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Yucca Mountain Project Technical Status Report

April–September 1989

U.S. Department of Energy
Nevada Operations Office

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1.0 INTRODUCTION

This Yucca Mountain Project Technical Status Report (TSR) on site characterization is the first in a series of reports that will be issued at approximately six-month intervals during site characterization. Summary information on the technical status and progress of site characterization activities described in the Site Characterization Plan (SCP) (DOE, 1988a) is reported in the TSR. In addition, progress made toward the initiation and conduct of site characterization activities is included. For this report, information on the technical progress made by Yucca Mountain Project participating organizations has been compiled covering the period from April 16, 1989, through September 30, 1989.

The Status Report consists of three sections: (1) an introductory section; (2) a section on the status of the site, repository, seals, waste package, and performance assessment programs; and (3) a reference section, which provides a complete listing of all published documents cited in the text. A companion document for the TSR, the Project Bibliography Update, is also produced at intervals of approximately six months. The Project Bibliography provides annotated bibliographies of the technical reports and research products produced by Project participating organizations.

Presentation of status information provided in Sections 2.2 through 2.6 follows the structure of Chapter 8 of the SCP, which describes the studies and activities that comprise the scope of the site technical program, as well as site-related design and performance assessment activities that the U.S. Department of Energy (DOE) plans to conduct at Yucca Mountain as part of site characterization. Activities that are part of site studies, or design or performance assessment information needs are not reported unless work was conducted as part of the activity during the reporting period. Studies showing "no progress" can be the result of their out-year status, or they may not have budgetary priority as a result of the Project Office's efforts to prioritize site characterization activities. In addition, only site characterization work directed by the Yucca Mountain Project Office (Project Office) has been statused as part of this Status Report.

2.0 STATUS OF SITE CHARACTERIZATION

This section presents summary information on the status of site characterization activities, including progress made toward the initiation and conduct of these activities. Technical documents that provide more detailed information on the results of work completed are cited as appropriate and listed in the reference section (Section 3.0).

2.1 PREPARATORY ACTIVITIES

2.1.1 Quality Assurance Program

During the reporting period, DOE continued implementing a 10 CFR Part 60 Subpart G quality assurance (QA) program. According to agreements between the U.S. Nuclear Regulatory Commission (NRC) and DOE, qualification of QA programs under Subpart G is required for the initiation of new site characterization activities. Data obtained through activities conducted before a fully qualified QA program is in place must be qualified if the data are to be used in the licensing process (NRC, 1988a).

In April 1989, the Quality Assurance Requirements (QAR) and Quality Assurance Program Description (QAPD) documents underwent a review by the NRC. The QAR defines the QA requirements governing activities affecting quality, and the QAPD describes the Office of Civilian Radioactive Waste Management (OCRWM) responsibilities, interfaces, and provisions necessary to implement the requirements of the QAR. The NRC issued a Safety Evaluation Report (SER) in May 1989 that accepted these two documents.

Work continued on revision of the DOE/Project Office and individual participant organization Quality Assurance Program Plans (QAPPs) to meet the requirements of Revision 2 of the Yucca Mountain Project Quality Assurance Plan (QAP), NNWSI/88-9. The QAP defines, for the entire Yucca Mountain Project, the QA requirements governing activities affecting quality and the responsibilities, interfaces, and provisions necessary to implement the requirements. The OCRWM has submitted all revised participant QAPPs to the NRC. Acceptance of the revised QAPPs by the NRC is pending.

The Project QAP specifies certain control measures for computer software, such as the development of a software QA plan by all participants. To date, one such plan, prepared by the United States Geological Survey (USGS), has been developed and approved based on requirements of NNWSI/88-9, Rev. 2. Six additional plans are currently in preparation or review. Once approved, the plans and procedures are subject to audit.

During the reporting period, the Project Office and participating organizations continued reviews of existing QA implementing procedures to determine whether existing procedures need to be revised to meet current requirements and whether new procedures need to be developed.

All quality-related procedures have been grouped into four categories:

1. Procedures required for the start of Title II design of the Exploratory Shaft Facility (ESF).

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

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

4. Balance of procedures required for QA program qualification.

A two-part verification surveillance on the Project Office by a Surveillance Task Force was completed on the procedures identified in each of the above categories. The first part of this surveillance consisted of a documented review of each procedure to ensure the incorporation of all applicable requirements of NNWSI/88-9, Rev. 2. The second part of this surveillance consisted of a review of the implementation of procedural requirements where such documentation exists. A total of 103 surveillances were performed by the task force. All deficiencies discovered, as well as the actions taken to correct the deficiencies, were formally documented.

The Project Office is in the process of consolidating procedures that are consistent with NUREG-1318, the NRC technical position on QA for a geologic repository (NRC, 1988b). The four existing administrative procedures addressing the preparation of the Q-List and Quality Activities List are currently being combined into one procedure, Administrative Procedure (AP) 6.17Q, Determination of the Importance of Items and Activities. The two existing administrative procedures addressing the assignment of QA levels and grading are being combined into one procedure, AP-5.28Q, Quality Assurance Grading.

During the reporting period, the Project Office completed a total of 11 surveillances and 4 audits directed toward participating organizations and contractors.

2.1.2 Exploratory Shaft Facility Design and Construction

During this reporting period, the initial stage of the Readiness Review for exploratory shaft (ES) site preparation was initiated by preparing a checklist of prerequisites to be completed prior to initiation of field activities. In addition, the Exploratory Shaft Field Management Plan and implementing procedures were completed in draft form.

