discussion and status is included in Section 2.2.2.7.

### **2.2.2.10 Study 8.3.1.3.5.1 - Dissolved Species Concentration Limits**

Resolution of all reviewers' comments on the study plan were verified and approved by YMPO on September 9, 1993. OCRWM explained, in the transmittal letter, how the study plan addressed Site Characterization Analysis Comment 96. The study plan was sent to NRC on September 17, 1993.

**Activity 8.3.1.3.5.1.1 - Solubility measurements.** A Los Alamos staff member participated in the panel discussion entitled "Review of Formation of Radiocolloids" at the Yucca Mountain Site Characterization Project (YMP) Colloid Workshop in Santa Fe, New Mexico, May 3-5, 1993.

Staff completed data collection on the final undersaturation experiments for Pu at pH 8.5 and Np at pH 6 in UE-25 p#1 water. A report detailing the results of these studies was being prepared.

Staff began new Np, Pu, and Am/Nd solubility experiments from oversaturation in 0.1-molar sodium perchlorate at 25°C.

Data collection was completed on the study of actinide solubilities and speciations at pH 6, 7, and 8.5 at 25° and 60°C in two Yucca Mountain ground waters, and a paper on this subject entitled "Radionuclide Solubility and Speciation Studies for the Yucca Mountain Site Characterization Project" (Nitsche et al., 1993a) was published. The results indicated that the ground waters differ substantially in total dissolved carbonate concentration, and to a lesser extent in ionic strength. In the waters with higher carbonate content, the solubilities of Np(V) decreased, whereas those of Am(III) increased at 25°C and decreased at 60°C. Pu solubilities did not significantly change with changing water composition because the solubility-controlling solids were mostly amorphous Pu(IV) polymers that contained only small amounts of carbonate.



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A Los Alamos report entitled "Measured Solubilities and Speciations of Neptunium, Plutonium, and Americium in Typical Ground Water (J-13) from Yucca Mountain Region" (Nitsche et al., 1993b) was published. The authors discussed the solubility and oxidation-state distribution of Np, Pu, and Am in UE-25 J#13 water at 25°, 60°, and 90°C and pH 6, 7, and 8.5. Experimental results indicated the following:

1. Neptunium solubility decreased with increasing temperature and with increasing pH.
2. Plutonium concentrations decreased with increasing temperature and showed no trend with pH. Plutonium(V) and Pu(VI) were the dominant oxidation states in the supernatant solution; as the amount of Pu(V) increased with pH, Pu(VI) decreased.
3. For the Am solutions, no clear solubility trend was found with increasing temperature and increasing pH.

Activity 8.3.1.3.5.1.2 - Speciation measurements. Staff participated in the second meeting of the YMP Radionuclide Solubility Working Group in Las Vegas, Nevada, on June 16, 1993. The meeting summary identified twelve major action items and assigned lead responsibility for each item. The next meeting of this group is tentatively scheduled for January 1994.

A Los Alamos staff member presented a talk entitled "Review of Formation of Radiocolloids" (Morris, 1993) at the YMP Colloid Workshop and moderated the session, "Potential Sources of Colloids at Yucca Mountain."

Data collection was completed on characterization of actinide speciation and a report entitled "Actinide(IV) and Actinide(VI) Carbonate Speciation Studies by PAS and NMR Spectroscopies" (Clark et al.) was prepared. It was approved by YMPO and will be published as a Los Alamos report. The report describes the authors' multifaceted approach to characterizing actinide speciation using a combination of photoacoustic spectroscopy, high-field multinuclear nuclear magnetic resonance spectroscopy, and related probes. Examples were chosen from recent results in carbonate media to illustrate the utility of this approach.

Data collection was completed on photoacoustic signal processing, and a paper entitled "Evaluation of Alternative Signal Processing Schemes for Actinide Speciation Using Photoacoustic Spectroscopy" (Tait et al.) was prepared and approved by YMPO. It was in review by the journal Review of Scientific Instruments. This report compares the photoacoustic signal processing schemes that this group developed for YMPO and compares these approaches to those presently in use by other investigators.

Data collection was completed on the speciation of Pu(IV) in carbonate solution as a function of pH, carbonate concentration, temperature, and plutonium concentration; a paper entitled "Plutonium(IV) Carbonate Speciation Changes" (Tait et al.) was being prepared on this subject and will be submitted to the Project for review. It is intended for submittal to the journal Inorganic Chemistry.

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The following three talks were presented at the Actinides '93 International Conference in Santa Fe, New Mexico, September 19-24, 1993:

1. "Carbon-13 NMR Kinetics and Ligand Exchange Dynamics of Actinyl(VI) Carbonate Complexes in Aqueous Solution" (Clark et al., 1993a) described carbonate ligand self-exchange studies conducted on  $\text{PuO}_2(\text{CO}_3)_3^{4-}$  and  $\text{AmO}_2(\text{CO}_3)_3^{4-}$  using  $^{13}\text{C}$  nuclear magnetic resonance spectroscopy. An abstract of this talk was approved by the Project and published in the conference program.
2. "Oxygen-17 and Carbon-13 NMR Studies of Uranyl and Neptunyl Carbonate Complexes in Near-Neutral Solution" (Clark et al., 1993b) discussed the species distribution of actinyl carbonate complexes [U(VI), Np(VI), Np(V)], which was examined using multinuclear nuclear magnetic resonance spectroscopy, for the pH ranges 6.0–9.0. An abstract of this talk was approved by the Project and published in the conference program.
3. "Speciation of Neptunium(V) Carbonates as a Function of Temperature Using Absorption Spectroscopies" (Tait et al., 1993) described recent results on the speciation of Np(V) in carbonate solutions as a function of temperature, pH, and carbonate concentration using conventional ultraviolet-visible-near infrared electronic absorption spectroscopy. An abstract of this talk was approved by the Project and published in the conference program.

Data collection continued on conventional electronic absorption spectroscopy for  $\text{NpO}_2^+$  speciation as a function of changes in bicarbonate concentration, pH, and temperature. New experimental approaches were developed to facilitate these measurements including adaptation of new thermostatted sample and reference cells and use of deuterated water to decrease interference from water absorption.

Data collection continued on using  $^{13}\text{C}$  and  $^{17}\text{O}$  nuclear magnetic resonance data. Explicit speciation information and thermodynamic binding constants for U(VI) in carbonate solution have been determined.

Model development continued on the determination of speciation information from experimental data. Los Alamos staff have developed a working model for use of carbonate/bicarbonate buffers in order to determine the true hydrogen ion concentration pH as a function of ionic strength, thereby removing the uncertainty associated with the need to know the activity coefficient in pH measurements. A more accurate determination of pH will allow direct curve-fitting and extraction of thermodynamic binding constants in Np experiments.

Activity 8.3.1.3.5.1.3 - Solubility modeling. No progress during the reporting period; this was an unfunded activity.

**Forecast:** Using pure crystalline or amorphous phases of the radionuclides, solubility studies for Np, Pu, and Am in J-13, UE-25 p#1 waters and in neutral electrolyte solutions

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from undersaturation experiments at three temperatures and three pH values will be completed. Solubility studies for U from oversaturation and undersaturation in the same solutions will begin. Temperature-dependent, higher concentration conventional UV-Vis spectrophotometric studies of the speciation of Np(V) in synthetic carbonate ground waters will be completed. Temperature-dependent photoacoustic studies of Pu(V), Pu(VI), and Np(V) at extreme dilution in synthetic carbonate ground waters will be continued. Nuclear magnetic resonance species identification and thermodynamic studies of U(VI), U(V), Np(V), Pu(VI), and Pu(V) in synthetic carbonate ground waters will be completed. Thermochemical modeling code EQ3/6 and/or other codes to model solubility and speciation of radionuclides and identify, acquire, and modify thermochemical data bases for actinides for use with these codes will be modified (if necessary).

### 2.2.2.11 Study 8.3.1.3.5.2 - Colloid Behavior

Resolution of all reviewers' comments on the study plan were verified and approved by YMPO on September 9, 1993. OCRWM explained, in the transmittal letter, how the study plan addressed Site Characterization Analysis Comment 96. The study plan was sent to NRC on September 17, 1993.

No progress during the reporting period; this was an unfunded study.

**Forecast:** Work will resume on Pu(IV) studies of chemical behavior and physical properties of colloids using photoacoustic spectroscopy, dynamic light scattering, and chemical reactivity, with emphasis on near-neutral conditions.

### 2.2.2.12 Study 8.3.1.3.6.1 - Dynamic Transport Column Experiments

Review comments on the study plan were received from YMPO in June 1993 and it was being revised to incorporate these comments.

Activity 8.3.1.3.6.1.1 - Crushed tuff column experiments. Data collection was completed on the study of elution of Np solutions using crushed-tuff columns composed of tuff from the Topopah Spring Member and zeolitic Calico Hills and UE-25 J#13 and UE-25 p#1 water. A report entitled "Summary Report on Np Transport through Yucca Mountain Tuffs" (Triay), which incorporates the results of these experiments was being prepared.

A talk was presented at Focus '93 entitled "Far-Field Transport of CO<sub>2</sub>: Retardation Mechanisms and Possible Validation Experiments" (Meijer, 1993). Possible retardation mechanisms for <sup>14</sup>C and delineated potential validation experiments to elucidate <sup>14</sup>C retardation in the Yucca Mountain environment were discussed. The proceedings paper was approved by YMPO.

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A paper entitled "Transport of Neptunium through Yucca Mountain Tuffs" (Triay et al., 1993b) was published in the proceedings of the Materials Research Society. The authors found that when surface complexation was the dominant sorption mechanism, Np sorption increased as pH increased. They also found that oxide minerals in solution can cause a significant amount of Np retardation. No differences were found between the Np retardation determined under flowing conditions and Np sorption determined using batch techniques.

Activity 8.3.1.3.6.1.2 - Mass transfer kinetics. In a published paper (Triay et al., 1993a), the authors reported on results of column experiments they conducted using crushed tuff from G4-1532 in solutions of Np in UE-25 J#13 water. They found that these distribution coefficients obtained under flowing conditions agree with previously obtained Np batch sorption coefficients, and Np sorption appears to be linear, reversible, and instantaneous. Consequently, they believe that performance assessment calculations for Np releases can be made using the concept of a sorption distribution coefficient to describe retardation.

Activity 8.3.1.3.6.1.3 - Unsaturated tuff columns. Staff began eluting Np solutions using water from Wells UE-25 J#13 and UE-25 p#1 through columns of intact unsaturated G4-1531 tuff.

Staff also initiated the study of Se transport through unsaturated tuff columns in collaboration with J. Conca of Washington State University. These experiments will verify whether the sorption coefficients obtained from batch sorption experiments adequately describe radionuclide transport through unsaturated tuff.

Activity 8.3.1.3.6.1.4 - Fractured tuff columns. Staff completed characterizing the hydrological parameters and mineralogy of a column of fractured tuff from drillhole USW G-1. They set up the experiments and began eluting an Np solution in UE-25 J#13 water through the fractured-tuff column.

Activity 8.3.1.3.6.1.5 - Filtration. Los Alamos staff organized and hosted the YMP Colloid Workshop. Its objective was to evaluate whether colloids will significantly increase radionuclide releases to the accessible environment at Yucca Mountain. Speakers reviewed the state of knowledge in colloid transport and its applicability to the conditions at Yucca Mountain. A strategy for future YMP colloid transport research was developed. A report on this subject was prepared entitled "Colloid-Facilitated Radionuclide Transport at Yucca Mountain" (Triay). The report described ongoing YMP colloid research, which will evaluate whether colloids will significantly increase radionuclide release from a potential high-level nuclear waste repository at Yucca Mountain to the accessible environment. The report also reviewed the evidence for the existence of colloids, both from sampling studies and from observation of colloid transport at field scale. The relevance of laboratory and field experiments on colloid transport to the conditions at Yucca Mountain were discussed. Research needs were identified in the following areas: colloid sampling, colloid generation, colloid stability, radionuclide sorption onto colloids, and colloid migration. Colloid transport calculations were presented. This report was in the YMP review process.

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**Forecast:** The effects of sorption and speciation kinetics on the transport of U and Pu using crushed-rock columns will be determined. Solid-rock column experiments to assess the validity of using batch sorption  $K_d$  values to describe the transport of U, Np and Pu through saturated and unsaturated solid tuff will be conducted. The effect of fracture coatings on radionuclide transport through fractured media for nonsorbing and sorbing radionuclides will be determined. Radionuclides such as Np, Tc, U and Cs will be used; solid- and fractured-tuff columns under various degrees of saturation to assess the potential for colloid-facilitated radionuclide transport at Yucca Mountain will also be used. The stability of colloids as a function of temperature and ground-water chemistry at Yucca Mountain will be determined.

### 2.2.2.13 Study 8.3.1.3.6.2 - Diffusion

Resolution of all comments was verified on June 28, 1993. The study plan was approved by the Project on August 6, 1993, and sent to the Commission on August 12, 1993.

Activity 8.3.1.3.6.2.1 - Uptake of radionuclides on rock beakers in a saturated system. In a published paper entitled "Diffusion of Sorbing and Nonsorbing Radionuclides in Tuff (3065)" (Triay et al., 1993c), the authors reported on their experiments in which the cavity of a tuff beaker was filled with a solution of the radionuclide of interest, and the uptake of the radionuclide by the tuff was measured as a function of time. The authors found that the diffusion coefficient for nonsorbing radionuclides into saturated Yucca Mountain tuff was on the order of  $10^{-6}$  cm<sup>2</sup>/s. They also found that large anions, such as pertechnetate, were excluded from tuff pores and their diffusion coefficients were on the order of  $10^{-7}$  cm<sup>2</sup>/s.

Activity 8.3.1.3.6.2.2 - Diffusion through a saturated tuff slab. Data collection was completed on the study of Np diffusion, using intact tuffs G4-270 and G4-1532 and UE-25 J#13 or UE-25 p#1 water. A report on these results was being prepared.

Activity 8.3.1.3.6.2.3 - Diffusion in an unsaturated tuff block. No progress during the reporting period; this was an out-year activity.

**Forecast:** The uptake of U and Pu by saturated tuffs under diffusive conditions and the diffusion of conservative and nonconservative tracers in unsaturated tuff blocks will be determined.

### 2.2.2.14 Study 8.3.1.3.7.1 - Retardation Sensitivity Analysis

The study plan was accepted by the Commission in a Phase I review on January 19, 1993. No comments were made, but a request was made for references cited in the study plan. The requested references were sent to the Commission on June 17, 1993.

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Activity 8.3.1.3.7.1.1 - Analysis of physical/chemical processes affecting transport. The dual porosity/dual permeability coding for air/water/heat was completed. More verification is needed as well as a more efficient solution procedure. The six unknowns per grid cell limits the problem size to several thousand nodes.

Activity 8.3.1.3.7.1.2 - Geochemical/geophysical model of Yucca Mountain and integrated geochemical transport calculations. A method for generating computational meshes for Yucca mountain flow and transport simulations was developed. This computer code, which employs triangles or tetrahedrals to accurately portray underground features in two or three dimensions, uses the hydrogeologic information contained in the SNL data base (Ortiz et al., 1985). Representations of Yucca Mountain containing up to one million nodes have been generated. The primary computational mesh for the FY 1993 runs contains 56,600 nodes and is on 76-m by 152-m centers with 35 nodes in the vertical direction.

A new version of FEHM, which incorporates dynamic memory allocation, was completed, and initial tests show an order of magnitude improvement in real performance on large memory intensive problems.

Activity 8.3.1.3.7.1.3 - Transport models and related support. Work was completed on FEHM enhancements that allow two-dimensional triangular elements in three-dimensional space. Testing of this capability is in progress.

**Forecast:** A locally refined model based on high-flow areas identified in previous coarser grid models will be produced. These transport calculations will reveal new sensitivities to  $k_d$  values of the hydrologic units in those over previous calculations because of the distributed flow through the repository. If time permits, transport studies with time varying flow will begin. These runs will reflect evolving climate conditions and will be the first of their kind. To support simplifying assumptions made by performance assessment for transport models, processes that affect the transport of radionuclides at Yucca Mountain will be studied. Computer codes will be developed; the development of algorithms for various processes and for optimization of the transport codes, TRACRN, FEHMN, and CTCN will be supported. Baseline documentation will be produced and the work necessary to bring codes TRACRN and FEHMN into compliance with the Software Quality Assurance Program will be performed.

### **2.2.2.15 Study 8.3.1.3.7.2 - Demonstration of Applicability of Laboratory Data to Repository Transport Calculations**

This study plan has been deferred because no funds were allocated.

Activity 8.3.1.3.7.2.1 - Intermediate-scale experiments. No progress during the reporting period; this was an out-year activity.

Activity 8.3.1.3.7.2.2 - Field-scale experiments to study radionuclide transport at Yucca Mountain. No progress during the reporting period; this was an unfunded activity.

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Activity 8.3.1.3.7.2.3 - Natural analog studies of radionuclide transport. No progress during the reporting period; this was an out-year activity.

Activity 8.3.1.3.7.2.4 - Data on radionuclide transport from other U.S. Department of Energy sites (Anthropogenic analogs). No progress during the reporting period; this was an out-year activity.

**Forecast:** In conjunction with LBL, a preliminary design of field tests at the Calico Hills geologic unit at Yucca Mountain will be prepared. Using this design, new data from the surface-based testing program and current radionuclide transport data on Calico Hills from the ESF will be evaluated. The study plan for this activity will be initiated.

### **2.2.2.16 Study 8.3.1.3.8.1 - Gaseous Radionuclide Transport Calculations and Measurements**

No progress during the reporting period; this was an out-year study.

**Forecast:** No activity is planned for FY 1994.

### **2.2.3 Rock Characteristics (SCP Section 8.3.1.4)**

Several strategic planning meetings were held with USGS staff to discuss inter-relationships and integration among several site characterization and three-dimensional modeling activities. Issues raised regarding potential duplication and overlap of characterization activities were resolved with several agreements-in-principle that expand the collaborative activities. The increasing emphasis on ESF design requirements predicated upon ramp access rather than on earlier shaft concepts has markedly increased the importance of the site-oriented systematic drilling program. This change in application of information has led to a larger role of the systematic drilling program in this early stage of overall site characterization, rather than to an expansion of plans for the drilling program.

The discussion also indicated that the modeling efforts described in Section 2.2.3.7 were largely synergistic, mostly due to ongoing development efforts by staff from both organizations. Under the idealized scenario, the geometric model developed by USGS using the LYNX Geotechnical Modeling System software package will be used to constrain geostatistical modeling of material properties. This latter activity will continue to be tightly focused on the "performance" uses of those models in both detailed "process" modeling and more limited "total systems" assessments. Increased consistency in interpretation of site characterization data is anticipated as a result.

### 2.2.3.1 Activity 8.3.1.4.1.1 - Development of an Integrated Drilling Program

Description of prototype drilling activities is discussed in Section 2.2.1.7, Study 8.3.1.2.2.3.

#### Catalog of Planned Boreholes for Surface-Based Testing

This catalog is an update and modification of drilling program information originally compiled in the Surface-Based Investigation Plan (DOE, 1988c). The Surface-Based Investigation Plan drew upon study descriptions contained in the SCP (DOE, 1988a). Since that time, detailed study plans have been developed for many surface-based testing activities. In addition, the catalog includes information from two drilling integration meetings held in early FY 1993. These meetings served as a forum for identifying the data needs and requirements of the various planned drilling activities. In particular, coring requirements were scrutinized and potential overlap with ESF testing was explored. Opportunities were sought to produce a more streamlined, cost-efficient program by consolidating multiple planned boreholes into single holes addressing multiple purposes. The results of these meetings, and subsequent discussions, are included in the catalog.

The catalog is a working compilation of borehole information for the surface-based testing program as currently envisioned. It provides a reference for planning, integration, and coordination of site investigation activities.

**Forecast:** The Catalog of Planned Boreholes will be updated twice each year. The next planned update is in December 1993.

### 2.2.3.2 Activity 8.3.1.4.1.2 - Integration of Geophysical Activities

Following the publication of the Geophysics White Paper (Oliver et al., 1990), the need was recognized for continued enhanced and coordinated integration of geophysical testing within the site characterization program. The Geophysics Integration Team was established within the YMPO Regulatory and Site Evaluation Division as part of the Geophysics Integration Initiative. The Geophysics Integration Team will oversee the geophysical testing program and ensure implementation of the integration initiative. The Geophysics Integration Team consists of highly trained geoscientists from YMP contractor and participant organizations and is chaired by a member of the Regulatory and Site Evaluation Division.

The YMPO has begun a concerted integration activity for geophysical testing during site characterization. This integration was designed to ensure:

- The early implementation of the currently proposed geophysical testing program
- The application of geophysical test results within the site characterization program
- Advance planning, scheduling, budgeting, and sequencing of geophysical tests



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- Consideration of technological advances in order to plan for
  - incorporation of new and potentially useful geophysical test methods into existing study plans
  - establishment of new geophysical study plans
- That objectives, scope, and methods for geophysical tests are well defined, with geophysical and nongeophysical testing programs fully integrated, test linkages and information needs established
- That the technical need and adequacy for all proposed geophysical tests is well understood and conduct of the tests is justified
- That implementation of a test will contribute to the development of models and assessments to be used for the determination of site suitability and license application.

The Geophysics Integration Team met several times during this reporting period to discuss the possible use of geophysics to aid in ESF design. Specifically, the Geophysics Integration Team discussed possible geophysical exploration techniques that could aid in the delineation of the Ghost Dance fault at the depth of the proposed repository (approximately 305 m below the Yucca Mountain crest), in order that the Tunnel Boring Machine might avoid encountering the fault along the Main Test Level. A recommendation was made by the Geophysics Integration Team to try two acoustical techniques: seismic reflection profiling across the Ghost Dance fault over the Main Test Level area, and vertical seismic profiling in boreholes near the proposed Main Test Level. The seismic reflection profiling has been budgeted, and is planned to be run by LBL in late October 1993. In addition, vertical seismic profiling was recommended, budgeted, and performed by LBL in boreholes USW NRG-6 and USW WT-2, to aid in the delineation of the Ghost Dance fault at the north and south ends of the Main Test Level. Results from these two surveys should be available in time to aid in the design of the Main Test Level. An additional vertical seismic profiling walkaway survey was performed by USGS in borehole UE-25 UZ#16 (Vertical Seismic Profiling-2) for hydrology studies, which may also aid in delineation of this fault.

The Geophysics Integration Team appointed several reviewers to review three USGS-developed draft Requests for Proposals for additional intermediate and deep seismic reflection services. The Requests for Proposals have gone back to USGS with Geophysics Integration Team comments (M&O comments and other members' comments), and may be reissued in FY 1994.

A Preliminary Draft Geophysics Catalog for FY 1993-1994 was submitted to YMPO and all Technical Project Officers for review and comment. This document is currently undergoing revision to account for reviewer comments, budgeting changes, and additional geophysical tests, and will be reissued in early FY 1994.

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An extensive geophysics section was compiled for the Site Characterization Activities Catalog, which will be issued in draft form in early FY 1994. This section includes all known planned geophysics tests, and cites relevant sections from both the SCP and the various study plans. This is the first time that all proposed geophysical tests have been compiled in one document.

A bibliography of all relevant geophysical publications related to work at the Yucca Mountain site has been compiled and will be issued in draft form in early FY 1994 for review and comment.

Monthly summaries of geophysical activities at the Yucca Mountain site are currently being compiled and informally transmitted to the Geophysics Integration Team and YMPO.

The Geophysics Integration Team met recently with the M&O to discuss the compilation of a Geophysics Integration Plan. Discussions are under way and are focusing on whether to issue this plan as a new study plan, or as a management integration plan.

Budgeting of all geophysical tests to be performed during FY 1994 was performed by the Geophysics Integration Team, and a new Work Breakdown Structure number was proposed for Geophysical Testing - 1.2.3.11. The following subheadings were proposed: 1.2.3.11.1 - Borehole Geophysics; 1.2.3.11.2 - Surface-Based Geophysical Tests; and 1.2.3.11.3 - ESF Geophysical Tests. Several new geophysical tests were proposed by the Geophysics Integration Team to be included in the FY 1994 budget, but could not be approved due to budget constraints.

The Geophysics White Paper (Oliver et al., 1990) was being updated during FY 1993 to include all geophysical surveys that have been performed by USGS in support of YMPO. This work was being done in preparation for issuance of the white paper by USGS in FY 1994. Due to budgeting constraints, this work has been postponed.

**Forecast:** The USGS Request for Proposals for seismic reflection services will be revised and reissued. The Geophysics Catalog for FY 1993-1994 will be finalized and issued. A draft Site Characterization Activities Catalog will be issued. A Geophysics Catalog for FY 1995-1999 is currently undergoing compilation and will be issued in draft form for review and comment in mid- to late-FY 1994. A draft bibliography of all relevant geophysical publications will be issued.

### **2.2.3.3 Study 8.3.1.4.2.1 - Characterization of the Vertical and Lateral Distribution of Stratigraphic Units Within the Site Area**

Revision 3 of the study plan was sent to NRC on August 30, 1993. The NRC sent two questions on the study plan in a letter dated June 22, 1993. The OCRWM responded to the NRC questions on August 30, 1993.

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Activity 8.3.1.4.2.1.1 - Surface and subsurface stratigraphic studies of the host rock and surrounding units. Rock characteristics staff worked throughout the second half of FY 1993 on partial and preliminary descriptions, and detailed logging of core from UE-25 UZ#16, USW UZ-14, UE-25 NRG#1, UE-25 NRG#2, UE-25 NRG#2A, UE-25 NRG#2B, UE-25 NRG#3, UE-25 NRG#4, UE-25 NRG#5, UE-25 NRG#6, UE-25 RF#8, UE-25 RF#3, and USW GU-3. This work was in support of studies of the USGS and the Soil Designation and Rock study conducted by SNL.

An Open-File Report entitled "Revised Stratigraphic Nomenclature and Macroscopic Identification of Lithostratigraphic Units Exposed at Yucca Mountain, Nevada" (Buesch et al.) was submitted for review. This report summarizes the newly revised stratigraphic nomenclature for the southwestern Nevada volcanic field, of which Yucca Mountain is included, and presents a detailed division of the Tiva Canyon and Topopah Spring Tuffs based on depositional, welding, and crystallization criteria. These divisions represent a compilation of descriptive characteristics of lithologic units in core from all holes listed above and a comparison with surface exposures, especially those determined for the Tiva Canyon Tuff in the Ghost Dance fault mapping activity.

Core logging activities by USGS staff of the North Ramp Geotechnical and Repository Facility (#3 and #8) drillholes directly interfaced with the Soil and Rock group of SNL in support of the evaluation of the ESF North Ramp. The logs and resulting geologic interpretations were used to interpret stratigraphic intervals which are poorly to not lithified, evaluating the location of existing and inferred faults, and for planning of successive North Ramp Geologic drillholes. USGS staff reviewed cross sections along the ESF North Ramp alignment and the lithologic and structural logs compiled by SNL.

The USGS participated in the collection of downhole video logs for UE-25 UZ#16 and UE-25 NRG#2. In UE-25 UZ#16, the video log was completed from surface to standing water. The video images showed thick coating of the walls with dust and water-saturated mud covering the walls at several intervals in the Calico Hills Formation and Prow Pass Formation. In UE-25 NRG#2, the video log is of the lower part of the hole in the Tiva Canyon Tuff to a depth of 65.5 m. Downhole video logs from UE-25 NRG#1 and UE-25 NRG#6 were provided to the USGS and have been reviewed.

The Isotope Geochemical Support Group analytical data base contains all available major-element, trace-element and radiogenic isotope data for Tertiary volcanics and Paleozoic sedimentary rocks at Yucca Mountain and surrounding areas. All analytical values in the data base have been quality checked and Project personnel have been trained in its use. All geochemical and isotopic data collected over the last six months have been entered into the data base. In addition, the most current lithostratigraphic nomenclature for the Tertiary volcanic rocks is now being used in order to more effectively correlate different sections.

Available lead and neodymium isotope data on whole rock samples of Tertiary volcanic rocks have been compiled in preparation for their addition to the data base. It was concluded that additional data are required in order to systematically characterize the primary and secondary geochemical behavior of these elements in unaltered and altered tuffs.

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Construction of isopach and structural contour maps continued. In April, USGS demonstrated a model of an integrated computer-interactive lithostratigraphic synthesis (LYNX Geosystems, Inc. software) of the subdivided Topopah Spring Member at Yucca Mountain including documentation on creation and interpretation of the synthesis to DOE/YMP, NRC onsite staff, and SNL. Staff traveled to LYNX Geosystems, Inc. in May 1993 to use their facilities to obtain output from the lithostratigraphic model. This output, consisting of 24 separate cross sections throughout the modeled area, was delivered to the engineers performing conceptual ramp design calculations. Staff received further training on the LYNX Geosystems software and software upgrades were installed on the work station.

Updates to the lithostratigraphic model continued. Isopach maps for each subdivision of the Topopah Spring Tuff were entered, and work began on a structure contour map of the top of the Topopah Spring Tuff. Staff conducted a review of the data used in the modeling process. This review performed on drillholes and isopach maps resulted in an overall increase in the precision of modeling near the North Ramp. Preliminary cross sections from the LYNX software were prepared and supplied to ESF designers for use in conceptual design.

The isopachs for each subdivision of the Topopah Spring Tuff were refined with the inclusion of additional measured sections data from the geologic mappers. The new 20-ft contour interval topographic data tape from EG&G was received and was included in the model. A request for four additional cross sections through the project area was processed in July.

USGS staff created a series of geologic cross sections along the new North Ramp alignment, with several cross sections cross-cutting the main North Ramp cross section. All these new cross sections were based on the latest isopach data, new borehole data, and recent geophysical data. A new structural interpretation of Drill Hole Wash was completed that incorporated all the new borehole data up through July 1993 and reconciled it with past surface and subsurface geological and geophysical data. This new structural interpretation was incorporated into the latest North Ramp cross sections.

Activity 8.3.1.4.2.1.2 - Surface-based geophysical surveys. USGS audits of seismic reflection proposals were completed in April. Negotiations continued with potential bidders. Planning discussions also continued with DOE/M&O staff regarding issues of safety and test interference. Analysis of bids continued through June, including interactions between Rock Characteristics and Contracts Sections and DOE/M&O staff. The anticipated FY 1993 award of the seismic contract was dropped in July due to high costs and difficulties with available bids. The process will be started with a revised proposal, with award scheduled for FY 1994.

New gravity and ground magnetic data sets obtained in Yucca Wash were reduced to obtain anomaly values. Both gravity and magnetic profiles of Midway Valley were reduced utilizing newly written computer programs.

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A manuscript for a proposed Open-File Report entitled "Gravity and Magnetic Study of Yucca Wash, Southwest Nevada" (Langenheim et al.) was submitted for USGS internal review.

Approximately 25 percent of the preparations for the planned seismic transect that passes through the Midway Valley and Yucca Wash areas was completed. Detailed gravity/magnetic data are available for these areas. Remaining work on this task was postponed until seismic line work begins again.

The task to prepare preliminary reports on Yucca Wash and Midway Valley was completed with the submittal of the following reports: "Gravity and Magnetic Data of Midway Valley, Southwest Nevada" (Ponce et al., 1993); "Gravity and Magnetic Study of Yucca Wash, Southwest Nevada" (Langenheim et al.).

An airborne magnetic survey was performed in June. The new aeromagnetic data along the Yucca Mountain transect was reduced, compiled, plotted, and transferred to YMP September 30, 1993.

Off-road shot locations for the seismic reflection survey were staked, and adjusted locations were clarified for DOE/NTS staff in preparation for preactivity surveys. Maps for seismic field investigations were submitted to DOE.

Activity 8.3.1.4.2.1.3 - Borehole geophysical surveys. Under this activity, methods for analyzing the existing (pre-1985) borehole logs were developed; the well log data base was expanded and disseminated; and well logs were obtained in a newly drilled borehole, UE-25 UZ#16.

Good estimates of moisture content and total porosity were obtained in the WT-series of boreholes using the epithermal neutron and density logs. First, the density and epithermal neutron logs which were corrupted by the rugose borehole in the unsaturated zone were treated with an algorithm which finds the right-hand bound to the density log and the left-hand bound to the epithermal neutron log. These bounds remove high-count errors caused by an air gap between the tool and the borehole wall. Next, using calibrations established for the epithermal neutron tool by Lawrence Livermore National Laboratory staff, an estimate of water content was obtained. Finally, using the water content result, an estimate of grain density, and the density log, total porosity was computed. This procedure was applied to logs from the WT-boreholes with consistent results.

The well log data base is now fully accessible on a personal computer system, using commercial log analysis software. An optical disk drive has adequate capacity and access speed to accommodate the entire data base. Redundant traces were eliminated, trace nomenclature was improved, and the data were sent to the Technical Data Base.

Magnetic susceptibility and magnetometer logs were acquired by USGS in boreholes UE-25 UZ#16 and USW NRG-6 during April. In July, neutron, density, caliper, induction, thermal decay time, gamma-ray spectrometry, and neutron activation logs were conducted in

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UE-25 UZ#16. An experimental radar tool and a developmental nuclear tool were also run in UE-25 UZ#16.

An Open-File Report entitled "Assessment of Geophysical Logs From Borehole USW G-2, Yucca Mountain, Nevada" (Nelson and Schimschal, 1993) was published.

Activities 8.3.1.4.2.1.4 - Petrophysical properties testing and 8.3.1.4.2.1.5 - Magnetic properties and stratigraphic correlations. No progress during the reporting period; this was an unfunded activity.

**Forecast:** USGS will work to streamline the release of preliminary stratigraphic identifications in drillholes and the culmination of the core logging activities into Open-File Reports.

Lithostratigraphic data from newly drilled boreholes will be normalized, synthesized and integrated with existing borehole data for utilization in the construction of isopach and structural contour maps, and in the development of the three-dimensional geologic model.

Work will involve writing the requests for proposals for seismic reflection profiling in part of Crater Flat and across Yucca Mountain, evaluating the bids, and possibly revising the study plan describing the seismic work. Efforts to integrate seismic work with the needs of the other studies to utilize geophysical solutions to geological problems and provide support for the three-dimensional model will be arranged.

An interpretive report will be written in FY 1994 regarding the airborne magnetic survey data.

The task to prepare a report and map of Yucca Wash was postponed due to delay in acquisition of seismic profile. The report will contain modeled data results of seismic data and of density and magnetic susceptibilities of field samples.

Computing porosity and water content in existing (pre-1985) boreholes and merging relevant logs into the three-dimensional (LYNX) data storage and viewing system will continue in FY 1994. The USGS staff will continue acquisition of logs in newly drilled borehole USW UZ-14 and others. The missing step to correct the density logs in the unsaturated zone, a procedure that ties the logs to core measurements, will be developed. Procedures being developed on existing borehole data will be useful for data being acquired under the current drilling program.

### **2.2.3.4 Study 8.3.1.4.2.2 - Characterization of the Structural Features Within the Site Area**

The NRC accepted the study plan, with no comments, in a Phase I review letter on February 8, 1993.

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Activity 8.3.1.4.2.2.1 - Geologic mapping of zonal features in the Paintbrush Tuff.  
USGS staff continued detailed stratigraphic and structural feature field mapping along the trace of the Ghost Dance fault system. The areas mapped during this period include Broken Limb Ridge, Whale Back Ridge, Split Wash, and Antler Ridge. Data were used for input into the Field Identification Summary and the Stratigraphic Column for the study area.

Work began on preliminary detailed petrographic examination of a suite of rock samples collected from subunits within the Tiva Canyon Tuff. This work was performed to determine if devitrification textures and vapor phase mineralogy (in addition to variability of pumice, crystal content, lithics, and any other characteristics observed in thin section) can be used as distinguishing criteria to better define subunit lithologies within the Tiva Canyon Tuff. Thin sections were made from outcrop samples collected from a vertical section along the south flank of Antler Ridge. Preliminary microscopic examinations of 30 thin sections from the Tiva Canyon Tuff subunits were described and documented by photomicrographs.

A table was prepared summarizing the textural petrographic variation with depth of lithostratigraphic subunits within the Tiva Canyon Tuff of the Paintbrush Group. The table summarizes criteria used to differentiate lithostratigraphic subunits within the Tiva Canyon ash flow tuff. This information was prepared for presentation at the Mineralogy/Petrology integration meeting with Los Alamos held on September 21, 1993.

Staff collected 35 rock samples from a vertical section along the southeastern flank of Whale Back Ridge (Tiva Canyon Tuff lithologies) and 49 additional samples of drill core from USW GU-3 for thin section (petrographic) and geochemical analysis. This work is being used to develop microstratigraphic criteria to better define the lithostratigraphic subunits within the Tiva Canyon Tuff of the Paintbrush Group.

Detailed geologic mapping of the northeast corner of site area continued throughout the remainder of the reporting period. Several square kilometers of the rhyolite of Calico Hills in Fortymile Canyon were mapped. Three measured sections were completed and 12 samples keyed to these measured sections were collected. Reconnaissance mapping was conducted in the rhyolite of Calico Hills exposed along the northern flank of Yucca Mountain and on the north flank of Busted Butte.

Field mapping in the Paintbrush Canyon, Fortymile Wash, adjacent canyons, and at Comb Peak revealed details of welded and nonwelded air-fall and ash-flow tuff and a possible transition zone of rheomorphic welded tuff at the base of the Comb Peak Rhyolite lava flow. Field relations defined parts of the Comb Peak crater rim, and flow foliations within the lava flows indicate the vent locations. Added map detail included definition of more outcrops of rhyolite of Delirium Canyon, and newly observed debris- and air-flow deposits which help constrain post-Rhyolite of Calico Hills paleotopography. Work in Fortymile Wash included describing post-Calico Hills and pre-Pah Canyon erosional surfaces and detailed mapping of a major fault.

The USGS staff completed mapping the Paintbrush Canyon fault to the southern end of the northeast quadrant in June and began the initial field-check of map data in Upper

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Paintbrush Canyon. The distal facies of fluviially reworked bedded tuffs and soil horizons were investigated at the northern end of Busted Butte.

Rhyolite of Calico Hills exposed along the northern flank of Yucca Mountain and on the north flank of Busted Butte sections was compared to the section exposed in upper Paintbrush Canyon to develop the architectural framework of the Calico Hills volcanic field.

Illustrations were prepared for an abstract presentation entitled "Primary and Secondary Volcaniclastics, Stream Grade Fluctuation, and Structural Events in the Rhyolite of Calico Hills, Nevada" (Buesch and Dickerson, 1993). The abstract was reviewed, approved, and presented at a meeting sponsored by the International Association of Volcanology and Chemistry of the Earth's Interior held in Canberra, Australia, September 24 - October 1, 1993.

The first draft of a paper entitled "Structural Character of the Northern Segment of the Paintbrush Canyon Fault" (Dickerson and Spengler), for presentation at the 1994 High-Level Waste Conference, was completed in August. The proposed report incorporates all of the map data recently obtained north of Yucca Wash, in addition to the most recent magnetic and gravity data along the trace of the Paintbrush Canyon fault south of Yucca Wash to the southern end of Midway Valley. Thin sections from 25 samples collected from this area were prepared for petrographic analysis.

An internal report on the current status and contents of the Isotope Geochemistry Support Group analytical data base through the end of April 1993 was completed. This report provides all spatial, geochemical and isotopic data available for samples of Tertiary volcanic rocks, Paleozoic sediments and Precambrian rocks exposed at the surface in the Yucca Mountain vicinity.

A major effort to use petrographic and chemical characteristics of the Tiva Canyon Member of the Paintbrush Tuff as potential markers for studying offsets along the Ghost Dance fault was undertaken. Samples of the Tiva Canyon Member were collected from Whale Back Ridge on the eastern flank of Yucca Mountain. These samples were crushed, powdered and prepared and x-ray fluorescence analyses were performed. Thin sections were made for petrographic study. Information may be important for determining the stratigraphic position within drillholes and tunnel excavations where the lithologic characteristics of the samples may be less distinct than in the outcrop samples.

X-ray fluorescence analyses of approximately 120 whole-rock samples of tuffs from northwestern Yucca Mountain and southern Crater Flat were completed. These data were collected for mapping studies and will be useful in correlating known stratigraphy with newly mapped areas.

Dr. Leonid A. Neymark, visiting Russian isotope geochemist from the Institute of Precambrian Studies in St. Petersburg, arrived and joined the Isotope Geochemistry Support Group staff for a temporary collaborative tenure. Dr. Neymark will focus his attention on developing procedures for the analysis of U and Th by mass spectrometry for dating



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carbonates from drill core veins. In addition, he will work with Pb, Nd and Sr isotopes in volcanic rocks and ground waters.

The following reports were published as USGS Open-File Reports: "Status of Aeromagnetic Survey Coverage of a Part of Southwestern Nevada and Southeastern California, 1992" (Sikora et al., 1993) and "Gravity and Magnetic Data of Fortymile Wash, Nevada Test Site, Nevada" (Ponce et al., 1992).

The following papers were also published in FY 1993: "Seismic Reflection Profiling Across Tertiary Extensional Structures in the Eastern Amargosa Desert, Southern Nevada, Basin and Range Province" (Brocher et al., 1993) and "Geological and Mineralogical Controls on Physical Properties of Tuffs at Yucca Mountain" (Nelson, 1993).

Activity 8.3.1.4.2.2.2 - Surface-fracture network studies. Analysis of new and previously acquired data on regional variations in fracture network parameters continued. The work describes the style and mode of fracturing of bedded tuffs at the base of the Tiva Canyon Tuff and will include a detailed fracture map of the UE-25 NRG#1 pavement. Analyses are under review by the USGS.

Approximately 46 percent of the area enclosed by pavement P2001 in the Topopah Spring Tuff exposed on Fran Ridge was mapped in an effort to analyze the ESF test-pit area in three dimensions. No further progress was accomplished in FY 1993 due to budget constraints. A Technical Data Information Form for collected data will be submitted.

An abstract entitled "Fracture Network Heterogeneity in the Tiva Canyon Member of the Paintbrush Tuff" (Fahy) was submitted for presentation at the 1994 High-Level Waste Conference.

Activity 8.3.1.4.2.2.3 - Borehole evaluation of faults and fractures. No progress during the reporting period; this was an unfunded activity.

Activity 8.3.1.4.2.2.4 - Geologic mapping of the Exploratory Studies Facility. Conventional and photogrammetrical mapping of the North Ramp Starter Tunnel began in April 1993, and continued through the end of FY 1993 with all excavation in the upper lithophysal zone of the Tiva Canyon Tuff. The pilot bore was mapped to station 0+97 and the upper half of the tunnel to station 1+95. The lower bench of the Starter Tunnel was also mapped to station 1+95 (the end of the Starter Tunnel). Mapping was completed in the Starter Tunnel in September 1993.

Geologists collected a total of 69 samples from the Starter Tunnel (under Job Package 92-20C) as part of the Consolidated Sampling program. Samples collected between stations 0+00 and 1+95 included fracture fillings, representative lithologic samples, smectite from lithophysae, and contaminated and uncontaminated wall rock, mineral infillings, and fault rubble. Fractures were filled with a variety of secondary materials in the portal cut and starter tunnel.

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Geologists completed a draft plan-view geologic map and detailed line surveys of the drainage channel above the portal cut.

Fracture data from the detailed line surveys were compiled and processed using the DIPS software program and stereonetts generated from various stations of the Starter Tunnel. Fracture families were identified from these stereonetts.

The underground mapping team provided data and support for the purposes of tunnel stability analysis. This information included fracture spacing, plan map showing occurrence of identified fractures along the right wall, lower hemisphere pole and contour plots, and family identification. Members of the mapping team attended various meetings and participated in numerous discussions with DOE representatives regarding tunnel support and excavation conditions.

Activity 8.3.1.4.2.2.5 - Seismic tomography/vertical seismic profiling. Incorporation and integration of the vertical seismic profiling model with rock characteristics work continued. In April, personnel from Los Alamos and LBL were accompanied by personnel from SNL and Morrison-Knudsen to inspect the excavations in the portal and to determine if seismic imaging measurements could be made on a timely basis to aid in the prediction of the geologic structure ahead of the tunnel face and of stability of the tunnel. A modest seismic imaging program that could be added to the existing work with minimal interference with the excavations was recommended. Recommendations were submitted including information on tomographic imaging above and off-end of the tunnel and on high-resolution surface-reflection imaging. A synopsis of tomographic modeling at the C-hole complex was presented to Rock Characteristics Section staff.

A presentation was made at the DOE-NRC Technical Exchange on Geophysical Integration on the past and present cross-hole and vertical seismic profiling work at the Nevada Test Site.

Information was prepared on the availability and applicability of seismic sources for cross-hole imaging at UE-25 UZ#16.

Work to develop and validate interpretational codes VELIN3D and ANI90 continued. Improvements were made to VELIN3D to provide for more stable inversions and to avoid local minima in the inversion using the cubic b-spline methods.

Discussions were held with Los Alamos and the M&O regarding work in the North Ramp Portal. Due to unexpected fracture content, the portal work progressed at a slower rate than planned. It was suggested that resolution of several questions regarding the extent of the fractured zone, a more precise extent of the Rainier Mesa Formation adjoining the Bow Ridge fault, and location of hidden faults may be possible by using high-resolution seismic imaging.

**Forecast:** Geologic mapping of the ESF work in FY 1994 will include expected completion of the geologic mapping of the test alcove in the Starter Tunnel at station 1+40. The alcove is expected to be approximately 18.3 m long and completed by the end of

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November 1993. Work through the end of January is expected to consist of completion and drafting of the geologic maps of the North Ramp Portal cut, Starter Tunnel, and drainage cut above the tunnel. Completion of the photogrammetric mapping of the Starter Tunnel is also expected during this time. Interpretation of the geologic data from excavations will culminate in a report near the end of February 1994. Technical procedures and training for mapping behind the Tunnel Boring Machine will be developed during the spring of 1994.

Underground mapping is expected to resume in mid-July 1994. Prior to the resumption of mining, geologists will be trained to Technical Procedures and familiarized with the volcanic and fracture terminology to be used in the North Ramp. Completion and assembly of the mapping gantry is also expected during this time. Underground mapping is anticipated to extend from July through September 1994.

Detailed petrographic and geochemical studies will be performed on rock samples collected from four vertical stratigraphic sections within and outside the Ghost Dance fault system. This work will be used to develop microstratigraphic criteria to better define the lithostratigraphic subunits within the Tiva Canyon Tuff of the Paintbrush Group.

The FY 1994 work for seismic tomography/vertical seismic profiling will focus on processing the vertical seismic profile data acquired in USW WT-2 and USW NRG-6. High resolution surface reflection work will be culled out and the resulting data processed for information on the Ghost Dance fault system and for structural information along the strike of the proposed ramp.

In FY 1994, mapping of the Ghost Dance fault will include selected areas northward to the northern edge of the potential repository and extend east and west of the main trace of the fault, near Whale Back Ridge and Antler Ridge. Mapping of the northeast corner of the proposed site area will involve field checking of FY 1993 data. A preliminary data base will be established and published summarizing lithologic attributes of the Paintbrush Tuff for use in unsaturated zone models.

### **2.2.3.5 Study 8.3.1.4.2.3 - Three-Dimensional Geologic Model**

No progress during the reporting period; this was an unfunded study.

**Forecast:** No activity is planned for FY 1994.

### **2.2.3.6 Study 8.3.1.4.3.1 - Systematic Acquisition of Site-Specific Subsurface Information**

The NRC accepted the study plan on July 19, 1993, and indicated that a detailed technical review would be undertaken.

Consolidated Work Scopes

The consolidated work scope process serves as an interface between the Annual Plan for Site Investigations and the test planning package. It is carried out by the M&O upon request from YMPO primarily for surface-based testing activities that potentially involve multiple investigators. The goal is to identify requirements from primary and secondary studies, and to define a set of consolidated requirements that meet as many secondary needs as possible while not compromising the primary purpose of the activity. For example, in a borehole drilled in support of the systematic drilling program, the needs of other activities can be met through distribution of core or cutting samples, or through testing in the borehole after it is completed. By maximizing the benefit of each activity, the overall cost-effectiveness of the program is increased.

During the reporting period, two consolidated work scopes were compiled: one for the drilling and testing planned in borehole USW SD-12, scheduled to be drilled in the first quarter of FY 1994; and the second for the pumping and cleaning of three WT (water table) wells that were drilled with drilling fluid or air foam in the 1980s, and never cleaned to permit the collection of water samples. In addition, work scope consolidation meetings, at which interested parties expressed their requests and requirements, were held for boreholes planned in FY 1994, to provide the input to upcoming consolidated work scope statements.

**Forecast:** Consolidated work scopes will be completed for boreholes to be drilled in FY 1994.

Activity 8.3.1.4.3.1.1 - Systematic drilling program. The proposed enhancement to the ESF configuration would result in the main exploration drift running north-south, subparallel to the Ghost Dance fault. The potential redesign has led to increased visibility and emphasis on the role of the site-oriented systematic drilling program. Work scope consolidation meetings and other Project-level conferences have been held for FY 1994 drillhole planning.

Specific drilling plans have undergone several iterations during the reporting period. Currently two SD-series drillholes are scheduled for FY 1994. Both drillholes are located to provide sufficient design information for the ESF main drift, including post-drilling instrumentation for monitoring of construction effects on in situ conditions (see Study 8.3.1.2.2.3, Characterization of Yucca Mountain Unsaturated Zone Percolation; Activity 8.3.1.2.2.3.2, Site Vertical Bore Holes; Section 2.2.1.7). A final surface location for the first drillhole (USW SD-12) was identified in the field and a drill pad is under construction. The location is slightly to the west of the planned ESF main-test-level drift, approximately 500 ft west of the Ghost Dance fault. Drilling is scheduled to commence early in FY 1994, following release of the LM-300 drill rig from drillhole USW UZ-14.

A tentative location was selected for a second SD hole (USW SD-9). This location is similarly located geologically, but is significantly further to the north along the trace of the main-test-level drift. Logistical constraints will be more significant in this region of steep topography and narrow drainage.

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Staff assigned to support the systematic drilling program spent a significant amount of time during the reporting period providing geologic support to the work being conducted in support of the Soil and Rock Properties Study (SCP Activities 8.3.1.14.2.1, 8.3.1.14.2.2, and 8.3.1.14.2.3; see Sections 2.2.10.1, 2.2.10.2, and 2.2.10.3). The Soil and Rock Properties Study is the basis for preparing geologic and engineering logs for the North and South Ramp geotechnical boreholes. Because the Soil and Rock Properties Study and the Systematic Acquisition of Site-Specific Subsurface Information Study both focus on engineering aspects of the immediate repository block, its access ramps, and Main Test Level drifts, close coordination between the two studies is essential. Geologic logging of core is the principal focus of the support provided under this activity. The logging was conducted under the scientific notebook procedure in use for the Soil and Rock Properties Study. This provided an opportunity to refine the technical procedure that will guide work on the systematic drilling program. The technical procedure, (TP-0162) "Geologic Description and Core Logging" was issued as a controlled document in late July.

Sample logging results were compared with the equivalent rock units now exposed in the portal excavations for the North Ramp. The comparison suggests some interesting interpretations of the cause of the "poor core recovery" observed in North Ramp Geologic Hole UE-25 NRG#1 and elsewhere. The poor core recovery may actually be the result of large (>30 cm) lithophysal cavities that have been prominently displayed in the new excavations. The implications of the core recovery in UE-25 NRG#1 and the nonconventional interpretations will be explored as additional data are gathered.

A journal paper entitled "Spatial Variability of Hydrologic Properties in Volcanic Tuff" (Istok et al.) was prepared for submission to Ground Water. It includes the results of a test of the hypotheses regarding stratigraphic control of material properties developed by the original work described in the paper, "Influence of Deterministic Geologic Trends on Spatial Variability of Hydrologic Properties in Volcanic Tuff" (Rautman et al., 1993). At the end of the reporting period, the paper had completed USGS review and was pending final resolution of comments at SNL.

**Forecast:** During FY 1994, any outstanding prerequisites for drilling will be completed, including (as necessary) revisions of the study plan, revision and/or preparation of technical procedures, letters of criteria, job packages, sample requests and other Project-level documents required for drilling. Additional developmental activities include: completing data reports covering entire transect data set; collecting and testing additional samples, if necessary, to resolve outstanding issues; evaluating data using statistical and geostatistical methods; and preparing a final report on the transect sampling project.

If the enhanced ESF configuration is approved, field activities will be conducted for the drillholes that are to be located near the projected trace of the revised main ESF test drift in support of site characterization activities. This work will consist of: providing onsite supervision and monitoring of drilling operations; creating detailed geologic log of core, including descriptions of lithology, units contacts, fracturing and faulting, alteration phenomena, core recovery and rock quality; and monitoring geophysical logging of drillholes,

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including downhole TV logging during drilling to determine hole conditions relevant to drilling decisions.

The systematic drilling program will continue to support field activities related to the remaining North Ramp (NRG-series) and the South Ramp Geologic (SRG-series) drillholes.

"Framework" rock properties measurements will be obtained for all SD-series drillholes. These properties include porosity, bulk density, particle density, and matrix permeability. In addition, water contents will be measured on core samples preserved on the rig-floor (to protect in situ conditions). Laboratory testing will be performed as a collaborative effort with Study 8.3.1.3.2.2 under a Memorandum of Understanding between SNL and USGS.

Laboratory and field data from drillhole samples will be evaluated using traditional geostatistical techniques to summarize framework material properties for this hole and determine if changes are required in the drilling and sampling program.

Two data reports are to be published as USGS Open-File Reports, and are tentatively entitled "Physical and Hydrologic Properties of Outcrop Samples from a Nonwelded to Welded Tuff Transition, Yucca Mountain, Nevada" (Flint et al.) and "Physical and Hydrologic Properties of Surface Outcrop Samples at Yucca Mountain, Nevada" (Flint et al.). These reports will contain the laboratory results of the outcrop sampling studies that were conducted at Yucca Mountain over the past several years under this activity.

### **2.2.3.7 Study 8.3.1.4.3.2 - Three-Dimensional Rock Characteristics Models**

Preparation was begun on the study plan using the revised DOE-NRC Level-of-Detail Agreement and Review Process for Study Plans (DOE, 1993p). Because the study will create custom models upon demand to support performance assessment and design evaluation activities, the study plan will be a listing and brief theoretical and practical description of a number of tools that can be used to create the physical property distributions necessary for a particular calculation. At the end of the reporting period, the study plan was still in draft form. However, additional staff resources were added near the end of the reporting period, and completion of the study plan is a high-priority item.

Activity 8.3.1.4.3.2.1 - Development of three-dimensional models of rock characteristics at the repository site. The geostatistical indicator simulation exercise of stochastic sequences of welded versus nonwelded tuff for Yucca Mountain that began last reporting period was completed and the results were incorporated into the ongoing Total System Performance Assessment (TSPA) 1993 (Andrews, et al. and Dockery, et al.). Ten complete stochastic realizations of the fully three-dimensional, six-million-node model were computed. Eight one-dimensional stratigraphic columns, each representing a different portion of the repository block, were extracted from these models for flow and transport computations. One-dimensional columns and similar stratigraphic models used in TSPA 1993 have stratigraphic information from multiple drillholes incorporated into each individual column in the new model. The stratigraphic models are controlled by a composite model of spatial continuity.

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Previously, drillhole information was incorporated into a stratigraphic model only if the cross section being prepared passed through the drillhole. A description of the modeling process and its results was prepared for incorporation in the TSPA 1993 report.

A modest exercise was initiated late in the reporting period to produce models of rock quality associated with the North ESF Ramp and to describe the uncertainty associated with those models. Input data consist of rock quality designator. Rock quality designator (Deere and Deere, 1989) is defined on drill core measurements obtained from the various NRG-series drillholes. The measurements are highly preliminary because rock quality designator values are not yet available from all holes. There is some difficulty with these preliminary results because it appears to be that the horizontal range of spatial correlation is extremely short compared with the (incomplete) drillhole spacing. This may, in part, be an artifact of the available data. However, it may also represent a more fundamental problem related to the dominant controls on rock quality at Yucca Mountain. The zones of poor rock quality designator are related directly to structural features which tend to be high-angle features. The difficulty of characterizing high-angle structures with vertical boreholes is well known in mining circles. Following receipt of the outstanding rock quality designator data from the North Ramp Geologic drillholes, the modeling exercise will be repeated. Depending on the outcome, the exercise will be reevaluated. Preliminary discussions have been initiated with geologists currently mapping in the ESF Starter Tunnel regarding equivalent rock quality designator data that may be obtained from horizontal line-scans in the underground workings. Incorporation of closely spaced horizontal data from the ESF might significantly add to the spatial analysis and modeling.

The annual contract-review workshop of the Stanford Center for Reservoir Forecasting was held at Stanford University. The Stanford Center for Reservoir Forecasting provides many of the geostatistical algorithms used in simulation of Yucca Mountain physical property distributions. Recent developments in geostatistical applications were presented by Stanford graduate students and by industrial affiliates. Significant topics addressed at the workshop included: (1) major work on the joint simulation of multiple spatially correlated variables using a Markov-Bayes-type model of coregionalization; (2) revisions to the sequential simulation algorithm to enhance reproduction of longer-range spatial continuity patterns; (3) a merging of fractal techniques with classic geostatistical methods; (4) an expansion of earlier work on simulating multiple-point statistics (most geostatistical methods are based on two-point continuity measures); and (5) efforts to speed simulation of very large models through probability-field techniques. Although the scope of research at the Stanford Center for Reservoir Forecasting is quite broad and many of the results are somewhat preliminary, some of these items have very direct applications to the YMP.

The Markov-Bayes approach to multiple variables is probably the most significant, because ground-water flow is inherently a multivariate problem. The material property fields used as input to flow computations must reflect properly the joint variability and continuity patterns. In all likelihood, simulating these fields separately distorts the cross-variable correlation patterns extant in nature, and these Markov-Bayes techniques may permit more reasonable simulations without the complexity and numerical problems added by a full

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coregionalization model. The technique has been applied to reservoir characterization of porosity and permeability in units in the North Sea with apparent success.

The reproduction of multiple-point connectivity statistics in simulated models also has particular application at Yucca Mountain, because the closest anticipated drillhole spacings (conditioning data) are probably close to or slightly greater than the expected range of correlation based upon surface transect sampling. The sparse nature of conditioning data relative to the correlation length can produce stochastic lithologies in conceptually and physically anomalous positions. Use of higher-order spatial statistics should alleviate this problem. Numerical artifacts induced precisely by this problem were encountered in the porosity simulations of the N-54/N-55 cross section as discussed in "Recent Developments in Stochastic Modeling and Upscaling of Hydrologic Properties in Tuff" (Rautman and Robey, 1993).

The probability-field approach to simulation may prove important to the YMP, in that stochastic approaches to uncertainty assessment require the generation of large numbers of physical property models. Experience with the six-million-node, welded-nonwelded indicator simulations conducted for TSPA 1993 (described above and in Progress Report 8) indicates that the computational effort for site-scale simulations is not trivial. Probability-field simulations take longer to produce and compute initially but, once computed, generation of alternative stochastic images is extremely rapid by comparison.

A plan for the development of software that allows explicit integration of the USGS-developed geometric model of Yucca Mountain (LYNX model) with geostatistical material properties modeling at SNL is in the initial stages. The methodology is probabilistic in nature. However, it makes use of geologically-based deterministic correlations between the statistical distribution of important hydrologic properties and the microstratigraphic or zonal subdivisions of the thick ash-flow tuff sequences at Yucca Mountain (Rautman et al., 1991). The use of the observed correlations allows incorporation of abundant soft information from the geologic setting in a theoretically rigorous manner that will reduce excessive uncertainty in modeling of material properties away from measured control points. The result will be more tightly constrained "numerical rocks" for use in performance calculations without unduly proscribing the residual uncertainty that is inherent in any geologic investigation. This work is aligned with, but slightly different in approach to that being used by the Stanford Center for Reservoir Forecasting.

Several Geostatistical Software Library and User's Guide (GSLIB) software routines were modified to better meet requirements for postprocessing replicated simulations and checking the successful completion of the simulations. A copyrighted, public domain PostScript utility (Ghostsript) to display and print GSLIB output on the personal computer was obtained during July. This will allow the migration of geostatistical modeling from the work station environment to the personal computer. Although display would appear to be a minor issue in a sophisticated modeling activity, personal computer software programs to serve with the powerful graphics of the PostScript language are almost nonexistent.



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**Forecast:** The study plan for three-dimensional rock characteristics study will be completed and enter Project review. It is anticipated that the necessary review and revisions will be completed during FY 1994, and the study plan submitted to NRC.

Development will continue on integrated geostatistical modeling tools that can efficiently produce multiple realizations of property distribution simulations and can integrate "soft information" from ongoing geologic modeling using the LYNX GMS software package. Development of these capabilities is a prerequisite to widespread application for statistically based property distributions for use in performance assessment and design analyses. Development of integrated geostatistical modeling software will continue; the "soft-information" link between the USGS geometric (stratigraphic) model (currently constructed using LYNX GMS software) and geostatistical simulation routines to utilize stratigraphic subdivisions within major welded units to constrain the simulated values will be implemented; the main simulation algorithms to incorporate new developments from the Stanford Center for Reservoir Forecasting will be upgraded as appropriate; methods for upscaling to flow simulator block sizes, as appropriate, either within simulation module or as post-processor to rock properties simulator will be incorporated; and participation in the Stanford Center for Reservoir Forecasting industrial research consortium for development of advanced geostatistical methods and algorithms will continue.

In support of the Soil and Rocks Properties Study, ESF ramp design, and construction monitoring activities, the GSLIB- and LYNX-based geologic and material properties models to provide cross sections along developing ESF ramp alignments will be developed and updated. The SNL interaction with LYNX Geosystems, Inc. personnel to guide development of user interface and geostatistical capabilities of the LYNX GMS will continue; upgraded versions of software will be installed and tested as received; test cases and models to LYNX personnel as appropriate to facilitate development will be provided; and development of geologic and material properties cross sections and updating sections as new data become available and as model links with geostatistical subroutines are developed will continue.

### **2.2.4 Climate (SCP Section 8.3.1.5)**

#### **2.2.4.1 Study 8.3.1.5.1.1 - Characterization of Modern Regional Climate**

The study plan was completed and submitted to the Project for review. It was returned to USGS with comments for resolution on August 30, 1993.

Activity 8.3.1.5.1.1.1 - Synoptic characterization of regional climate. Strontium analyses of several precipitation samples gathered from February storms at Yucca Mountain were performed.

Precipitation sample collection was initiated from five sites in the vicinity of Yucca Mountain and five regional sites at Rainier Mesa (Stockade Pass), Pahute Mesa (Rattlesnake Wash), Fortymile Wash (near confluence with E. Cat Canyon), Beatty, and Stateline, Nevada.

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**Forecast:** In the first half of FY 1994, the comments on the study plan will be resolved. No other work in this activity has been funded in FY 1994.

### 2.2.4.2 Study 8.3.1.5.1.2 - Paleoclimate Study: Lake, Playa, and Marsh Deposits

The study plan was accepted by NRC on April 27, 1993, with no comments.

Activity 8.3.1.5.1.2.1 - Paleontologic analyses. No progress during the reporting period; this was an out-year activity.

Activity 8.3.1.5.1.2.2 - Analysis of the stratigraphy-sedimentology of marsh, lacustrine, and playa deposits. Work was initiated that will provide the basis for reconstruction of both the amount and type of precipitation that has occurred in southern Nevada during and since the last glacial period. That work includes identifying the general fate of precipitation once it has entered the hydrosphere as to evaporation, surface runoff, or infiltration and recharge. Establishing the geological history of water as it moves through the atmospheric and hydrospheric segments of the hydrological cycle will provide the basis to integrate this work in the calcite-silica studies in Study 8.3.1.5.2.1.

To establish if modern day dry and wet playas store water, and if so, how much, during the generally wetter late Pleistocene, three playas in the vicinity of Pahrump were cored by Desert Research Institute staff with assistance from USGS. The playas included Pahrump, Peter's, and Stewart Valley. Cores from those playas were subsampled for aquatic macrofossils and microfossils as well as terrestrial pollen content. Samples from those cores are currently under study. The presence of calcareous microfossils such as ostracodes, if found, will provide the data needed to reconstruct the past water chemistry and provide material for isotopic analyses. Pollen content will provide information about changes in the terrestrial vegetation surrounding the playas through time.

Molluscs and ostracodes collected from the late Pleistocene and early Holocene marsh deposits near Corn Creek Springs, as well as from modern springs, were analyzed for stable isotopes.

Field work was conducted in the Sheep and Spring Mountain Ranges to collect modern terrestrial gastropods from different elevations. Those taxa will be identified and their shells analyzed for stable isotopes. This modern data will serve as a calibration set for evaluating how well the shells record the isotope composition of precipitation. It will also help to evaluate whether an elevational or a latitudinal climate analog model should be applied to fossil data in southern Nevada. A latitudinal model will invoke a much wetter climate reconstruction than one would obtain from an elevational model.

A summary abstract entitled "Strontium Isotope Geochemistry of Playa Deposits near Yucca Mountain, Nevada" (Marshall et al.) was prepared for the 1994 High-Level Waste Conference. The paper presents strontium isotopic data determined on fine-grained sediments from several playas in southern Nevada and utilizes these data to help characterize eolian

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components present in pedogenic carbonates at Yucca Mountain. This report reflects a continuing effort to precisely define the origin of the pedogenic carbonate in light of continued controversy regarding pedogenic carbonates at Trench 14 and elsewhere.

Twenty Sr analyses of fine-grained playa deposits from the northern Nevada Test Site and northern Death Valley were performed. A memo summarizing results was prepared.

Activity 8.3.1.5.1.2.3 - Geochemical analyses of lake, marsh, and playa deposits. No progress during the reporting period; this was an out-year activity.

Activity 8.3.1.5.1.2.4 - Chronologic analyses of lake, playa, and marsh deposits. No progress during the reporting period; this was an out-year activity.

**Forecast:** The USGS will continue to subsample cores collected by Desert Research Institute from about 12 lake, playa, and marsh deposits throughout the southern Great Basin to provide dates for the deposits.

### 2.2.4.3 Study 8.3.1.5.1.3 - Climatic Implications of Terrestrial Paleocology

The study plan was accepted by NRC on August 27, 1993, with no comments.

The DOE has committed grant monies to Desert Research Institute, University of Nevada, Reno to provide data concerning paleoclimatic tasks. The Desert Research Institute has agreed to follow USGS QA techniques in its studies. This will allow USGS to use data collected by Desert Research Institute in its own studies.

#### Activity 8.3.1.5.1.3.1 - Analysis of pack rat middens.

During the reporting period, Desert Research Institute conducted the following work:

1. Ten previously collected, but unprocessed middens were processed, sorted and analyzed. Analysis of 20 previously "archived" middens was completed as well (i.e., insects were separated and all materials counted, dried and weighed if they had not been previously). Contents sheets were updated and checked. Materials from the ten newly processed middens were separated for dating (and isotope analysis) and 20 additional middens were redated to verify the plant associations in each of the strata. The midden data base was updated and modified.
2. During the spring, cores were taken from three localities in southern Nevada including: Pahrump Playa (three localities, four cores), Stewart Playa (two localities, three cores), and Peter's Playa (one locality, one core). Desert Research Institute personnel went to Denver to sample the cores retrieved during the spring. Three hundred pollen, weight loss and ostracode samples were taken about every 20 cm from one representative core from each playa. Cores were transported to Reno where they are presently stored in the Quaternary Sciences Center cold room.

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3. Extraction of 60 pollen samples from the southern Nevada playas, woodrat middens and Summer Lake in the northern Great Basin was completed. Simultaneously, weight loss on ignition of 104 samples taken from these localities has been performed.

Activity 8.3.1.5.1.3.2 - Analysis of pollen samples. No progress during the reporting period; this was an out-year activity.

Activity 8.3.1.5.1.3.3 - Determination of vegetation-climate relationships. No progress during the reporting period; this was an out-year activity.

**Forecast:** A meeting will be held with participants in this study and other climate and paleoclimate studies to evaluate progress, plan the next series of studies, or modify existing plans as needed.

### **2.2.4.4 Study 8.3.1.5.1.4 - Analysis of the Paleoenvironmental History of the Yucca Mountain Region**

Activity 8.3.1.5.1.4.1 - Modeling of soil properties in the Yucca Mountain region. No progress during the reporting period; this was an out-year activity.

Activity 8.3.1.5.1.4.2 - Surficial deposits mapping of the Yucca Mountain area. A report (published abstract) entitled "Quaternary Allostratigraphy of Surficial Deposit Map Units at Yucca Mountain, Nevada: A Progress Report" (Lundstrom et al., 1993) was presented in the session on Recent Geoscience Advances at Yucca Mountain and Surrounding Region at the Geological Society of America Cordilleran Section Meeting in Reno, Nevada, May 19, 1993. This stratigraphy defines mappable alluvial, colluvial, and eolian units in terms of diagnostic sedimentologic, pedologic, morphologic, and surficial characteristics. Using and further characterizing this stratigraphy, three surficial deposit maps (1:12,000 scale) of the northern part of the designated surficial deposit map area were completed and are in technical review. These map reports, intended for publication as USGS Open-File Reports, are entitled "Preliminary Surficial Deposits Map of the Northeast 1/4 of the Busted Butte Quadrangle" (Lundstrom et al.), "Preliminary Surficial Deposits Map of the Southeast 1/4 of the Topopah Spring NW Quadrangle" (Lundstrom and Taylor), and "Preliminary Surficial Deposits Map of the Southwest 1/4 of the Topopah Spring NW Quadrangle" (Lundstrom and Taylor).

In the course of mapping, a lithologically distinctive older gravel was recognized and mapped along Fortymile Wash, four miles east of the proposed repository area. The position and age of this gravel are significant in constraining the geomorphic evolution and tectonic history of Fortymile Wash and Yucca Mountain, and in providing further geologic evidence for the predominance of Late Miocene geomorphic and tectonic activity relative to activity in post-Miocene time. A summary report of this topic entitled "New Geologic Data Concerning the Geomorphic Evolution of Fortymile Wash" (Lundstrom), was submitted for presentation at the 1994 High-Level Waste Conference.

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Mapping of the remaining central and southern surficial deposit map area is in progress, as are isotopic, geochemical, and thermoluminescence analyses to better constrain age estimates of the predominantly Quaternary surficial deposits mapped to date.

U-series chemistry on a Q3 soil carbonate from Midway Valley Trench 5, a sample of rhizoliths from the stratigraphically-lowest units exposed in Midway Valley Trench 7, and a sample of rhizoliths from an eolian deposit in Fortymile Wash were completed. Analyses of additional samples (i.e., laminar soil carbonate) are needed to confirm the age dating, as well as to assess whether rhizoliths are temporally associated with the eolian deposits, or whether they were introduced into this permeable horizon at a later date.

Activity 8.3.1.5.1.4.3 - Eolian history of the Yucca Mountain region. In conjunction with surficial deposit mapping activities (Activity 8.3.1.5.1.4.2), sandy eolian deposits were mapped, including a previously unrecognized eolian unit which underlies high terrace gravels of Fortymile Wash. The eolian deposits and buried soils within the deposits were sampled for U-series disequilibrium and thermoluminescence analyses.

Sample preparation and x-ray fluorescence analyses of ten sediment samples from playas between Beatty and Tonopah were completed and an internal report was prepared. These samples provide information relevant to the Oasis Valley ground-water flow system.

**Forecast:** These activities are unfunded; no activity is planned in FY 1994.

### **2.2.4.5 Study 8.3.1.5.1.5 - Paleoclimate-Paleoenvironmental Synthesis**

No progress during the reporting period; this was an out-year study.

**Forecast:** No activity is planned in FY 1994.

### **2.2.4.6 Study 8.3.1.5.1.6 - Characterization of the Future Regional Climate and Environments**

The draft study plan underwent SNL internal review and was sent to YMPO for review.

A plan for the transition of global and empirical climate modeling activities (Activities 8.3.1.5.1.6.1 and 8.3.1.5.1.6.4) from Pacific Northwest Laboratory to a single, consolidated effort by SNL was prepared for issue as a YMP Controlled Document. Completion of transition actions and preparation to resume technical activity for this study in FY 1994 is essentially complete and on schedule.

A number of Corrective Action Reports were closed out. The Corrective Action Reports were generated during an October 1992 internal QA audit of activity performed for this study under a contract between SNL and the National Center for Atmospheric Research. The study plan was drafted and is presently undergoing internal reviews. Because of the

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emphasis during this reporting period on planning, corrective actions, and preparatory activity, and limited FY 1993 funding, no technical work was performed specifically for this study. A readiness review is planned for early in FY 1994 as a precedent to resuming technical activity. A presentation on Long-Term Climate Modeling, describing the planned approach to the work, was made at the April Review Board Meeting as part of a series of presentations on the Department's approach to complex problems using the effects of future climate on infiltration as an example.

Activities 8.3.1.5.1.6.1 - 8.3.1.5.1.6.4. It has been proposed that the scope of work be modified for each of the four activities identified in the SCP for this study. The former activity designations and titles are:

- 8.3.1.5.1.6.1 - Global Climate Modeling
- 8.3.1.5.1.6.2 - Regional Climate Modeling
- 8.3.1.5.1.6.3 - Linked Global-Regional Climate Modeling
- 8.3.1.5.1.6.4 - Empirical Climate Modeling

The proposed replacement activities have been tentatively entitled:

- 8.3.1.5.1.6.1 - Global Climate Modeling
- 8.3.1.5.1.6.2 - Nested Global-Regional Climate Modeling
- 8.3.1.5.1.6.3 - Empirical Interpolation
- 8.3.1.5.1.6.4 - Future Climate Synthesis.

These modifications are needed to account for recent developments in climate modeling and to focus the study more directly on Project interests. In particular, the potential impacts of climate change on postclosure repository performance will be addressed.

**Forecast:** Early in FY 1994, a readiness review will be performed to verify readiness to resume technical work under the controls of the QA program. Other remaining actions defined in the transition plan to consolidate future climate modeling work at SNL will also be completed, including evaluating and dispositioning products developed in preliminary efforts performed over the last several years prior to study plan approval.

A significant portion of the effort for this study in FY 1994 will focus on validating computer models selected for predicting future climate conditions. This validation activity will include the comparison of model results with current meteorological data, and the initiation of validation activities comparing model results with paleoclimate data interpretations. Validation for paleoclimate conditions will initially focus on modeling a past climate state considered representative for providing an upper bound for the future precipitation rate; the preliminary results will be provided for use in ground-water travel time and future TSPA analyses.

A second major effort in FY 1994 will focus on the initial development of methods for interpolating numerical climate modeling results in both spatial and time domains, using

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empirically derived information, and for transforming climate modeling information into information useful for future hydrology performance assessment.

### **2.2.4.7 Study 8.3.1.5.2.1 - Characterization of the Quaternary Regional Hydrology**

Revision 2 of the study plan was approved by OCRWM on November 10, 1992, and sent to NRC on December 24, 1992. The NRC evaluated the responses to four comments and six questions provided by OCRWM at the December 19, 1990, detailed technical review. On the basis of these responses, NRC agreed that one comment and five questions were resolved. In a letter dated July 13, 1993, YMPO requested USGS to address the one comment and one question remaining. USGS provided responses and revised text on September 29, 1993, in response to NRC comments and questions.

Activity 8.3.1.5.2.1.1 - Regional paleoflood evaluation. Project staff reduced, analyzed, and compiled flood flow and related precipitation data for the Yucca Mountain/upper Amargosa River watershed. Arc/Info drainage basin maps of the Death Valley watershed and storm volume runoff tables of the upper Amargosa River drainage basin were completed.

A draft of a report, "Late Holocene Regional Paleoflood Evaluation of the Death Valley Watershed, Southwest United States" (Grasso), was nearly ready for review. This report presents numerical correlations between regional precipitation and peak discharge and storm runoff volumes. The numerical correlations will help to quantitatively characterize regional paleoflood conditions and provide a means for establishing the potential magnitudes and frequencies of large-scale floods and debris flows that may occur due to storms in the Yucca Mountain area.

Activity 8.3.1.5.2.1.2 - Quaternary unsaturated zone hydrochemical analysis. This activity has been deleted and the scope of work moved to Study Plan 8.3.1.2.2.7.

Activity 8.3.1.5.2.1.3 - Evaluation of past discharge areas. Fifty-four water samples (springs and wells) were collected and analyzed for major ions and/or Sr isotopes. All of the playas in the study area (approximately 50), except those off limits on the Nellis Air Force Bombing and Gunnery Range, have been sampled and sent for ostracode, chemical, and/or Sr isotope analysis. These data, together with previously analyzed samples, are being used to help define and analyze the regional ground-water flow system.

A report entitled "Vegetation Distribution in the Amargosa Desert" (Turner et al.) was submitted for technical review. The data from this report are being compared to regional vegetation mapping developed from remote sensing imagery.

A report entitled "Water Chemistry and Ostracode Occurrence from Springs in Colorado, Kansas, and New Mexico: Basic Data" (Gutentag et al.) received USGS technical review and was awaiting USGS approval.

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A report entitled "Logs and Interpretation of Trench 14 on the Bow Ridge Fault at Exile Hill, Nye County, Nevada" (Taylor and Huckins) received USGS technical review and was awaiting USGS approval.

An abstract entitled "U-Th Dating of Climate-Controlled Water Table Fluctuations, Yucca Mountain, NV" (Paces and Taylor) was submitted for presentation at the Fall '93 American Geophysical Union Meeting.

A paper entitled "Late Quaternary History and Uranium Isotopic Compositions of Ground Water Discharge Deposits, Crater Flat, Nevada" (Paces et al., 1993) was published and presented at the 1993 High-Level Waste Conference. The young ages (19 to 45 ka) presented in this paper have been criticized as representing minimum ages reflecting physical or chemical modifications of older deposits that have been exposed at the surface. Therefore, some effort was spent addressing various mixing models and other modification processes and their effects on U-series dates. These results provide additional support for the interpretations of young ground-water discharge that were expressed in the paper. In addition, investigations in obtaining  $^{14}\text{C}$  dates from rhizoliths from these deposits was initiated, and samples were submitted for determination of total, inorganic and organic carbon.

Strontium isotope characterization of ground-water flow systems in the Yucca Mountain region was presented at the Underground Test Area Remedial Investigation and Feasibility Study Information Exchange in Las Vegas, July 27-28, 1993. Informal discussions with Geotrans, Inc. were held concerning the possibility of improving communications and data exchange between the Yucca Mountain and environmental restoration studies at the test site.

Compilation, synthesis and interpretation of geochemical and isotopic data from waters (springs and wells) in the Ash Meadows flow system continued. Available data include major cation, anion and Sr concentrations, as well as Sr, H, O, and C isotopes. Data are also being viewed as several sub-basinal flow systems in addition to the larger Ash Meadows flow system boundaries. Correlations between isotopic systems (e.g., Sr and H) and chemical concentrations are being investigated. Additional geologic control pertaining to specific spring discharge localities is currently being compiled. These data will be used to investigate ground-water flow paths in the Ash Meadows system, as well as for the broader regional hydrologic model. The Oasis Valley Sr isotopic data base for ground-water samples including new data was compiled and evaluated.

U-Th chemistry on samples of spring discharge carbonate from the Crater Flat deposit and the Horse Tooth deposit was completed. These samples are being analyzed by alpha-emission spectrometry. The purpose of these analyses is to obtain more reliable results on previously estimated ages from these rocks of  $179 \pm 30$  ka and  $39 \pm 25$  ka, respectively.

Field work to investigate stratigraphic relationships and collect samples for geochronological studies was performed at the spring discharge sites near the southern end of Crater Flat. Eight samples of carbonate-rich materials were collected for U-Th disequilibrium purposes, and four samples of unconsolidated silty materials were collected for thermoluminescence studies. Stratigraphic relationships within this sample suite are much more



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clearly represented than in previously collected samples and should allow a more accurate interpretation of the depositional history of these deposits. Special attention was given to field evidence that would contribute to a better understanding of the history of deposition at Crater Flat given the concerns about secondary modification of carbonates exposed at the surface.

An informal meeting was organized to explore possible future activities at the paleo-discharge sites at the southern end of Crater Flat. Attendees from the saturated zone activity discussed various possible hypotheses for the origin of the deposits and suggestions for future work included core sampling and trenching.

U-series ages for a sample of carbonate collected from within a sequence of fine-grained palustrine deposits in Pahrump Valley were obtained to test the concordance of U-series and  $^{14}\text{C}$  ages on these materials. A final age is difficult to interpret.

Pedogenic and spring discharge deposits at Yucca Mountain and vicinity were re-examined in the field in light of the uncertain origins of some of these deposits. Several sites, including Nevares Spring, Ash Meadows, and Ute Crossing were selected to represent deposits whose ground-water discharge origins are well-established, so that their physical, morphological and geochemical features can be compared with deposits of a more equivocal nature (e.g., deposits currently mapped as Pavits Spring in Rock Valley and elsewhere). Seven rock and water samples were collected and prepared for further Sr and U isotopic analysis. Strontium analyses from a suite of banded travertine veins and massive Tertiary/Quaternary limestone from Rock Valley were performed to test the hypothesis that the prominent rock mound in Rock Valley north of Highway 95 represents a spring discharge site.

Activity 8.3.1.5.2.1.4 - Analog recharge studies. Two field trips were conducted to the East Stewart Creek and Kawich Creek study sites. Above average snow water equivalent observed in Kawich basin resulted in above average spring runoff. Near normal snow water equivalent observed in East Stewart basin resulted in near normal spring runoff. Field work conducted in late September was directed toward discontinuing data collection activities at these analog recharge sites.

Hydrologic data for the period October 1992 through May 1993 were compiled and added to the water data management file to update watershed model applications using the precipitation-runoff modeling system. The testing of the precipitation-runoff modeling system was completed.

The synthesis of the results of the chloride ion mass balance approach to estimate effective moisture and the results derived by simulation using the precipitation-runoff modeling system was completed. It was concluded that the inconsistent results derived by application of the chloride-ion method were attributable to nonrepresentative sampling characteristics of the index site(s) as regards to water chemistry. However, useful data on chloride ion deposition from bulk precipitation collectors and chloride concentrations from periodic grab samples of streamflow yield meaningful estimates of ground-water recharge

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from a reduced form of the chloride-ion mass balance technique. A report presenting modeling results, "Estimates of Recharge for Two Small Basins in Central Nevada" (Lichty), is in preparation.

The report, "An Estimate of the Roughness Length and Displacement Height of Sonoran Desert Vegetation, South-Central Arizona" (Claassen and Riggs, 1993), was published. It describes the techniques used to measure the effect that Sonoran Desert plants have on atmospheric circulation in the planetary boundary layer.

The long-term meteorological instrumentation array was shut down for two days while: newly calibrated instruments were installed, the data logger program was corrected so that the pyranometer functions properly, and the correct offsets for the thermometer calibration curves for the newly calibrated probes were input. Other than that, the long-term meteorological data collection at all three levels on the tower at Organ Pipe Cactus National Monument was completed. The April and July bulk precipitation collections were made without incident.

At the soil monitoring sites, five instrument shelters, complete with data loggers, batteries, solar panels and voltage regulators were installed. Four soils pits were dug and another was more than half completed; all were described pedologically and one was sampled for stable isotopes. Four tipping-bucket rain gauges were installed. Stilling ponds for five v-notch weirs were dug and the weirs, stilling wells, and water-level detectors installed.

Criteria for evaluating aerial photography, surveying, and topographic mapping proposals were developed with the help of USGS National Mapping Division staff.

Twenty-two soil samples were prepared for ion chromatograph analysis and 50 analyses were performed. Fifty-six soil-water samples and one rain-water sample were analyzed for deuterium. The top and bottom of one boulder from a debris-flow channel, two boulder samples from a fan surface and one sample from a terrace surface were analyzed for boron, uranium and major elements. The chloride analysis of soil waters was completed, as was the stable isotope analysis of soil carbonates.

**Forecast:** The precipitation-runoff modeling report will be completed; no other work is funded in 1994.

Activity 8.3.1.5.2.1.5 - Studies of calcite and opaline silica vein deposits. Fluid inclusion investigations were continued of fracture and vein calcite from Yucca Mountain drill core samples. This work resulted in two abstracts being submitted, one to the Geological Society of America Annual Meeting entitled "Isotopic Composition of Soil CO<sub>2</sub> (Carbon Dioxide) near Yucca Mountain" (McConnaughey et al.), and one to the 1994 High-Level Waste Conference entitled "Fluid Inclusion Crushing Studies of Calcite Veins from Yucca Mountain, Nevada, Tuffs: Environment of Formation" (Roedder et al.).

Laboratory space was obtained for the construction of a vacuum manifold for the extraction of CO<sub>2</sub> from soil gases and carbonates. This laboratory will also support isotopic aspects of unsaturated zone site characterization studies.

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Studies of the applicability of fossil molluscs to paleoclimate reconstructions were initiated with Desert Research Institute. Molluscs are widespread in terrestrial and aquatic environments of southern Nevada and provide paleoclimatic information both by the species assemblages and the isotopic composition of the shell carbonate.

A study was initiated of the geochemistry of carbon dioxide and water in the soil zone in the Yucca Mountain area. Monitoring of the isotopic compositions and concentrations of soil moisture and carbon dioxide continued at several locations spanning more than 1 km in elevation and spanning the local variations in climate/plant community. Vertical profiles through the soil typically show maximal CO<sub>2</sub> concentrations and minimal  $\delta^{13}\text{C}$  values within 1-2 m of the surface, usually corresponding with the depth of soil wetting and extensive root development. Intra-site variations in concentration and  $\delta^{13}\text{C}$  value of CO<sub>2</sub> as a function of season and depth often exceed inter-site variations, whereas variations in the  $\delta^{18}\text{O}$  of CO<sub>2</sub> appear to be smaller suggesting that a non-fractionating process, such as plant transpiration, is the dominant mechanism for water loss. Preliminary results of this work will be presented at the Fall '93 American Geophysical Union Meeting and at the 1994 High-Level Waste Conference. About 370 analyses of the  $\delta^{13}\text{C}$  and  $\delta^{18}\text{O}$  values of soil gas CO<sub>2</sub> (including operational checks) were performed. The values for  $\delta^{13}\text{C}$  and  $\delta^{18}\text{O}$  from about 575 samples of calcite from drill core, soil calcrete, spring deposits, and standards were determined.

Project personnel performed checks on U-Th chemical procedures used in the mass spectrometric technique, including chemical yields, and process blanks, and obtained additional data to further refine calibration values. In addition, system calibrations were performed by analyzing the *Acropora* marine coral standard. This represents the first reliable data collected from a natural carbonate on the Isotope Geochemistry Support Group mass spectrometer. The resulting data are encouraging: external precision on six age determinations is at a level of about 0.5 to 1 percent which is acceptable for most geochronological problems at Yucca Mountain. However, the accuracy of the resulting ages is systematically biased by Th spike calibration uncertainties which will have to be corrected by preparing and calibrating new Th spikes and standards.

Twenty-three soil samples from four locations at Yucca Mountain were collected for a <sup>90</sup>Sr scoping study. Sites were selected to obtain profiles through soils of different ages and pedogenic characteristics. If measurable <sup>90</sup>Sr concentrations are observed, results will be used to model the chemical behavior and rates of mobility of Sr in the pedogenic environment. Samples from pits in Midway Valley were submitted for <sup>90</sup>Sr determinations. Data are currently being evaluated in terms of analytical detection limits, world-wide post-World War II background levels in soils, and with respect to the stratigraphic relationships between radiogenic and nonradiogenic samples.

**Forecast:** Because the funding for this activity is less than a minimal budget to support ongoing studies, only a few reports are scheduled to be completed in FY 1994.

Research to be published in FY 1994 includes: "Isotopic Composition of Soil CO<sub>2</sub> (Carbon Dioxide) near Yucca Mountain (McConnaughey et al.), to be presented at the Fall '93 American Geophysical Union Meeting; "Environment of Formation of Calcite Veins

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from Yucca Mountain, Nevada, Tuffs as Evidenced by Fluid Inclusion Crushing Studies" (Roedder et al.), to be presented at the Geological Society of America Annual Meeting. The following research will be presented at the 1994 High-Level Waste Conference: "Fluid Inclusion Crushing Studies of Calcite Veins from Yucca Mountain, Nevada, Tuffs: Environment of Formation" (Roedder et al.); "Paleoclimatic and Paleohydrologic Records from Secondary Calcite: Yucca Mountain, Nevada" (Whelan et al.); "Molluscs as Climate Indicators: Preliminary Results of Stable Isotope and Species Analysis" (Sharpe et al.); "Paleohydrologic and Paleoclimatic Inferences from Calcite Petrography, Chemistry, and Stable-Isotope Studies" (Vaniman and Whelan); and "Isotopic Studies of Yucca Mountain Soil Fluids and Carbonate Pedogenesis" (McConnaughey et al.).

### **2.2.4.8 Study 8.3.1.5.2.2 - Characterization of Future Regional Hydrology due to Climate Change**

The NRC accepted the study plan in a letter dated April 5, 1993, with no comments, and requested a reference cited in the study plan.

Activity 8.3.1.5.2.2.1 - Analysis of future surface-water hydrology due to climate changes. No progress during the reporting period; this was an unfunded activity.

Activity 8.3.1.5.2.2.2 - Analysis of future unsaturated-zone hydrology due to climate changes. No progress during the reporting period; this was an unfunded activity.

Activity 8.3.1.5.2.2.3 - Evaluation of possible future changes of the climate and regional geologic framework on the regional saturated zone hydrology. No progress during the reporting period; this was an out-year activity.

**Forecast:** No activity is planned for FY 1994.

### **2.2.5 Erosion (SCP Section 8.3.1.6)**

The Commission accepted the Erosion Topical Report (DOE, 1993g), and requested the data packages supporting the report and other review materials in a letter to OCRWM dated October 15, 1993. The Program is preparing the requested materials for transmittal to the Commission.

**Forecast:** Comments and questions on the topical report on erosion will be addressed when they are received early in FY 1994.

**2.2.6 Postclosure Tectonics (SCP Section 8.3.1.8)**

**2.2.6.1 Study 8.3.1.8.1.1 - Probability of Magmatic Disruption of the Repository**

The revised study plan, which addressed Commission comments from the Phase II review, was submitted to the Project in February 1993 and approved in March 1993. The revised study plan was being reviewed by the Commission during this reporting period.

The first draft of the Los Alamos technical report, "Status of Volcanic Hazards Studies for the Yucca Mountain Site Characterization Project," was completed. A DOE-NRC Technical Exchange was held on June 9, 1993, to solicit comments from the Commission on this draft.

Activity 8.3.1.8.1.1.1 - Location and timing of volcanic events. No progress during the reporting period. Funding for this activity was scheduled to start in FY 1994; however, it will be delayed until FY 1995.

Activity 8.3.1.8.1.1.2 - Evaluation of the structural controls of basaltic volcanic activity. Field studies were conducted in Crater Flat to evaluate a geologic map and tectonic models of Crater Flat. Thirteen structural models for the controls of the distribution of basalt centers in the Yucca Mountain region were identified.

Activity 8.3.1.8.1.1.3 - Presence of magma bodies in the vicinity of the site. A contract was finalized with a consultant to review the status of geophysical data in the Yucca Mountain region as it relates to the volcanism issue.

Activity 8.3.1.8.1.1.4 - Probability calculations and assessment. The first phase of risk simulation modeling of E1 and E2 was completed. A paper entitled "Simulation Modeling of the Probability of Magmatic Disruption of the Potential Yucca Mountain Site" (Crowe, 1993) was presented at Focus '93. Using a form of a triangular distribution, cumulative probability curves for E1 were generated. The paper was in the YMPO approval process and will be published in the conference proceedings.

**Forecast:** For FY 1994 work will focus on the development of alternative structural models for the distribution of past basaltic centers. These models will use constraint probability ranges of E2. Data will be integrated into this activity from field geologic studies, and from aspects of the tectonics programs (seismicity, geophysical studies, studies of Quaternary faulting and fault systems, and the evaluation of tectonic models). A report on this work will be prepared.

**2.2.6.2 Study 8.3.1.8.1.2 - Physical Processes of Magmatism and Effects on the Repository**

The draft study plan was submitted to DOE in October 1992. Review comments were completed on June 2, 1993. All comments were resolved and verified in August 1993, and the study plan was sent to NRC on October 4, 1993.

Activity 8.3.1.8.1.2.1 - Eruptive effects. Field work, which focused on the distribution of lithic fragments in basaltic pyroclastic deposits, was begun at Alkali Butte in New Mexico. Geologic mapping of this site was completed. A paper was presented entitled "Effects of Magmatic Processes on the Potential Yucca Mountain Repository: Field and Computational Studies" (Valentine et al., 1993) at Focus '93. Initial results of field analog studies at small-volume basaltic centers where detailed measurements are being conducted of the amount of wall-rock debris that can be erupted as a function of depth in the volcanic plumbing system were described. Constraints from field evidence of wall-rock entrainment mechanisms were also discussed.

**Forecast:** Efforts will be continued to establish the probability of direct magmatic disruption of the repository resulting in dispersal of significant quantities of radioactive waste surface to exceed the regulatory requirements for licensing of a repository. A two-part approach will be used. First, an examination will be made of the physical constraints on the amount of waste that can be carried to the surface by comparison to the total abundance of lithic fragments (country rock) in magma and the depth of derivation of the lithic fragments. If the component of the repository inventory released at the surface is sufficiently small ( $<0.1R$  where  $R$  is the maximum radiological releases allowed under regulatory requirements), studies on the direct effects of future volcanic activity will be terminated. Second, work will continue on the direct effects of eruptions through the controlled area. If the released inventory is  $>0.1R$ , eruption modeling will be carried out to attempt to determine the partitioning of the waste inventory in surface eruptions (scoria cone, scoria-fall sheet, fine-grained component, lava flows) and the percentage of the waste that is released in the accessible environment in 10,000 years. A letter report on lithic fragment studies will be prepared.

Activity 8.3.1.8.1.2.2 - Subsurface effects of magmatic activity. Basalt intrusion forms were studied at the Nye Canyon and southern Crater Flat sites. Lucero and Rio Puerco volcanic fields in New Mexico were evaluated for field studies of subsurface geometry of basalt feeder systems. A revised dike-swarm geometry of the lava sequences of the Lathrop Wells volcanic center was completed.

**Forecast:** Work will continue on the potential subsurface effects of intrusion of magma into a repository, topographically below or above the repository or in the waste isolation system. The primary intrusion forms examined will be individual dikes, dike swarms and sills (grading to lopoliths). The analysis will be focused on the effects of mechanical emplacement of the intrusions, on the thermal perturbations from the intrusions, and on the effects of volatile degassing on the unsaturated and saturated zone hydrology.

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Activity 8.3.1.8.1.2.3 - Magma system dynamics. Staff revised the section on magma system dynamics in the Los Alamos technical report on the status of volcanism studies.

**Forecast:** The following work will be performed:

1. Attempt to bound E3, the probability of magmatic activity carrying significant quantities of waste radionuclides to the surface through direct eruption.
2. Evaluate the possible subsurface effects of magma activity through formation of dikes or sills in or below the waste isolation system.
3. Examine the processes of magmatic activity, from generation of magma at depth, through segregation and ascent, storage within chambers in the crust or mantle, and eruption at the surface.

A letter report on magma system dynamics will be prepared.

### **2.2.6.3 Study 8.3.1.8.2.1 - Analysis of Waste Package Rupture Due to Tectonic Processes and Events**

The Principal Investigator completed the current draft of Study Plan 8.3.1.8.2.1, Rev. 1 in the new study plan format. It was submitted for USGS review September 30, 1993.

**Forecast:** Work on the combined study plan package will continue in FY 1994. The study plan will be revised after USGS review and submitted to YMPO for review by mid-year. Synthesis studies will continue to compile information on the tectonic setting and structural field relations of basalts in Crater Flat. Scenarios of tectonic disruption of the hydrologic system will be developed and analyzed.

### **2.2.6.4 Study 8.3.1.8.3.1 - Analysis of the Effects of Tectonic Processes and Events on Average Percolation Flux Rates Over the Repository**

Activities 8.3.1.8.3.1.1 through 8.3.1.8.3.1.7. No progress during the reporting period; these were out-year activities.

**Forecast:** This study will be combined with Study 8.3.1.8.2.1.

### **2.2.6.5 Study 8.3.1.8.3.2 - Analysis of the Effects of Tectonic Processes and Events on Changes in Water-Table Elevation**

Activity 8.3.1.8.3.2.5 - Effects of faulting on water-table elevation. The Principal Investigator completed the current draft of Study Plan 8.3.1.8.2.1, Rev. 1 in the new study plan format. It was submitted for USGS review September 30, 1993.

**Forecast:** This study will be combined with Study 8.3.1.8.2.1.

**2.2.6.6 Study 8.3.1.8.3.3 - Analysis of the Effects of Tectonic Processes and Events on Local Fracture Permeability and Effective Porosity**

No progress during the reporting period; this was an out-year study.

**Forecast:** This study will be combined with Study 8.3.1.8.2.1.

**2.2.6.7 Study 8.3.1.8.4.1 - Analysis of the Effects of Tectonic Processes and Events on Rock Geochemical Properties**

No progress during the reporting period; this was an out-year study.

**Forecast:** This study will be combined with Study 8.3.1.8.2.1.

**2.2.6.8 Study 8.3.1.8.5.1 - Characterization of Volcanic Features**

**Activity 8.3.1.8.5.1.1 - Volcanism drillholes.** Los Alamos and USGS staff held discussions about obtaining ground-magnetic and gravity data to investigate aeromagnetic anomalies. These activities have been postponed because the drillholes will not be funded in FY 1994.

**Activity 8.3.1.8.5.1.2 - Geochronology studies.** New  $^{39}\text{Ar}/^{40}\text{Ar}$  age determinations were obtained for the basalt of Thirsty Mesa, the Amargosa Valley aeromagnetic anomaly, the 1- and 3.7-Ma basalt centers of Crater Flat, and tuff xenoliths enclosed within basalt at Lathrop Wells. Field sites were flagged in preparation for environmental surveys of trenching sites at the 1-Ma basalt centers of Crater Flat. Trench sites at the Sleeping Butte center were surveyed. At Lathrop Wells, new age determinations were obtained using the cosmogenic He and thermoluminescence methods.

**Forecast:** Final assessments of the utility of the U-Th disequilibrium, the cosmogenic He, and the thermoluminescence methods for establishing the ages of Late Pleistocene and Holocene volcanic centers will be made. Age determinations using the  $^{39}\text{Ar}/^{40}\text{Ar}$  method will be obtained for the basalt at Sleeping Butte, Crater Flat, Buckboard Mesa, the Thirsty Mesa Shield, and the approximately 10 Ma basalt dike intruded into the Solitario Canyon fault. Soil and geomorphic studies will continue at Lathrop Wells, Sleeping Butte, and Crater Flat and at selected localities in the Cima volcanic field. Exploratory paleomagnetic work will be extended to the basalt Sleeping Butte and the basalt units of Crater Flat.

**Activity 8.3.1.8.5.1.3 - Field geologic studies.** Twenty-three shallow pits were excavated at the Lathrop Wells volcanic center to investigate the distribution and clast size



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variations of the scoria-fall sheet. A revised geologic map of the lava sequences of the Lathrop Wells center was completed. Field studies of the historic eruptions of Cinder Cone in Mt. Lassen National Monument were completed. The distribution of basaltic ash in trench sites in the southern part of Yucca Mountain was examined in conjunction with USGS. Two tephra units were discovered in alluvial units north of the Lathrop Wells center.

**Forecast:** Geologic mapping of the basalt of Buckboard Mesa will be completed. Final topographic maps of the Lathrop Wells, Sleeping Butte, and basalt units of Crater Flat will be converted to digital data for volume calculations. Some field studies will be conducted in the Cima and Lunar Crater volcanic fields in support of geochronology, soil, and geomorphic studies. Preliminary geomaps of the Pliocene volcanic centers of Crater Flat and the Quaternary volcanic centers of Crater Flat and a revised geomap of Lathrop Wells volcanic center will be prepared.

Activity 8.3.1.8.5.1.4 - Geochemistry of scoria sequences. Major element geochemical data were obtained for the Lathrop Wells volcanic center. Microprobe studies of the mineral composition of basaltic ash in alluvial deposits were begun. Modeling of fractionation, eruption, assimilation, and recharge processes was begun to discriminate between polycyclic and monogenetic eruptive activity at Lathrop Wells.

**Forecast:** Petrological and isotopic studies of the basalt of Lathrop Wells, Sleeping Butte, and the 1 Ma and 3.7 Ma basalt of Crater Flat will be focused on. Isotopic analyses of Sr, Nd, and Pb will be obtained for these units. INAA data for a selected suite of trace elements will also be obtained. Petrological modeling of the isotopic and geochemical data will be conducted to examine alternative models of basalt petrogenesis. The results of the modeling will be used to test assumptions used in probability calculations. A report on the geochemistry of Lathrop Wells eruptive sequences will be prepared.

Activity 8.3.1.8.5.1.5 - Geochemical cycles of basaltic volcanic fields. Staff began geochemical evaluations of alternative models of the time-compositional variations in basalt units of the Yucca Mountain region.

**Forecast:** Studies of the Cima, Lunar, San Francisco Peak, and Springerville volcanic fields will be continued. New data will be gathered on the volcanic fields of Saline Valley, the Big Pine area, and selected volcanic fields in southern Arizona and southern New Mexico. A report on the evolution of volcanic fields in the southwestern United States will be prepared.

### 2.2.6.9 Study 8.3.1.8.5.2 - Characterization of Igneous Intrusive Features

The study plan underwent YMPO review and comments were being addressed by USGS.

Activity 8.3.1.8.5.2.1 - Evaluation of depth of curie temperature isotherm. No progress during the reporting period; this was an unfunded activity.

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Activity 8.3.1.8.5.2.2 - Chemical and physical changes around dikes. Technical activities for this report period were limited to maintaining laboratory and field capabilities and providing input to drilling plans. Temperature-calibration facilities in the laboratory were improved, a new NIST-calibrated platinum-resistance thermometer was installed, and the calibration baths were modified. An apparatus for measuring the thermal conductivity of saturated rocks at elevated temperatures was calibrated and put into service, initially for a geothermal application. The apparatus might be used for Yucca Mountain-related work to determine the conductivity of rocks from the saturated zone of newly drilled deep boreholes.

Information was provided to drilling planners regarding core hole USW G-5 and to the hydrologic staff regarding planned reconfiguration of some of the WT-series holes, to allow high-resolution temperature logs through the unsaturated zone. Information was also provided to planners of the ESF for proposed horizontal temperature logging and thermal-conductivity determinations in the ESF.

Activity 8.3.1.8.5.2.3 - Heat flow at Yucca Mountain and evaluation of regional ambient heat flow and local heat flow anomalies. No field measurements were carried out due to the lack of available drillholes for thermal study. A dedicated laboratory for thermal studies was maintained and apparatus was kept calibrated.

**Forecast:** Presently available drilling plans make it unlikely that new drillholes will be available for temperature measurements during the next reporting period. However, reconfiguration of three of the existing Water Table wells is likely, in which case, high-resolution temperature logs will be obtained from them. Temperature measurements may be possible in reconfigured H-series, G-series, and ESF ramp-alignment boreholes to improve baseline data before in situ conditions are disturbed by ESF ramp construction. Measurements in USW UZ-14 are also being considered if results of drilling and hydrologic testing indicate that thermal studies can contribute to an understanding of the occurrence and stability of apparent perched fluids. A summary and analysis of existing heat-flow and temperature data in the Yucca Mountain area will be prepared. Input to plans for horizontal temperature-profiling off the ESF tunnels will continue.

Heat flow work planned for FY 1994 includes resolving final comments on the study plan and transmitting the plan to NRC. Precision temperature logs will be done as opportunities arise to collect data. This may happen in FY 1994 at USW UZ-14, UE-25 UZ#16 and selected WT holes. A summary of existing heat-flow information will be prepared for a Geophysics White Paper.

### **2.2.6.10 Study 8.3.1.8.5.3 - Investigation of Folds in Miocene and Younger Rocks of the Region**

Activity 8.3.1.8.5.3.1 - Evaluation of folds in Neogene rocks of the region. No progress during the reporting period; this was an out-year activity.

**Forecast:** This activity is not funded in FY 1994; work is planned to start in FY 1995.

**2.2.7 Human Interference (SCP Section 8.3.1.9)**

**2.2.7.1 Study 8.3.1.9.1.1 - An Evaluation of Natural Processes that Could Affect the Long-Term Survivability of the Surface Marker System at Yucca Mountain**

Activity 8.3.1.9.1.1.1 - Synthesis of tectonic, seismic, and volcanic hazards data from other site characterization activities. No progress during the reporting period; this was an out-year activity.

Activity 8.3.1.9.1.1.2 - Synthesis evaluation of the effects of future erosion and deposition on the survivability of the marker system at Yucca Mountain. No progress during the reporting period; this was an out-year activity.

**Forecast:** No activity is planned for FY 1994.

**2.2.7.2 Study 8.3.1.9.2.1 - Natural Resource Assessment of Yucca Mountain, Nye County, Nevada**

Activity 8.3.1.9.2.1.1 - Geochemical assessment of Yucca Mountain in relation to the potential for mineralization. Work began in April 1993, to assemble new information on radiometric age data from altered rocks and known mineral occurrences in the vicinity of Yucca Mountain. A report entitled "New Radiometric Ages Related to Alteration and Mineralization in the Vicinity of Yucca Mountain, Nye County, Nevada" (McKee and Bergquist), was completed and was in USGS internal review. This report contains previously unpublished information that relates ages of mineralization to volcanism and enhances our understanding of the relationship between Tertiary volcanic events and mineralization in the vicinity of Yucca Mountain. The radiometric data were verified and supporting data produced. This will be an important help in the evaluation of mineral resources at the potential repository site. The report is accompanied by a map produced in the Geographic Information System format and shows sampling sites superimposed on a generalized geologic base.

Activity 8.3.1.9.2.1.4 - Assessment of hydrocarbon resources at and near the site. Work to evaluate hydrocarbons in the Yucca Mountain region continued through September 1993. Density, resistivity, gamma ray, and caliper well logs from the Felderhoff 25-1 and 5-1 wells were analyzed; figures summarizing the logs were prepared. The analysis of lithologies of rock data from the Amargosa Valley are described in a proposed Open-File Report entitled "Lithologic and Geophysical Logs of Drill Holes Felderhoff Federal 5-1 and 25-1, Amargosa Desert, Nye County, Nevada" (Carr et al.).

Evaluation of hydrocarbons in the Railroad Valley analog area continued. Surface mapping information from field studies in the Pancake Range on the west side of Railroad Valley was analyzed. The northern end of the Pancake Range includes an east-verging overturned syncline involving Late Paleozoic sedimentary strata which is part of the Central Nevada Thrust Belt. The implications of the Pancake Range mapping are that there are

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significant differences in the timing and character of the deformation between the Central Nevada thrust belt and the Utah and Wyoming thrust belt. Proposed similarities in oil potential are extremely speculative, especially if extended southward to Yucca Mountain.

Staff visited the Nevada Bureau of Mines and Geology to collect additional cuttings/samples of Chainman Shale and Sheep Pass Formation occurrences in wells throughout Railroad Valley. Coal samples were also provided as additional possible analogs to the Area 8 peats. The USGS wells in Fish Lake Valley were sampled for recent peat which may be an analog to the Neogene peat found in Area 8 of the Nevada Test Site. A first draft of "Source Rocks and Thermal Maturity History of the Yucca Mountain Region, Southern Nye County, Nevada" (Barker) and a technical data information form were prepared for future publication.

A summary abstract entitled "Isotopic Tracers of Gold Mineralization in Paleozoic Limestones of Southern Nevada" (Peterman et al.) was submitted for the 1994 High-Level Waste Conference. This paper presents Sr and Pb isotopic results from mineralized and nonmineralized Paleozoic carbonates, and suggests a powerful exploration approach that utilizes deviations in isotopic compositions from original marine signatures.

Six dacite dike samples from the northeast part of Bare Mountain were obtained from the University of Nevada, Reno for elemental and Sr and Pb isotopic analyses. These materials are being geochemically characterized since they have commonly been assumed to represent part of the igneous system responsible for hydrothermal precious metal mineralization of Paleozoic limestones at Bare Mountain. Since much of the mineralization at Bare Mountain is thought to be associated with intrusion of Tertiary igneous bodies, these dikes may provide an opportunity to characterize, in part, the intrusive component of the hydrothermal systems.

Digital Elevation Model data was used to produce topographic base maps of Bare Mountain and the Striped Hills areas and limestone sample localities were plotted on these base maps. In addition, Sr isotopic compositions and average ages of the rock units were compiled and compared to the marine Sr isotopic evolution curve. Deviations of observed  $^{87}\text{Sr}/^{86}\text{Sr}$  compositions are presumably caused by secondary alteration, and the extent of deviations and their spatial distributions are currently being evaluated. Subsequently, a contoured base map of the Bare Mountain area was prepared by digitizing a portion of the Beatty 1:100,000 sheet. This digitized map is now used as a base for computer-plotting of sample locations and geochemical parameters and will allow spatial visualization of alteration patterns in the Paleozoic carbonate section. In addition, all current sample locations were determined, verified, and plotted on the base map. Possible correlations between Sr isotopic compositions and Sr and Ba concentrations were examined from Bare Mountain carbonates. Correlations are not strong, although  $\delta^{87}\text{Sr}$  does exhibit a general increase with Sr and Ba concentrations. Data may be affected by the type of carbonate analyzed, and steps were initiated to quantitatively identify the degree of dolomitization in all of the samples by x-ray fluorescence analysis of Mg/Ca ratios.

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Strontium isotopic data for Paleozoic limestones from Bare Mountain, Striped Hills, Spring Mountains, and ranges in the Indian Springs Valley have been compiled and evaluated. Samples from Bare Mountain were identified as either being mineralized or nonmineralized. Samples from the Striped Hills, Spring Mountains, and ranges in the Indian Springs Valley are from nonmineralized terranes and retain their original Paleozoic marine carbonate  $\delta^{87}\text{Sr}$  signatures. In contrast, mineralized carbonates from Bare Mountain have had their  $\delta^{87}\text{Sr}$  values increased dramatically through an influx of Sr which was enriched in radiogenic strontium ( $^{87}\text{Sr}$ ). These results imply that mineralization included interaction with high  $\delta^{87}\text{Sr}$  fluids which probably represent ascending hydrothermal fluids percolating through the Precambrian basement. Thus far, this isotopic approach appears to hold considerable promise as a tool for evaluating mineral potential of carbonate terranes.

Field work included several days in the Yucca Mountain vicinity collecting field data and samples for use in assessing the potential for mineralization in the area. The first portion of the collecting trip included an underground tour of the Sterling Gold Mine at Bare Mountain. The purpose of the trip was to examine and sample altered host rock and secondary mineralization associated with low-angle structures and associated gold deposits in Paleozoic carbonates. Approximately 15 samples were collected for geochemical and isotopic (Sr and Pb) analysis. In addition, spectacular specimens of secondary carbonate speleothems were collected from open dug and cavity surfaces for geochronological, paleohydrological and paleoclimate investigations. The second portion of the collecting trip aimed at characterizing the largely unaltered section of Paleozoic carbonates in the Specter Range. These samples may serve to verify that large areas of unmodified carbonate retaining its original sea-water isotopic signatures are preserved throughout the region. In addition to collecting approximately 15 samples of marine carbonate bedrock, abundant banded travertine veins (presumably representing calcite deposition from carbonate-saturated ground waters) were observed and sampled.

The Principal Investigator participated in a mine tour of the Round Mountain Gold Mine near Tonopah, Nevada. The purpose of this trip was to closely examine a well-exposed volcanic-hosted gold deposit. Mineralization is hosted by Oligocene felsic pyroclastic volcanics. Hydrothermal solutions were introduced around 25 Ma along zones of high permeability. Hydrogeologic transmissivity at the time of mineralization was dependent on depositional porosity and fracture density which, in turn, was controlled by the degree of welding of various different lithostratigraphic units.

The following publications were presented at Geological Society of America meetings in Reno, Nevada, May 19-21, 1993, in support of the Yucca Mountain region petroleum model: "Seismic Constraints on Fault Angles in Railroad Valley, NV" (Grow et al., 1993); "Structure and Timing of Deformation in the Central Pancake Range, Nye County, Nevada" (Perry and Grow, 1993); "Controls on Cross-Sectional Geometry of Extensional Basins -- A Seismic-Stratigraphic Approach" (Potter et al., 1993); and "The Case for Pre-Middle Cretaceous Extensional Faulting in Northern Yucca Flat, Southwestern Nevada" (Cole et al., 1993).

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**Forecast:** Scientists plan to analyze chemical and petrologic information from core and cuttings produced from boreholes that are scheduled to be drilled for the YMP at and near Yucca Mountain and to run transects across Yucca Mountain to analyze for soil gases that can provide information on indications of mineralization or lack thereof at depth.

### **2.2.7.3 Study 8.3.1.9.2.2 - Water Resource Assessment of Yucca Mountain, Nevada**

The State of Nevada sent 25 comments on the study plan to OCRWM on December 24, 1992. DOE responded to the State's comments on April 22, 1993. No other progress during the reporting period; this was an out-year study.

**Forecast:** No activity is planned for FY 1994; this is an out-year study.

### **2.2.7.4 Study 8.3.1.9.3.1 - Evaluation of Data Needed to Support an Assessment of the Likelihood of Future Inadvertent Human Intrusion at Yucca Mountain as a Result of Exploration and/or Extraction of Natural Resources**

No progress during the reporting period; this was an out-year study.

**Forecast:** No activity planned in FY 1994; this is an out-year study.

### **2.2.7.5 Study 8.3.1.9.3.2 - An Evaluation of the Potential Effects of Exploration for, or Extraction of, Natural Resources on the Hydrologic Characteristics at Yucca Mountain**

No progress during the reporting period; this was an out-year study.

**Forecast:** No activity planned in FY 1994; this is an out-year study.

## **2.2.8 Meteorology (SCP Section 8.3.1.12)**

### **2.2.8.1 Study 8.3.1.12.1.1 - Characterization of the Regional Meteorological Conditions**

No progress during the reporting period. This study will be combined with Study 8.3.1.12.1.2 and Study 8.3.1.12.4.1.

**Forecast:** The study plan preparation will be initiated in FY 1994.

**2.2.8.2 Study 8.3.1.12.1.2 - Plan for Synthesis of Yucca Mountain Site Characterization Project Meteorological Monitoring**

No progress during the reporting period. This study will be combined with Study 8.3.1.12.1.1 and Study 8.3.1.12.4.1.

**Forecast:** The study plan preparation will be initiated in FY 1994.

**2.2.8.3 Study 8.3.1.12.2.1 - Meteorological Data Collection at the Yucca Mountain Site**

Revision 1 of the study plan was sent to NRC on August 11, 1993.

**Activity 8.3.1.12.2.1.1 - Site meteorological monitoring program.**

The Meteorological Monitoring Summary Report (SAIC, 1993c), for the reporting period December 1985 through December 1991, was submitted to YMPO. Two quarterly ambient air monitoring reports were submitted to the State of Nevada; this met the reporting requirements for Air Quality Permit No. 2693 during the period to allow continuation of surface disturbing activities.

Meteorological monitoring continued at nine sites. Equipment upgrades were completed at five sites, enhancing the capability to measure additional parameters and improving the reliability and quality of the existing systems. This upgrade will also provide more detailed data to be used as part of the diurnal cold air drainage study associated with the mountain terrain around Yucca Mountain.

**Activity 8.3.1.12.2.1.2 - Data summary for input to dose assessments.**

No progress during the reporting period; this was an out-year activity.

**Forecast:** Data collection will continue during FY 1994. The data required to maintain the State of Nevada Air Quality permit will continue to be collected and reported.

**2.2.8.4 Study 8.3.1.12.3 - Studies to Provide Data on the Location of Population Centers Relative to Wind Patterns in the General Region of the Site**

A scoping field study for air diffusion measurements in mountain terrain was conducted in June 1993, with support of the National Oceanic and Atmospheric Administration Turbulence and Diffusion Division, and Technical and Management Support Services personnel. Procedures for performing full-scale diffusion measurement field activities were drafted. A report entitled "Summary of Socioeconomic Data Analyses Conducted in Support of the Radiological Monitoring Program During Calendar Year 1992" (SAIC, 1993d) was prepared in May 1993. This is an annual summary report from the socioeconomic data base

which provides population density and community characteristics for 1992 to support the "NV/YMP Site Specific Radiological Control Manual" (REECo, 1992).

**Forecast:** A diffusion measurement field activity will be accomplished with support of the National Oceanic and Atmospheric Administration Turbulence and Diffusion Division in the October/November time period. A report of the results will be prepared and submitted to the Project. An annual update of population density for Task 1, "Determine Population Centers," of this study plan will be obtained from the summary of socioeconomic data analyses.

#### **2.2.8.5 Study 8.3.1.12.4.1 - Characterize the Potential Extreme Weather Phenomena and Their Recurrence Intervals**

No progress during the reporting period. This study will be combined with Study 8.3.1.12.1.1 and Study 8.3.1.12.1.2.

**Forecast:** The study plan preparation will be initiated in FY 1994.

#### **2.2.9 Offsite Installations and Operations (SCP Section 8.3.1.13)**

The radiological environmental monitoring program for YMP, being implemented by the Technical and Management Support Services contractor for YMP, will provide the background radiological information needed to respond to the objectives of the various SCP 8.3.1.13 activities. Sampling under a qualified QA program began in 1990. Program activities are being reported annually (by calendar year) in the Site Environmental Report.

Sample collection and analysis continued for air particulate radionuclide concentrations, ambient gamma radiation, ambient radon concentrations, and radionuclide concentrations in surface soil at a limited number of locations. Biota samples collected in FY 1993 are being prepared for analysis. Data validation and reduction is in process.

**Forecast:** Sample collection and analysis will essentially remain at present levels through FY 1994 with the exception of biota. No biota samples will be collected for analysis.

#### **2.2.10 Surface and Subsurface Access Characteristics (SCP Section 8.3.1.14)**

The Transition Plan for Soil and Rock Properties of Potential Locations of Surface Facilities was prepared and submitted to YMPO. This plan effects the transition of the work from USGS to SNL.



### **2.2.10.1 Study 8.3.1.14.2.1 - Exploration Program**

Activity 8.3.1.14.2.1.1 - Site reconnaissance. This activity began in October 1991 and was essentially completed in March 1992. The purpose of this reconnaissance was to identify the locations for a series of soil test pits to be excavated.

Activity 8.3.1.14.2.1.2 - Preliminary and detailed exploration. The SNL Principal Investigator and staff met with the ESF design team, Sample Management Facility staff geologists, and DOE staff at the Sample Management Facility to review the core from UE-25 NRG#2A and to discuss further drilling along the North Ramp alignment in the vicinity of the Bow Ridge fault. As a result of these discussions, UE-25 NRG#2A was deepened to provide a lithologic contact of high confidence. UE-25 NRG#2 was deepened to ensure complete penetration of the Bow Ridge fault and to provide a lithologic contact of high confidence to the east of the fault. Another borehole, UE-25 NRG#2B, was drilled to provide additional information for a zone of no core recovery in UE-25 NRG#2.

A section map of the North Ramp Bow Ridge fault area was prepared to incorporate the information from boreholes UE-25 NRG#1, UE-25 NRG#2, UE-25 NRG#2A, UE-25 NRG#2B, UE-25 NRG#3 and UE-25 RF#8. An overview of the Soil and Rock Properties Study and the section map of the North Ramp Bow Ridge fault area was presented to NRC staff during a site visit in May.

Drilling was also completed on boreholes UE-25 NRG#4 and UE-25 NRG#5. The cored interval in UE-25 NRG#4 was increased to accommodate the enhanced ESF option. The location for an additional North Ramp borehole designated USW NRG-7 was surveyed. Criteria for the engineering design use of data from borehole USW SD-12 have been established, and the hole has been located and surveyed.

The locations for additional North Ramp boreholes designated USW NRG-8a, USW NRG-8b and USW NRG-8c were identified. These shallow boreholes will investigate the depth of alluvium to the west of Exile Hill above the North Ramp.

**Forecast:** The objective of the exploration program is to plan the strategy for collection and analysis of the geotechnical information that is necessary to site and design surface facilities and underground openings for the ESF. Existing data will be evaluated to determine the additional information needed to adequately address design issues for construction of the ESF. On the basis of these data needs and the expected soil and rock conditions at the site, an exploration program will be implemented using such methods as drilling, test pit excavation, sampling and geophysical investigations. Results of data collection and analysis activities will be summarized and published in an SNL report.

## **2.2.10.2 Study 8.3.1.14.2.2 - Laboratory Tests and Material Property Measurements**

### Mechanical and Bulk Properties Testing:

Mechanical and bulk properties testing (unconfined compression, splitting tension, triaxial compression and bulk properties) has been completed for core from boreholes UE-25 NRG#2, UE-25 NRG#2A, UE-25 NRG#3, and USW NRG-6 (see Section 2.2.11.3).

### Thermal Conductivity Testing:

The SNL Work Agreement for thermal conductivity testing of samples from USW NRG-6 was issued. The thermal conductivity of each sample is being measured at nominal temperatures of 30°, 50°, 70°, 110°, 155°, 200°, 245°, and 290°C. Testing of samples from eleven different depths between 0.0 m and 126.8 m has been completed at three different saturation states (air-dry, fully saturated, and oven-dry). The scientific notebooks containing these data are being reviewed and testing at temperatures above 100°C is in process. Samples from USW NRG-6 below 126.8 m were selected and are in the process of being machined.

### Thermal Expansion Testing:

The SNL Work Agreement for thermal expansion testing of samples from USW NRG-6 was issued. For these samples, testing will be conducted from ambient to 300°C, and at three different saturation states (air-dry, fully saturated, and oven-dry) below 100°C (see Section 2.2.11.2).

Testing of air-dry samples from ten different depths between 0.34 and 126.8 m was completed from ambient to 110°C. Thermal expansion testing on saturated samples was delayed so that parts for the saturation test apparatus can be cloned for the additional dilatometer system (see Section 2.2.11.2). The saturation test apparatus is used to control the atmosphere (i.e., high humidity) around the sample to minimize sample dehydration at temperatures below the nominal boiling point of 100°C. Reassembly of the dilatometer system is in process. Thermal expansion testing on fully saturated samples will resume after the system is calibrated. For these tests, thermal expansion will be measured from ambient to 100°C, then the temperature will be held constant for 30 hours to allow the sample to dehydrate and the length to stabilize. Heating will then be restarted and will continue until 300°C is reached, then the sample will be cooled to ambient temperature.

### Mineralogy:

The SNL Work Agreements for preparing polished thin sections and laboratory petrologic determination of samples from USW NRG-6 were issued.

Polished thin sections were made on 17 samples from depths 6.8 to 126.8 m and mesoscopic descriptions were completed for these samples. Microscopic thin section descriptions and point counts are in process. Powdered samples are being prepared for whole-rock chemical and x-ray diffraction analysis. Mineralogic, petrologic, and whole-rock

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chemistry of the samples will be used to interpret data from thermal and mechanical tests and to determine if correlations exist between these values and the physical properties of the rock.

**Forecast:** The objective of this program is to determine physical, mechanical, thermal, and dynamic properties of the soil and rock. Laboratory tests and material property measurements will be performed on representative samples of soil and rock. The results of this testing will provide engineering data for the design of surface structures, fills, roads, slopes, and underground openings. Testing activities on core samples from several drillholes include laboratory mechanical tests and laboratory thermal properties tests. In addition, laboratory tests will be performed on unconsolidated tuff recovered from NRG-2B, and soils testing will be performed for a booster pump station, water storage tanks, and conveyer support locations. Results of the laboratory testing will be summarized and published in an SNL report.

### 2.2.10.3 Study 8.3.1.14.2.3 - Field Tests and Characterization Measurements

A Scientific Notebook Procedure for Geotechnical Core Logging was developed and used to develop geologic and structural logs for core from boreholes UE-25 NRG#1, UE-25 NRG#2, UE-25 NRG#2A, UE-25 NRG#2B, UE-25 NRG#3, UE-25 NRG#4, UE-25 NRG#5 USW NRG-6 and UE-25 RF#8.

The procedures for Schmidt-Hammer tests of core from the North and South Ramp boreholes were prepared and the equipment to perform these tests was procured. Equipment to perform the soil resistivity testing was procured and calibrated. The M&O has assumed responsibility for earth resistivity testing at the North Portal and SNL will provide calibrated test equipment and limited support for these tests.

The existing open soil test pits for the North Ramp Portal and access roads were closed.

Standard Penetration Tests were performed in borehole UE-25 NRG#2B to determine the bearing capacity of the unconsolidated tuff.

**Forecast:** Field tests will be performed to determine the in situ physical, mechanical and dynamic properties of the soil and rock. Characterization measurements will be conducted on the rock to classify and quantitatively describe rock structure. The results of these tests and measurements will be used to develop estimates of the engineering characteristics of the soils and rock. This geotechnical information will be used for structural design and to group soil and rock into stratigraphic units with similar properties. Testing activities include preparation of structural and geologic logs for designated North Ramp Geologic and South Ramp Geologic holes, rock mass quality estimates for selected surface locations, and submission of results of the in situ soils testing forecast in Section 2.2.10.2. Results of the data collection and analysis will be summarized and published in an SNL report.

**2.2.11 Thermal and Mechanical Rock Properties (SCP Section 8.3.1.15)**

**2.2.11.1 Study 8.3.1.15.1.1 - Laboratory Thermal Properties**

Revision 1 to the study plan was reviewed, approved by YMPO on August 27, 1993, and sent to NRC on September 14, 1993. This revision updates the study plan with respect to the current configuration of the ESF. The OCRWM transmittal letter to NRC explained how this study plan addressed Site Characterization Analysis Comment 55.

In the last half of FY 1993, priority was given to thermal conductivity testing of samples from USW NRG-6 (see Section 2.2.10.2). Initiation of studies to determine baseline test conditions for thermal conductivity testing were delayed until additional test equipment was procured and calibrated.

Activity 8.3.1.15.1.1.1 - Density and porosity characterization. No progress during the reporting period; this was an unfunded activity.

Activity 8.3.1.15.1.1.2 - Volumetric heat capacity characterization. No progress during the reporting period; this was an unfunded activity.

Activity 8.3.1.15.1.1.3 - Thermal conductivity characterization. Calibration runs using moisture containment cells made from the polymer Delrin® were found to be unstable. New cells made from Kel-F® were fabricated and successful calibration runs were completed. The moisture containment cells are used for testing samples in a controlled environment (high humidity) below 100°C.

An additional low temperature instrument for measuring thermal conductivity from ambient to 100°C was procured. Component and system calibrations were completed for the low temperature instrument and the Thermal Conductivity Analyzer. The Thermal Conductivity Analyzer is used for thermal conductivity testing at temperatures above 100°C.

The SNL Work Agreement for the study of the saturation effects on thermal conductivity was issued. Three samples of welded devitrified tuff and three samples of nonwelded zeolitic tuff were selected to be used for this study. Nominal temperatures of 30°, 50°, and 70°C were selected to measure the thermal conductivity of each sample at five different saturation states (fully saturated, oven-dry, air dry, and two other intermediate states). Testing of air-dry samples was completed and the samples were saturated in preparation for the next series of tests. These experiments are necessary to determine whether thermal conductivity has a predictable dependence on the saturation state of the sample and, if so, to describe the nature of the relationship. Results from these experiments will be used to determine the optimal baseline test conditions for thermal conductivity characterization.

The SNL Work Agreement for the study on the effects of a fracture on the thermal conductivity of TSw2 was issued. Machining of samples for this study, which was delayed to give priority to samples from USW NRG-6 and UE-25 NRG#2, has proceeded. The nominal temperature of 30°C and stress levels of 0, 2.5, 5, 7.5, and 10 MPa were selected to measure

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the thermal conductivity of samples from TSw2. These measurements will be made using the comparative method before and after the intact samples are fractured. If fractures are observed to have a significant effect, samples containing natural fractures will be obtained and tested.

Rock crushing and grinding equipment was procured and installed at the University of New Mexico. The equipment will be used for preparing powdered rock samples for chemical analysis and mineralogic determination by x-ray diffraction. A petrographic photograph album of Yucca Mountain rocks was also assembled to provide a visual reference for evaluating welding, devitrification, and alterations observed in thin sections. Mineralogic and chemical analyses will be used to aid in the interpretation of thermal properties data.

**Forecast:** The studies on the effects of saturation on and the effects of fractures on thermal conductivity testing will be completed. Samples from North Ramp Geologic and South Ramp Geologic holes to support the Soil and Rock Properties Study (see Section 2.2.10.2); and Systematic Drilling holes to support design of the main ESF/repository drifts will be characterized by measuring saturated bulk density, dry bulk density and grain density; calculating matrix porosity; and performing mineralogic, petrologic, petrographic, and bulk chemical analyses.

Technical procedures will be developed to support activities that measure the heat capacity of tuff samples by adiabatic pulse calorimetry and to perform tests to establish baseline test conditions for measuring the heat capacity of tuff samples.

Testing will be conducted on and limited to the Topopah Spring Member of samples from North Ramp Geologic, South Ramp Geologic, and Systematic Drilling holes. Results of the tests will support the soil and rock properties study and ESF design. Tests to be conducted are heat capacity measurements and thermal conductivity measurements on several samples from various North Ramp Geologic and South Ramp Geologic holes, as well as on several samples from various Systematic Drilling holes.

In addition, analyses on heat capacity data and thermal conductivity data will be performed to include:

- Calculating the heat capacity of the solid components as a function of temperature using measured values of heat capacity heat, matrix porosity and textbook values for the heat capacity of water and air
- Calculating the heat capacity of the solid components as a function of temperature based on bulk chemistry and mineralogy and compare with values derived from measured heat capacities
- Calculating the thermal conductivity of the solid components as a function of temperature using measured values of thermal conductivity, matrix porosity and textbook values for thermal conductivity of water and air

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- Examining potential correlations between thermal properties and other sample characteristics
- Performing preliminary statistical analyses to examine the spatial variability of thermal conductivity and heat capacity
- Examining potential correlations between thermal properties and other sample characteristics (e.g., bulk properties, porosity, mineralogy)
- Developing preliminary three-dimensional models for thermal conductivity and heat capacity

### 2.2.11.2 Study 8.3.1.15.1.2 - Laboratory Thermal Expansion Testing

Revision 1 to the study plan was reviewed, approved by YMPO on August 27, 1993, and sent to NRC on September 14, 1993. This revision updates the study plan with respect to the current configuration of the ESF.

In the last half of FY 1993, priority was given to thermal expansion testing on samples from USW NRG-6 (see Section 2.2.10.2). Until additional test equipment is brought on line, the studies to establish baseline test conditions for thermal expansion measurements have been delayed.

Activity 8.3.1.15.1.2.1 - Thermal expansion characterization. Thermal expansion tests were completed using samples from USW G-1 (128.5 m) to establish the maximum heating rate ( $\leq 1^\circ\text{C}$ ) for samples containing tridymite and cristobalite. The test results indicated that the  $\alpha$ - $\beta$  transformations of these silica polymorphs are detected at approximately the same temperatures ( $163^\circ\text{C}$  for tridymite and  $250^\circ\text{C}$  for cristobalite) when heating rates of  $0.25^\circ\text{C}$  and  $1^\circ\text{C}$  are used. An irreversible shifting of the inversion temperatures was observed on repeated tests of a given sample. The inversions for tridymite and cristobalite were measured as low as  $150^\circ\text{C}$  and  $175^\circ\text{C}$ , respectively, on subsequent test runs.

An additional dilatometer and the saturation test apparatus, used for controlling the sample test environment, were procured. This equipment is undergoing operational checks and calibration.

The SNL Work Agreement for the study on the effects of sample size on thermal-expansion behavior was issued. The samples for this study were machined in right cylinders of two sizes, 0.6 cm diameter by 2.54 cm, and 2.54 cm diameter by 10.2 cm, nominally. The samples were vacuum saturated in preparation for testing. Five samples of four different lithologies (welded devitrified, welded vitric, nonwelded vitric, and nonwelded zeolitic) will be tested from ambient to  $300^\circ\text{C}$ . These experiments are necessary to determine whether the measured thermal expansion of tuff has a predictable dependence on the sample size, and if so, to describe the nature of the relationship. Results from these experiments will be used to determine the optimal baseline test conditions for thermal expansion characterization.

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The SNL Work Agreement for the study on the effects of sample saturation on thermal expansion behavior was issued to conduct the testing of five samples of four different lithologies (welded devitrified, welded vitric, nonwelded vitric, and nonwelded zeolitic). Three initial saturation states will be examined: fully saturated, air-dry, and oven-dry.

**Forecast:** Studies will be conducted to determine baseline test conditions, including completing the study on the effects of sample size on thermal expansion behavior and completing the study on the effects of sample saturation on thermal expansion behavior.

Thermal expansion will be measured on samples from North Ramp Geologic and South Ramp Geologic holes in support of the Soil and Rock Properties Study (see Section 2.2.10.2); and Systematic Drilling holes to support ESF design. The measurements will be limited to only samples from the Topopah Spring Member. The use of velocity measurements to determine if microcracking occurs due to thermal cycling during testing will also be investigated.

In addition, analyses on thermal expansion data will be performed to include:

- Performing preliminary statistical analyses to examine the spatial variability of thermal expansion
- Developing preliminary three-dimensional model for thermal expansion
- Examining potential correlations between thermal expansion and other sample characteristics
- Developing a graphical interface for integrating test locations and thermal and mechanical properties data

### **2.2.11.3 Study 8.3.1.15.1.3 - Laboratory Determination of Mechanical Properties of Intact Rock**

Revision 1 to the study plan was submitted to YMPO for review on July 7, 1993. Comments were returned to SNL on September 23, 1993. This revision will update the study plan to the current ESF design.

Activity 8.3.1.15.1.3.1 - Compressive mechanical properties of intact rock at baseline experiment conditions. Samples are not yet available for this testing effort; however, the prototype experiments have been completed and the technical procedures necessary for future testing at baseline conditions have been drafted in anticipation of sample availability in the next one to three years.

Testing of several rock types was conducted at eight government and private rock mechanics laboratories in support of the American Society for Testing and Materials/Institute for Standards Research Steering Committee for the Interlaboratory Testing Program for Rock

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Properties. An SNL staff member served on the committee and provided test data from contractors for the Phase I testing. The results were reported in an American Society for Testing and Materials/Institute for Standards Research report and summarized in a document published in the ASTM Geotechnical Testing Journal. The report suggested measures of precision for published rock-property standard American Society for Testing and Materials test methods. The protocols were written to accompany the standard methods being used for the testing in Phase II. The testing for the second phase was initiated in December 1992 and should be completed by late 1993.

Activity 8.3.1.15.1.3.2 - Effects of variable environmental conditions on mechanical properties. A study was conducted of the mechanical properties of tuff samples from the series of North Ramp Geologic drillholes located along the length of the planned position of the north ramp of the ESF. The samples were machined, dried, and saturated prior to testing at uniaxial and triaxial conditions. Other samples were tested in indirect tensile (Brazil) experiments and for average grain densities. Sample porosity was calculated from dry bulk density and average grain density values, compressional and shear wave velocities were measured on both the dry and saturated samples, and computerized tomography images were taken of the pretest samples. To date, a total of 82 unconfined experiments, 16 confined experiments, 63 Brazil tests, and 124 measurements of average grain density have been performed on samples from UE-25 NRG#2, UE-25 NRG#3, and USW NRG-6. These data are being analyzed.

In addition, a study of time-dependent deformation involving high-temperature experiments at creep and low strain rate conditions was conducted by SNL and subcontractors. The most recent series of experiments consisted of at least six samples of TSw2 to be tested at a pore pressure of 4.5 MPa, a confining pressure of 5 MPa, and a maximum constant differential stress of 80 MPa. Initially, the experiments were performed with a series of stress steps at room temperature and then at 250°C. Three experiments have been completed. The results to date exhibited a large scatter and will be difficult to interpret until the entire series of experiments is completed.

A report entitled "Unconfined Compression Experiments on Topopah Spring Member Tuff at 22°C and a Strain Rate of  $10^{-9}\text{s}^{-1}$ : Data Report" (Martin et al., 1993) was approved by YMPO and published.

An abstract entitled "Strength-Size-Porosity Empirical Model for Yucca Mountain Tuff" (Price) was approved by YMPO for presentation and publication at the Fall '93 American Geophysical Union Meeting.

**Forecast:** SNL will complete a set of experiments on samples from North Ramp Geologic and South Ramp Geologic drillhole core, and reduce, analyze, and report data to support ESF design activities. Minimal support of the American Society for Testing and Materials/Institute for Standards Research Steering Committee will also be continued.



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### 2.2.11.4 Study 8.3.1.15.1.4 - Laboratory Determination of the Mechanical Properties of Fractures

Revision 1 of the study plan was submitted to YMPO on September 9, 1993.

Several SNL staff members participated in the Fracture Properties Working Group, which met seven times during the last six months. The discussions centered on revising the study plan and plans for supporting ESF design efforts.

Activity 8.3.1.15.1.4.1 - Mechanical properties of fractures at baseline experiment conditions. Samples are not yet available for this testing effort; however, studies are proceeding to define the baseline-condition test technique and the approach for future characterization of fracture topography.

Rotary friction (axial compression-torsion) was chosen as the test technique for gathering the majority of the data on the mechanical properties of fractures. In this procedure, thin-walled cylinders with a fracture oriented perpendicular to the cylinder axis are tested. Normal and shear forces are independently applied to the fracture surface in the desired order and proportions to create the desired load path. A Standard Test Method for the rotary shear technique has been drafted and submitted to American Society for Testing and Materials Committee on Soil and Rock Properties (Committee D-18).

A draft of the American Society for Testing and Materials procedure, "Standard Test Method for Normal and Shear Stiffness of Rock Fractures Using a Compression/Rotary Shear Apparatus" completed the first review by the American Society for Testing and Materials Subcommittee on Rock Mechanics (Subcommittee D-18.12). This review was discussed at the committee meetings in Atlanta, Georgia, June 22-23, 1993. The draft received relatively few technical comments.

Detailed characterization and analysis of fracture surfaces will aid in the interpretation of mechanical properties (e.g., stiffness and shear strength) and transport properties. In order to accomplish this, a laser profilometer was designed, built, and tested. The existing profilometer system (profiler and software) was used to characterize the topography of all samples used in the experiments under this study. The data from the fracture topographies were analyzed to quantify the roughness of each surface, the scaling properties, and the degree of mismatch between the two opposing surfaces. The ultimate goal of this program is to use the surface characterizations as a predictor of the mechanical properties.

An abstract entitled "Simple Mathematical Model of a Rough Fracture Using the Concepts of Fractal Geometry" (Brown, 1993) was approved by YMPO for presentation and publication at the Geological Society of America Annual Meeting.

Activity 8.3.1.15.1.4.2 - Effects of variable environmental conditions on mechanical properties of fractures. Amonton's law  $\tau = \mu\sigma$ ; where  $\tau$  is the shear stress parallel to the fracture,  $\sigma$  is the normal stress across the fracture, and  $\mu$  is called the coefficient of friction) is the most common relationship used to describe the mechanical properties of relatively

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smooth (or artificial) fractures. A study continued that addressed whether or not other variables (e.g., time-of-stationary contact, velocity of sliding, degree of saturation, temperature, and history) are important for inclusion into the constitutive description, or whether the simple formulation of Amonton's law is sufficient for most modeling efforts. The results are being analyzed and summarized.

Work continued on the development of a computer program to model the dilation, normal stiffness, and shear stiffness of single fractures in rock. An early version of the code was used to study the changes in the aperture of a fracture under normal stress.

Several studies produced data relating to the time-dependent mechanical properties of fractures and to the effect of roughness on the mechanical properties. The studies include experiments on artificial (i.e., relatively smooth) fractures in rate-stepping tests and a creep experiment in triaxial compression. The data are being analyzed and future reports are being considered.

Two abstracts entitled "Joint Creep in Yucca Mountain Tuff" (Olsson) and "Effect of Roughness and Material Strength on the Mechanical Properties of Fracture Replicas" (Wibowo et al.) were approved by YMPO for presentation and publication at the Fall '93 American Geophysical Union Meeting.

Two reports entitled "Effect of Boundary Conditions on the Strength and Deformability of Replicas of Natural Fractures in Welded Tuff: Data Report" (Wibowo et al.) and "Effect of Boundary Conditions on the Strength and Deformability of Replicas of Natural Fractures in Welded Tuff: Comparison Between Predicted and Observed Behavior" (Wibowo et al.) were approved by YMPO and will be published in the next two months.

**Forecast:** SNL will continue performance of experiments on samples from North Ramp Geologic and South Ramp Geologic drillhole core, and reduce, analyze, and report data to support ESF design activities.

### 2.2.11.5 Study 8.3.1.15.1.5 - Excavation Investigations

Revision 1 of the study plan includes changes required by the new ESF design. Revision 1 was submitted to YMPO for review and comments were returned to SNL on May 10, 1993.

Activities 8.3.1.15.1.5.1 through 8.3.1.15.1.5.3. No activity during the reporting period; these were unfunded activities.

**Forecast:** During FY 1994, a sequence of measurements will be performed at stations in the North Ramp of the ESF to monitor both instantaneous and long-term response of the rock mass. These measurements will include both stress measurements and rock mass deformation measurements. The rock mass deformation measurements will be conducted using multipoint borehole extensometers and tape extensometer. Stations will be installed in

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each major thermomechanical unit encountered in the ramp access, with special emphasis on units in the Topopah Spring Member. Specific locations will be selected based on location of stratigraphic contacts and faults.

SNL will compile test documentation and early data analysis from the North Ramp and develop experiment plans for access convergence test instrumentation of North Ramp in FY 1994 and FY 1995. This plan will form the basis for the test planning package.

### **2.2.11.6 Study 8.3.1.15.1.6 - In Situ Thermomechanical Properties**

SNL staff finished a draft of the study plan and gave a presentation that detailed the plans and objectives of the experiments which are contained in the study plan at the Nuclear Waste Technical Review Board meeting held July 13-14, 1993.

Activities 8.3.1.15.1.6.1 through 8.3.1.15.1.6.5. No progress during the reporting period; these were out-year activities.

**Forecast:** The study plan will be completed reflecting the current ESF configuration and construction method, and will be submitted to YMPO for review and comments.

Detailed analyses to support the development of the design and instrumentation layout and requirements for incorporation into the study plan will be performed. The thermomechanical tests described in this study will require development and prototyping of instrumentation that can survive the high temperature environment. Development and testing of optical sensors for high temperature work will be started. Previous instrumentation studies have identified fiber optics as a potential solution to displacement and stress measurements at elevated temperatures.

### **2.2.11.7 Study 8.3.1.15.1.7 - In Situ Mechanical Properties**

A rough draft of the study plan has been completed.

Activities 8.3.1.15.1.7.1 and 8.3.1.15.1.7.2. No progress during the reporting period; these were out-year activities.

**Forecast:** No activity is planned in FY 1994.

### **2.2.11.8 Study 8.3.1.15.1.8 - In Situ Design Verification**

The NRC accepted the study plan in a letter dated April 15, 1993, with no comments.

Activities 8.3.1.15.1.8.1 through 8.3.1.15.1.8.3. The SNL staff conducted construction monitoring of the ESF North Ramp of the Starter Tunnel. The monitoring included seismic

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monitoring of blasting, blast damage assessment, rock mass quality determination, ground support system performance monitoring, and cross-drift convergence monitoring.

A summary of construction monitoring activities of the ESF North Ramp Starter Tunnel was presented at the 34th U.S. Rock Mechanics Symposium, in Madison, Wisconsin, June 27-30, 1993, at a special session on the YMP. The presentation was entitled "The Influence of Strain Rate and Sample Inhomogeneity on the Moduli and Strength of Welded Tuff" (Price et al.).

As an activity separate from construction monitoring, staff began fielding additional monitoring activities in the North Ramp Starter Tunnel to address safety concerns. Convergence measurements were made to the tunnel to monitor stability of the ramp and the rock bolt load cells for evaluating ground support were installed and monitored.

**Forecast:** In situ design verification experiments will be conducted in FY 1994, including evaluation of mining methods, monitoring of ground support systems, and monitoring of drift stability. Activities include:

- Evaluating mining methods by assessing induced damage of the surrounding rock mass resulting from construction using borehole television cameras.
- Monitoring ground support systems using rock mass classification indices, rock bolt load cells, and pull tests.
- Monitoring drift stability by continuing to observe the instrumentation installed in the Starter Tunnel. Additional monitoring stations will be installed as required by local ground conditions. Under the assumption that the ramp will be constructed by Tunnel Boring Machine from the Starter Tunnel, the Access Convergence Test will serve the dual role of measuring rock mass relaxation behind the mining face and monitoring long-term rock movement.

The SNL staff will also provide support to the Los Alamos Test Coordination Office in developing detailed test plans for the North Ramp.

Activity 8.3.1.15.1.8.4 - Air quality and ventilation experiment. No progress during the reporting period; this was an unfunded activity.

**Forecast:** No activity is planned for FY 1994.

### 2.2.11.9 Study 8.3.1.15.2.1 - Characterization of the Site Ambient Stress Conditions

Activity 8.3.1.15.2.1.1 - Anelastic strain recovery experiments in core holes. No activity during the reporting period, this was an out-year activity.

**Forecast:** No activity is planned for FY 1994.

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Activity 8.3.1.15.2.1.2 - Overcore stress experiments in the Exploratory Studies Facility. No progress during the reporting period; this was an out-year activity.

**Forecast:** No activity is planned for FY 1994.

**2.2.11.10 Study 8.3.1.15.2.2 - Characterization of the site ambient thermal conditions.**

A draft of the study plan which incorporated reviewer comments was returned to YMPO on May 19, 1993.

**Forecast:** Preparation of the study plan will continue in preparation for out-year activities.

**2.2.12 Preclosure Hydrology (SCP Section 8.3.1.16)**

**2.2.12.1 Study 8.3.1.16.1.1 - Characterization of Flood Potential of the Yucca Mountain Site**

Activity 8.3.1.16.1.1.1 - Site flood and debris hazards studies. No progress during the reporting period; this was an unfunded activity.

**Forecast:** No activity is planned for FY 1994.

**2.2.12.2 Study 8.3.1.16.2.1 - Location of Adequate Water Supply for Construction, Operation, Closure, and Decommissioning of a Mined Geologic Disposal System at Yucca Mountain, Nevada**

No progress during the reporting period; this was an out-year study.

**Forecast:** No activity is planned for FY 1994.

**2.2.12.3 Study 8.3.1.16.3.1 - Determination of the Preclosure Hydrologic Conditions of the Unsaturated Zone at Yucca Mountain, Nevada**

No progress during the reporting period; this was an out-year study.

**Forecast:** No activity is planned for FY 1994.

**2.2.13 Preclosure Tectonics (SCP Section 8.3.1.17)**

**2.2.13.1 Study 8.3.1.17.1.1 - Potential for Ash Fall at the Site**

Activities 8.3.1.17.1.1.1 through 8.3.1.17.1.3. No progress during the reporting period; these were unfunded activities.

**Forecast:** No activity is planned for FY 1994.

**2.2.13.2 Study 8.3.1.17.2.1 - Faulting Potential at the Repository**

Activities 8.3.17.2.1.1 and 8.3.17.2.1.2. No progress during the reporting period; these were unfunded activities.

**Forecast:** No activity is planned for FY 1994.

**2.2.13.3 Study 8.3.1.17.3.1 - Relevant Earthquake Sources**

The study plan was revised to address comments by NRC and the State of Nevada concerning the seismic hazard methodology proposed in the SCP. Responses to 32 comments from the State of Nevada, received by OCRWM on January 7, 1993, were returned to the State in a letter from YMPO dated April 21, 1993.

Activity 8.3.1.17.3.1.1 - Identify relevant earthquake sources. Participants conducted several field trips in Nevada in an effort to identify possible earthquake sources; gather current information; and update interpretations concerning Quaternary fault activities, potential earthquake magnitudes, and recurrence rates. Information was compiled from available geologic maps, reports, and reconnaissance investigations to prepare a preliminary table of source parameters for known and suspected Quaternary faults within 100 km of Yucca Mountain. The preliminary table of fault parameters was used to identify and rank the sources in terms of those that are most important to earthquake ground motion and fault displacement hazards. Participants began to examine the quality, reliability, and completeness of the fault data.

Activity 8.3.1.17.3.1.2 - Characterize 10,000-year cumulative slip earthquakes for relevant seismogenic sources. A group of seismic hazard experts held meetings to discuss and develop a methodology for seismic source characterization and hazard analysis that is appropriate for a potential repository at Yucca Mountain. The proposed probabilistic and deterministic seismic hazard methodologies were evaluated in order to update the study plan (and others), perform a technical assessment for the ESF, and contribute to the DOE topical report on Methodology to Assess Seismic Hazards at Yucca Mountain. Participants composed portions of the topical report including Appendix A, "Technical Data Base for Seismic Hazard Analyses at Yucca Mountain" and Appendix B, "Seismic Source Characterization at Yucca Mountain." A progress report entitled "Recommendations and Revisions to Seismic Source

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Characterization" (Pezzopane), was submitted as planned and accepted for revision. The study plan has been revised and submitted for review. A preliminary source characterization was completed for all known or suspected Quaternary faults, based on the revised methodology and currently available fault parameters. Participants contributed to the seismic hazard analysis for the ESF.

**Forecast:** Work planned for FY 1994 will focus on synthesizing new and existing data concerning the activity, magnitudes, and recurrence intervals of known or suspected seismic sources. Effort will focus on locating unrecognized, buried, or hidden seismogenic structures, characterizing the magnitudes and recurrence parameters for these sources, and estimating the impacts of alternative tectonic models towards uncertainties in the seismic source parameters. Additional effort will be placed in estimating the parameters of potential nuclear explosion sources and earthquakes related to volcanic processes, including swarms, tremors, and potential triggering of tectonic earthquakes as a result of volcanic eruptions. The preliminary table of Quaternary fault and seismic source parameters will be updated continually as new data and interpretations become available. Methods to estimate maximum magnitudes will be developed, emphasizing updated paleoseismic information and alternative models of fault segmentation and fault geometries. Potential earthquake magnitudes will be refined and the uncertainties will be described. The maximum magnitudes and closest source-to-site distances will be used to complete a preliminary deterministic seismic hazard analysis in an attempt to identify with a high degree of confidence all relevant seismic sources. The deterministic analysis will be used to rank the relevant sources in order of importance, based on the level of ground motion that they can produce at frequency ranges of engineering significance, and to determine which relevant sources may call for more detailed field investigations, based on the quality and amount of paleoseismic and geologic data that are currently available.

### **2.2.13.4 Study 8.3.1.17.3.2 - Underground Nuclear Explosion Sources**

Activities 8.3.1.17.3.2.1 and 8.3.1.17.3.2.2. No progress during the reporting period; these were out-year activities.

**Forecast:** No activity is planned for FY 1994.

### **2.2.13.5 Study 8.3.1.17.3.3 - Ground Motion From Regional Earthquakes and Underground Nuclear Explosions**

An internal working draft of Study Plan 8.3.1.17.3.3 was revised by SNL to reflect continued development of the ESF design and revised approaches to model development and define an approach for developing a preliminary ground motion model for Yucca Mountain.

Completion of the study plan to develop earthquake ground-motion models is delayed so that the results of collaborative research and evaluation by the Seismic Hazards Working Group, a team of seismic hazard experts assembled by YMP, to develop an appropriate methodology for seismic hazard analysis at the potential repository can be incorporated. The

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methodology relies on a hybrid approach, which incorporates both deterministic and probabilistic components, and will be described in detail in the "Topical Report on Methodology to Assess Seismic Hazards at Yucca Mountain," which is in preparation.

Activity 8.3.1.17.3.3.1 - Select or develop empirical models for earthquake ground motions. Participants worked to develop the seismic hazard methodology and contributed to the YMP topical report. Members of the Seismic Hazards Working Group and additional USGS seismic hazard experts held meetings to discuss and develop a methodology for modeling earthquake ground motions. The ground work has been laid for the study plan to commence, and work will proceed in accordance with methodologies stated in the topical report and new ground motion models based on site-specific information developed for Yucca Mountain.

**Forecast:** The draft study plan will be completed in the first few months of FY 1994, and comment resolution will follow in the remainder of the year. An informal tectonics conference is planned for early next year to gather seismologists and tectonicists together to discuss potential earthquake source characteristics for relevant faults and the impacts of postulated tectonic models toward ground motion models. Plans are to exchange up-to-date information concerning the paleoseismic behavior of relevant faults in an effort to build a consensus concerning the plausible earthquake sizes, locations and geometries, and to provide a prospectus for future work. The conference will provide input to the seismologists for developing ground motion models as well as be useful to direct the geologists in site characterization activities.

Activity 8.3.1.17.3.3.2 - Select or develop empirical models for ground motion from underground nuclear explosions. No progress during the reporting period; this was an unfunded activity.

**Forecast:** SNL will complete the development of a preliminary ground motion model for Yucca Mountain. Activities to be conducted include development of a preliminary earthquake ground motion model which utilizes available seismic data (i.e., natural seismicity and induced seismicity) for supporting a YMP topical report on Seismic Hazard Assessment Methodologies.

### **2.2.13.6 Study 8.3.1.17.3.4 - Effects of Local Site Geology on Surface and Subsurface Motions**

Responses to 26 comments from the State of Nevada received by OCRWM on January 6, 1993, were returned to the State in a letter from YMPO dated April 27, 1993.

Activity 8.3.1.17.3.4.1 - Determine site effects from ground-motion recordings. In April 1993, Experiment 1 used 12 Reftek portable stations in and near Midway Valley to gather data for the site effects study. This experiment was conducted through June 1993. In addition, prior recordings made at Yucca Mountain were assembled for study of site effects. A preliminary one-dimensional structural model was constructed for the Yucca Mountain area.



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S-wave spectra of signals recorded in the above experiment from Little Skull Mountain aftershocks were used to determine the local site effects. A least-squares method was used to determine the seismic moment, the corner frequency, and the spectral decay parameter. A standard model spectrum was computed from the average estimates, and the site responses were computed by averaging the differences of the spectra for individual stations from this standard spectrum.

**Forecast:** The standard ground motion model will be updated during FY 1994 with additional data collection, analysis, and modeling studies. During FY 1994 it is anticipated that two phases of improvement will occur. The first phase will result from refining the low-frequency models based on crustal structure and teleseismic and Nevada Test Site recordings. The second phase will result from spectral ratios based on regional earthquakes and possible Nevada Test Site blasts.

In FY 1994 Experiments 2 and 3 will be conducted. Experiment 2 is a short-duration deployment to record microseisms to improve our velocity model at Yucca Mountain. Experiment 3 is a long-duration deployment to record local events and teleseisms at the surface, downhole, or underground within a three-dimensional grid to understand the three-dimensional wave propagation effects at Yucca Mountain.

### **2.2.13.7 Study 8.3.1.17.3.5 - Ground Motion at the Site From Controlling Seismic Events**

Activity 8.3.1.17.3.5.1 - Identify controlling seismic hazard. No progress during the reporting period; this was an out-year activity.

**Forecast:** This activity is not funded in FY 1994, and is planned to start in FY 1995.

### **2.2.13.8 Study 8.3.1.17.3.6 - Probabilistic Seismic Hazards Analyses**

Activities 8.3.1.17.3.6.1. through 8.3.1.17.3.6.2. No progress during the reporting period; these were out-year activities.

**Forecast:** These activities are not funded in FY 1994, and are planned to start in FY 1995.

### **2.2.13.9 Study 8.3.1.17.4.1 - Historical and Current Seismicity**

Activity 8.3.1.17.4.1.1 - Compile historical earthquake record. Surveys for precarious rocks have been continued in various parts of California and Nevada, both seismic and aseismic areas. Correlations with intensity maps for historical seismicity and, if possible, with measured or estimated ground motions have been made for precarious rock locations.

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The area around the May 17, 1993, Eureka Valley earthquake was examined for rock falls and also the area around the Utah earthquake of October 25, 1992.

The two-dimensional computer code for predicting the effect of strong motion on various rock shapes was completed and run on various cases. Results have been compared with physical models of rocks toppled in the laboratory to verify the computer code.

The Meremonte-Rogers historical earthquake catalog for the Southern Great Basin was searched for events near Yucca Mountain. One potentially important earthquake occurred in 1948, apparently at Yucca Mountain itself, and had a magnitude of 3.6. Original records at the California Institute of Technology were photographed for this and other nearby events, and analysis of them suggests that the magnitude = 3.6 event was mislocated and is, in fact, at least 10 km from Yucca Mountain.

A progress report on historical seismicity and another on precarious rocks were submitted for internal USGS review on September 30, 1993.

Activity 8.3.1.17.4.1.2 - Monitor current seismicity. Since April 1, 1993, the University of Nevada, Reno Seismic Laboratory has continuously detected events and created signal files for the Southern Great Basin Seismic Network, except for downtime that amounted to approximately 37 hours. Develocorder film was continuously recorded as a backup. The California Institute of Technology-U.S. Geologic Survey seismic processing software (CUSP) system was moved to the new VAX 4000/200 computer in August 1993, with a significant increase in the reliability and efficiency of the online recording processes.

During the reporting period, the seismicity rate due to the Little Skull Mountain aftershocks has continuously fallen to a rate of about six events per day in the Southern Great Basin. The Eureka Valley earthquake of May 17, 1993, caused a large sequence of aftershocks. Another significant sequence of events occurred in Rock Valley of the Nevada Test Site in June 1993. Portable instruments were deployed for both of these sequences and have made hundreds of additional records of these events. Calibration of the 62 stations of the Southern Great Basin Seismic Network was complete in September of 1993, except for one station in a highly secure area of Nellis Air Force Base.

Planning for the digital upgrade of the Southern Great Basin Seismic Network in this reporting period has included preparing procurement documents for a 49-station network, upgrading the microwave telemetry equipment on the link from the Southern Great Basin to Reno, and selecting seven additional sites around Yucca Mountain for digital stations.

Considerable effort was expended by the University of Nevada, Reno Seismic Laboratory in August and September 1993, to prepare for recording the nonproliferation experiment shot at the Nevada Test Site and the Ryan shot to the south of the Nevada Test Site. These shots were recorded with good to excellent quality on the permanent Southern Great Basin Seismic Network and on nearly 50 portable instruments deployed at the time. The data have been collected for analysis to refine the seismic velocity structure in the vicinity of Yucca Mountain.

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A report on 1992 seismicity for the Southern Great Basin entitled "Seismicity for the Southern Great Basin of Nevada and California in 1992" (Brune) was submitted for internal USGS review on September 30, 1993.

Activity 8.3.1.17.4.1.3 - Evaluate potential for induced seismicity at the site. No progress during the reporting period; this was an out-year study.

**Forecast:** Work on historical seismicity will increase in FY 1994 with additional staff to analyze the historical record in more detail.

Work on precarious rocks in FY 1994 will involve calculation of toppling accelerations for approximately ten precarious rocks in Solitario Canyon. Actual field tests will be carried out of toppling forces in situ. Rock-varnish and geomorphic studies will be carried out to more accurately estimate the length of time for which rocks have remained in their current precarious positions.

The Southern Great Basin Seismic Network will be recorded throughout FY 1994, the bulletin for calendar year 1993 will be prepared, and signals for events recorded by the Southern Great Basin Seismic Network will be recorded. The digital upgrade work will include seven new sites in FY 1994. The Reftek network recorder will be moved to Reno and the 13 digital stations will be put on a telemetry link to Reno. The limited digital network will then be recorded continuously in Reno at the same time that signal detection will be performed by the network recorder. Software acquisition and development for the output of this system will be undertaken to provide efficient and reliable handling of the data and to provide routine bulletin preparation capabilities.

The data collected from the nonproliferation experiment and Ryan shots will be analyzed and the Little Skull Mountain aftershocks analysis will be completed in the first quarter of FY 1994. Upgrade and repair work for the portable instrumentation is required for future experiments. An array of roughly 10-12 strong-motion instruments at Yucca Mountain will be installed, pending DOE funding.

### **2.2.13.10 Study 8.3.1.17.4.2 - Location and Recency of Faulting Near the Prospective Surface Facilities**

The NRC accepted Revision 2 of the study plan in a letter to OCRWM dated June 16, 1993, with no comments.

Activity 8.3.1.17.4.2.1 - Identify appropriate trench locations in Midway Valley. This activity is complete. The Principal Investigator reviewed map contacts, aerial photographs, descriptions of soil profiles, and reviewed field activities in preparation of the report on the mapping in Midway Valley. The final map and report on the surficial geology of Midway Valley entitled "Surficial Geologic Map of the Midway Valley Area" (Wesling et al.) was completed and submitted for USGS internal review at the end of FY 1993.

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Activity 8.3.1.17.4.2.2 - Conduct exploratory trenching in Midway Valley. Bedrock faults exposed in the "box cut" of the ESF portal were mapped to determine their locations relative to the faults and fractures observed in trenches (now backfilled) in the construction area. Work continued to prepare and draft maps of the trench walls, and to prepare the report of the investigations of the trenches near the ESF.

Trench logs and a draft report entitled "Preliminary Report and Map of Trench MWV-T4 Across the Paintbrush Canyon Fault, Yucca Mountain Area, Nye County, Nevada" (Wesling et al.). The report was submitted for USGS internal review on September 30, 1993.

**Forecast:** Trench A-3 on the Paintbrush Canyon fault will be excavated and logged early in FY 1994. Results of geologic mapping and trench studies will be summarized in a final report on Midway Valley and submitted for USGS review during the first half of FY 1994.

Additional time will be required to complete the review process for publication of the final map and report on the surficial geology of Midway Valley.

### **2.2.13.11 Study 8.3.1.17.4.3 Quaternary Faulting Within 100 km of Yucca Mountain, Including the Walker Lane**

The study plan was approved by YMPO on January 21, 1993 and sent to NRC on February 9, 1993. The NRC accepted the study plan in a letter to OCRWM dated September 2, 1993, with one comment and two questions. The USGS assessed the impact of the comment and questions in a letter to YMPO dated September 20, 1993, and a response to the NRC comment and questions is being prepared.

Activity 8.3.1.17.4.3.1 - Conduct and evaluate deep geophysical surveys in an east-west transect crossing the Furnace Creek fault zone, Yucca Mountain, and the Walker Lane. No progress during the reporting period; this was an out-year activity.

Activity 8.3.1.17.4.3.2 - Evaluate Quaternary faults within 100 km of Yucca Mountain. The USGS staff completed a compilation of known and suspected Quaternary faults within 100 km of Yucca Mountain; two maps showing fault locations are accompanied by text and tables. This document entitled "Preliminary Surficial Geologic Map of the Bare Mountain Frontal Fault; Bureau of Reclamation" (Anderson) was submitted for USGS internal review on June 30, 1993.

To evaluate faults southwest of Yucca Mountain, the Principal Investigator interpreted low-sun-angle aerial photographs of the Amargosa Desert area and conducted reconnaissance studies of the Death Valley—Furnace Creek fault zone in the field. Several areas in Death Valley were identified where detailed geologic mapping could provide specific information on the age of the most recent surface faulting event and amount of slip on this important fault zone.

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The Los Alamos staff conducted a scoping study in preparation for dating the surface exposure of scarps along Windy Wash and Solitario Canyon faults. Samples were collected and were being processed.

Preliminary data collection was completed on a study of scarps along the Windy Wash and Solitario Canyon fault, and an abstract was prepared on this subject for the Fall '93 American Geophysical Union Meeting entitled "Preliminary Analysis of Erosionally Enhanced Scarps Associated with Faults in Crater Flat, Nevada" (Harrington). This abstract is in the YMPO approval process.

A paper entitled "Relict Colluvial Boulder Deposits as Paleoclimatic Indicators in the Yucca Mountain Region, Southern Nevada" (Whitney and Harrington, 1993) was published. The authors found that by interpreting the necessary conditions to form hillslope boulder deposits in the Yucca Mountain region, they could infer paleoclimatic conditions for the periods of their formation. They dated the deposits by cation-ratio dating of rock varnish and confirmed their early- to mid-Quaternary age. They also used the deposits as hillslope datum to calculate hillslope erosion rates and to interpret differences in climatic conditions between early Quaternary climates, those of the last full glacial (ca. 18 ka), and those of today.

Activity 8.3.1.17.4.3.3 - Evaluate the Cedar Mountain earthquake of 1932 and its bearing on wrench tectonics of the Walker Lane within 100 km of the site. No progress during the reporting period; this was an out-year activity.

Activity 8.3.1.17.4.3.4 - Evaluate the Bare Mountain Fault Zone. Staff compiled a preliminary surficial geologic map of the Bare Mountain frontal fault zone based on analyses of low-sun-angle aerial photographs and reconnaissance geologic studies.

Preparations were made for the NRC field trip, which included a visit to a trench across the Bare Mountain fault zone, and preliminary findings were presented. The trench required re-excavation and shoring in July, which delayed logging and analysis until after that time. Four soil pits were excavated, and at the end of September a trench at the mouth of Tarantula Canyon (BMT-1) was excavated.

Activity 8.3.1.17.4.3.5 - Evaluate structural domains and characterize the Yucca Mountain region with respect to regional patterns of faults and fractures. No progress during the reporting period; this was an out-year activity.

Activity 8.3.1.17.4.3.6 - Analyze rotation (drag) of bedrock along or over suspected wrench faults based on rotation of paleomagnetic declinations. No progress during the reporting period; this was an out-year activity.

**Forecast:** Detailed studies will be conducted at several localities along the Death Valley—Furnace Creek fault zone to determine the age, amount of slip, and recurrence of surface faulting events. In order to determine the age and recurrence of faulting on the Bare Mountain frontal fault zone, detailed mapping and trench analysis will be completed.

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### **2.2.13.12 Study 8.3.1.17.4.4 - Quaternary Faulting Proximal to the Site Within Northeast-Trending Fault Zones**

The study plan was approved by YMPO on March 18, 1993, and sent to NRC on May 18, 1993. The NRC accepted the study plan in a letter to OCRWM dated September 2, 1993, with no comments.

Activity 8.3.1.17.4.4.1 - Evaluate the Rock Valley fault system. Field work was undertaken to characterize fault disruption and history of displacement among faults in Rock Valley. Parameters included location, attitude and length of fault planes, style and width of disruption of faults within the system, and amount and recurrence of displacements. Field examinations of fault exposures, lineaments, and other deformation features of inferred tectonic origin (i.e., exhibiting structural control) were guided by previous USGS mapping and recursive analysis of aerial photos. Principal structural parameters were noted, field locations described and, where feasible, recorded by Global Positioning Satellite receiver, and plotted on field maps for further annotation and analysis. Five sites of surface fractures, possibly related to fault creep, were observed. Nine samples of volcanic rocks were obtained for radiometric age dating to constrain the older displacement events and hence the cumulative offsets. Candidate trench sites were determined from field and aerial photo examination and in consultation with other Principal Investigators. An interim report entitled "Interim Report: Rock Valley Fault Zone, Nevada Test Site, Nevada" (O'Leary) was submitted at midyear. A second interim report entitled "Preliminary Fault Slip Analysis of Northeast Trending Strike-Slip Faults in Rock Valley, Nevada, Proximal to the Potential Yucca Mountain Repository Site" (O'Leary) was prepared at the end of FY 1993.

Activity 8.3.1.17.4.4.2 - Evaluate the Mine Mountain fault system. No progress during the reporting period; this was an out-year activity.

Activity 8.3.1.17.4.4.3 - Evaluate the Stagecoach Road fault zone. The Stagecoach Road fault evaluation has been transferred to Study Plan 8.3.1.17.4.6, "Quaternary Faulting in the Site Area."

Activity 8.3.1.17.4.4.4 - Evaluate the Cane Spring fault system. No progress during the reporting period; this was an out-year activity.

**Forecast:** Studies in FY 1994 will include continued evaluation of the Rock Valley fault system. A final decision on the location of one or two trench sites will be made along with preparations for excavation, logging and interpretation. Data on the history and nature of Quaternary displacement will support a final report on the Rock Valley fault zone. Field examination of the Mine Mountain fault zone will begin by aerial photographic overview and appraisal of previous mapping.

### **2.2.13.13 Study 8.3.1.17.4.5 - Detachment Faults at or Proximal to Yucca Mountain**

The NRC accepted the study plan in a letter to OCRWM dated February 2, 1993.

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Activity 8.3.1.17.4.5.1 - Evaluate the significance of the Miocene-Paleozoic contact in the Calico Hills area to detachment faulting within the site area. The Principal Investigator spent several weeks in the field at Calico Hills examining the Miocene-Paleozoic contact and mapping low-angle faults. Exposures of Paleozoic stratigraphy were examined and a new, tectonically important breccia unit was identified. A field trip was conducted to examine detachment faults in the region of Yucca Mountain and dissimilarities were noted between regional detachment faults and the low-angle structures in the Calico Hills. Field work was compiled and a draft report was prepared. An interim report entitled "The Miocene-Paleozoic Contact at the Calico Hills" (Simonds) was prepared and submitted to USGS as an administrative report.

Activity 8.3.1.17.4.5.2 - Evaluate postulated detachment faults in the Beatty-Bare Mountain area. Field work in April brought the bedrock mapping to 75 percent completion in the Big Dune 7.5 minute quadrangle (southern Crater Flat) and 100 percent completion in the East of Beatty Mountain 7.5 minute quadrangle (northern Crater Flat). Airphoto interpretation, including photogrammetry was used to produce a final compilation map of the East of Beatty Mountain quadrangle and a map entitled "Geologic Map of the East of Beatty Mountain 7.5 Minute Quadrangle, Nye County, Nevada" (Fridrich et al.) was submitted for internal USGS review, to be an Open-File Report (uncolored) at 1:12,000 scale. A map of the middle quadrangle in Crater Flat (between the two above-mentioned quadrangles) was mapped by J. Faulds and others of the State of Nevada. USGS personnel participated in a two-day field review of this map and found that it is of excellent quality; little additional work will be required now in the middle quadrangle. An interim report entitled "The Miocene History of Extension in the Yucca Mountain Region: A Preliminary Report" (Fridrich) synthesizes the results of mapping in Crater Flat to date.

Project Participants attended a field trip to examine both upper and lower plate rocks of the major detachment faults in the region. Field work was conducted at Bare Mountain and vicinity collecting metamorphic samples for thermobarometric studies. The samples were prepared for petrographic analysis, fission track and  $^{40}\text{Ar}/^{39}\text{Ar}$  dating, and thermobarometric studies. An interim report entitled "Thermobarometric and Kinematic Studies of Metamorphic Rocks at Bare Mountain and Proximal Sites" (Hoisch) was submitted to USGS as an administrative report.

Activity 8.3.1.17.4.5.3 - Evaluate potential relationship of breccia within and south of Crater Flat to detachment faulting. No progress during the reporting period; this was an out-year activity.

**Forecast:** Work will begin on this activity in FY 1994.

Activity 8.3.1.17.4.5.4 - Evaluate postulated detachment faults in the Specter Range and Camp Desert Rock areas. No progress during the reporting period; this was an out-year activity.

**Forecast:** Work will begin on this activity in FY 1994.

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### Activity 8.3.1.17.4.5.5 - Evaluate the age of detachment faults using radiometric ages.

Samples were collected, primarily from lower plate rocks, to determine the ages of metamorphic minerals and thus constrain the age of metamorphism and subsequent uplift. The samples were examined petrographically and eight were selected for fission track and/or  $^{40}\text{Ar}/^{39}\text{Ar}$  dating. Metamorphic minerals sphene, apatite, and zircon were separated for fission track analysis and hornblende, muscovite, and biotite were separated for  $^{40}\text{Ar}/^{39}\text{Ar}$  analysis. The mineral separates were sent to the USGS isotope lab for analysis. A report was prepared describing the samples along with a map showing sample locations. The report was included as part of an administrative report entitled "Thermobarometric and Kinematic Studies of Metamorphic Rocks at Bare Mountain and Proximal Sites" (Hoisch).

**Forecast:** Work on the Calico Hills map and report will continue and is expected to be submitted for USGS review early in FY 1994. Mapping in Crater Flat will continue in FY 1994 with the following goals: (1) Finish mapping in the Big Dune 7.5 minute quadrangle (southern Crater Flat), and submit preliminary map for internal USGS review to be published as an Open-File Report; (2) Generalize the 1:12,000 scale map of the East of Beatty Mountain quadrangle at a 1:24,000 scale and submit for publication as an I-series map (colored); (3) make a preliminary version of a map of the volcanic rocks in the Beatty Mountain 7.5 minute quadrangle; and (4) synthesize map data into graphical formats that document extensional history, and how it varies over different parts of the Crater Flat basin and in adjacent structural domains. Thermobarometric analysis of metamorphic rocks will continue in FY 1994 and the results will be incorporated with mineral dates in a report by the end of the fiscal year.

### **2.2.13.14 Study 8.3.1.17.4.6 - Quaternary Faulting Within the Site Area**

The NRC accepted the study plan in a letter to OCRWM dated October 3, 1991.

Activity 8.3.1.17.4.6.1 - Evaluate Quaternary geology and potential Quaternary faults at Yucca Mountain. Compilation of field data and mapping of Quaternary faults at Yucca Mountain was completed during the reporting period. Compiled maps at 1:12,000 scale were reduced and merged to fit a 1:24,000 scale topographic base map. The 1:24,000 scale map was drafted and annotated and a descriptive text was prepared. The map and text were submitted for USGS internal review.

Activity 8.3.1.17.4.6.2 - Evaluate age and recurrence of movement on suspected and known Quaternary faults. To study the Paintbrush Canyon fault in the vicinity of Busted Butte, Project staff completed plotting contacts and structures on photographs of exposure #4.; systematically re-evaluated fault event chronology and field measurement of vertical offsets; and measured slickenside lineations on fault planes.

Study of the southern Windy Wash fault included six lines of a shallow seismic reflection survey. The seismic survey successfully imaged a buried basalt flow, thus providing evidence for the amount of offset on the Windy Wash fault.



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Study of the Stagecoach Road fault included field logging of structures and contacts on photographs of the north wall of both SCR-T1 and SCR-T3 trenches. Grids for conventional logging of the south wall, east half, of both trenches were established, and for plotting contacts and structures. Results were presented on Stagecoach Road trenches, and on the southern trench of the Solitario Canyon fault, to NRC during a field trip.

A talk entitled "Stratigraphic Evidence for Multiple Small Quaternary Displacement on the Bow Ridge Fault at Northeast Yucca Mountain, Nye County, Nevada" (Menges et al., 1993) was presented at a regional Geological Society of America meeting.

To evaluate scarp evolution in north Windy Wash, field work was conducted and potential sites for cosmogenic isotopic dating were examined and sampled on the Windy Wash and Solitario Canyon fault scarps. An interim report entitled "Progress Report on Study of Scarp Evolution Along the Solitario Canyon and Windy Wash Faults, Crater Flat, Nevada" (Harrington) was submitted to USGS on the potential application of the dating technique.

Excavation on four new trenches and exposures on Solitario Canyon fault, and two new or modified trenches at Alice Ridge on the Northern Paintbrush Canyon faults were almost completed by the end of the reporting period. Existing trenches and fault scarps near those trenches were examined on North Solitario Canyon and Pagany Wash fault to prepare for future relogging.

**Forecast:** Continued work on each of the major faults at Yucca Mountain will include both trench and scarp studies. Trench logging activities will continue at new trenches on the Solitario Canyon fault and Paintbrush Canyon faults, and at old trenches on the southern Windy Wash fault and Fatigue Wash fault. A cosmogenic dating study will attempt to establish faulting ages on the Ghost Dance fault. Data from these studies will be compiled to produce review drafts of final reports for the Bow Ridge fault, Stagecoach Road fault, and the Paintbrush Canyon fault at Busted Butte.

### **2.2.13.15 Study 8.3.1.17.4.7 - Subsurface Geometry and Concealed Extensions of Quaternary Faults at Yucca Mountain**

No progress during the reporting period; this was an out-year study.

**Forecast:** No activity is planned for FY 1994.

### **2.2.13.16 Study 8.3.1.17.4.8 - Stress Field Within and Proximal to the Site Area**

Activity 8.3.1.17.4.8.1 through 8.3.1.17.4.8.4. No progress during the reporting period; these were out-year activities.

**Forecast:** No activity is planned for FY 1994.

**2.2.13.17 Study 8.3.1.17.4.9 - Tectonic Geomorphology of the Yucca Mountain Region**

Activities 8.3.1.17.4.9.1 through 8.3.1.17.4.9.3. No progress during the reporting period; these were out-year activities.

**Forecast:** No activity is planned for FY 1994.

**2.2.13.18 Study 8.3.1.17.4.10 - Geodetic Leveling**

The NRC accepted the study plan in a Phase I review letter to OCRWM dated October 4, 1991, with two comments. OCRWM responded to these comments in a letter dated September 17, 1993. The State of Nevada sent 16 comments to OCRWM on January 29, 1993, which were responded to in a letter from YMPO dated April 19, 1993.

Activity 8.3.1.17.4.10.1 - Relevel base-station network, Yucca Mountain and vicinity. The base-station network was releveled. A data records package on geodetic leveling was completed in July 1993, and submitted to the records center for the periods November 1990 to July 1991, and November 1992 to April 1993.

Activity 8.3.1.17.4.10.2 - Survey selected base stations, Yucca Mountain and vicinity, using global positioning satellite. A 50-km aperture trilateration network centered on Yucca Mountain was resurveyed in April. Previous surveys of the network were done in 1983 and 1984. Except at one station in the southeast corner of the network, no significant deformation was observed even though the precision of the surveys was such that the detection threshold (95 percent confidence) was  $0.02 \mu\text{strain/year}$ . The station near the southeast corner of the network was disturbed on June 29, 1992, by the Little Skull Mountain earthquake (surface wave magnitude=5.4), whose epicenter was only 3 km away. The measured displacement there is consistent with the reported  $4.1 \times 10^{17}$  N-m moment of the earthquake. An abstract entitled "Strain Accumulation near Yucca Mountain, Nevada, 1983-1993" (Sgoss et al.) was submitted to the Fall '93 American Geophysical Union Meeting.

Activity 8.3.1.17.4.10.3 - Analyze existing releveled data, Yucca Mountain and vicinity.

**Forecast:** A quadrilateral survey will be conducted during the first half of FY 1994. Observations will be made on four corners of a previously established quadrilateral at Yucca Mountain. Latitude, longitude and elevation will be calculated for each point and the data compared with previous results.

**2.2.13.19 Study 8.3.1.17.4.11 - Characterization of Regional Lateral Crustal Movement**

No progress during the reporting period; this was an out-year study.

**Forecast:** No activity is planned for FY 1994.

**2.2.13.20 Study 8.3.1.17.4.12 - Tectonic Models and Synthesis**

The study plan was returned from YMPO review and was in process of revision.

Activity 8.3.1.17.4.12.1 - Evaluate tectonic processes and tectonic stability at the site. Initial review of the geologic/tectonic map of the Death Valley region has been completed and it is undergoing final revision and drafting; the 1:100,000-scale map of the Beatty Quadrangle was submitted for initial review; segments of the TMM color-ratioed remote sensor image set (showing Yucca Mountain and terrain north) were received from the Jet Propulsion Laboratory; field excursions at and around the site were led by Principal Investigators to demonstrate field evidence pertaining to process and stability and to discuss problems of interpretation. Various data from published sources, instrumented surveys, and site characterization studies are presently being compared and evaluated.

Activity 8.3.1.17.4.12.2 - Evaluate tectonic models. The boundary element modeling scoping study was initiated and preliminary results were being evaluated; the methodology was being modified to match the geologic setting of Yucca Mountain. Geologic evidence for the existence and/or character of tectonic model components was being evaluated (e.g., bounding range-front faults, detachment faults, strike-slip faults) at Bare Mountain, Calico Hills, and Rock Valley, as well as in the Death Valley—Bullfrog Hills regions to the north and west. Evaluation of strike slip faulting and detachment faults was reported in an interim report, "Detachment Faulting and Tectonic Modeling in the Yucca Mountain Region" (Hamilton).

Activity 8.3.1.17.4.12.3 - Evaluate tectonic disruption sequences. No progress during the reporting period; this was an out-year activity.

**Forecast:** Results of the boundary element model scoping study will be integrated into the evaluation procedure along with results of radiometric age dating and tectonic field studies. Integration/evaluation of published data, compiled geophysical (including remote sensor) data, and site-specific field studies will continue. Preliminary reports on boundary element modeling results, and a preliminary tectonic model will be prepared. The Beatty map and the Death Valley region map will be released.