Work began on Title II design for the ESF. Several design packages, representing subelements of the overall design scope, are currently under development, and two participant organizations submitted a Basis for Design (BFD) document and an Engineering Plan to the Project Office for review and acceptance. A BFD contains or refers to all design inputs needed by an organization to do its design work. An Engineering Plan presents an organization's approach to its design activities. Both BFDs were conditionally accepted subject to revision per Project Office instructions. The Engineering Plans are currently being revised.

A management review of ESF drawings showing the general arrangement of facilities and features and a portion of a design package dealing with site preparation was conducted in August. Documented comments were submitted and are currently being resolved. Some changes may be made in the general arrangement of the facilities and features as a result of these comments.

A management review of a second ESF design package dealing with the headframe, shaft collar, and main test level layout was started in September. Resolution of comments will occur early in the next reporting period.

Revision 1 of the ESF Subsystems Design Requirements Document (SDRD) for Title II has been completed. This revision incorporated comments from the Technical Assessment Review (TAR) conducted on Revision 0 in February 1989. The SDRD presents all the requirements the DOE will impose on the ESF design. A change request to approve issuance of Rev. 1 has been prepared, but submittal of the request to the Change Control Board (CCB) is awaiting completion of document verification.

Preparation of an ESF Test Support Requirements Document (TSRD) is underway to facilitate test support planning and budgeting. This document will define non-design-related support requirements and responsibilities for all ESF tests.

A consolidated draft of the Preliminary Safety Analysis Report (PSAR) for the ESF was completed just prior to the end of the reporting period. The PSAR provides a preliminary assessment of safety aspects of all ESF operations.

The Environmental Safety and Health Program Implementation Plan (ESHPIP) was written and reviewed and is awaiting Project Office approval. The ESHPIP implements the environmental health and safety program for all ESF operations.

An action plan for implementation of the Integrated Data System (IDS), a computer-based central data collection utility, for Title II design was prepared and issued in mid-April. A readiness review was initiated on September 8 and is expected to be completed in mid-October. In anticipation of beginning IDS Title II design work, an IDS Liaison Group has been formed. The group is made up of IDS users and has responsibility for coordinating users' needs and requirements. Initial meetings of the Liaison Group were held in August. It is anticipated that meetings will be held on a monthly basis.

Meetings were held with the Nuclear Waste Technical Review Board (NWTRB) on June 26-28 and again on July 24. Most of the discussion at these meetings focused on the need for ESF perimeter drifts and the possible mechanical excavation of the ESF shafts and perimeter drifts using boring machines versus drill-and-blast methods. These suggestions are under consideration by the Project.

A meeting was held between the DOE and NRC on July 5-6, 1989, to present the ESF design control process. This was a follow-on to meetings held in October, November, and December 1988. Most of the problem issues on design control since the 1988 meetings have been resolved, and these NRC open items were closed. AP-5.18Q, ESF Design Control, has been revised and is currently awaiting approval following completion of the Project Office review.

A proposal for a prototype demonstration of excavation feasibility was prepared and submitted for Project Office consideration. The document evaluates the feasibility of constructing an 80-ft deep prototype shaft for testing and developing construction methods and procedures, developing test procedures, and defining interfaces with construction.

The Project has proposed that the minimum ESF design life stated in Appendix E of the Generic Requirements for a Mined Geologic Disposal System be changed from 5 to 15 years. Proposed text for the baseline change proposal is awaiting DOE approval prior to resubmittal to the CCB.

2.1.3 Surface-Based and Underground Testing Program

During this reporting period, the DOE initiated the prototype dry-drilling and coring program. Dry-drilling and coring is highly advantageous for deep drilling and core sampling in the unsaturated zone at the Yucca Mountain site to limit the potential for altering rock parameters, such as moisture content, and to reduce water usage. Dual-wall reverse circulation is the drilling method used in the prototype drilling tests. To meet the drilling requirements of the Project, the DOE has contracted Lang Exploratory Drilling, Inc., to drill prototype holes and further develop the dual-wall reverse circulation drilling technique. Procurement of a large dry-drilling rig is planned in the next reporting period.

A location was originally selected in Area 25 south of Busted Butte on the Nevada Test Site (NTS) to conduct prototype drilling. However, drilling at this site has been delayed due to the lack of an Operating Permit for Yucca Mountain Project activities as required by Nevada air quality regulations. As a result, the first drilling was done at a mine site near Tooele, Utah. This location was selected because of its close proximity to the drilling contractor's shop to facilitate equipment modification and fabrication, as necessary, during drilling. Eight-inch and twelve-inch diameter holes were drilled during this phase of equipment development. The rock drilled at this site was a silicified limestone in the unsaturated zone. As a result of this first prototype drilling, it was determined that the dry-drilling methodology has a high probability of success at Yucca Mountain. However, some drill bit modifications were made in preparation for additional prototype drilling.

A second alternate prototype drilling site was selected in volcanic rocks at an old mining area approximately 15 miles west of Milford, Utah. Four holes were drilled to various depths in the unsaturated zone. However, because water was encountered in each of these holes, they were all abandoned before reaching depths greater than 550 feet. Despite not reaching desired depths, considerable experience was gained in wireline coring and in sample recovery using dry-drilling technology.

Efforts will continue through the next reporting period to select a site where appropriate rock type and ground water depths are sufficient to further test the dry-drilling and coring techniques at depths and conditions similar to those that will be encountered at Yucca Mountain. In lieu of the State of Nevada granting the DOE the necessary air quality related Operating Permit to allow drilling on the NTS, alternate sites in southern Utah and Arizona are being examined to continue the prototype dry-drilling program.

Branch technical procedures and several administrative procedures for operation and use of the Project Sample Management Facility (SMF) have been written and were approved by the Project Office this reporting period. A Readiness Review for the facility was also conducted. The SMF is now fully operational, and the SMF staff is in the process of testing field and process procedures on core and cutting samples collected during the prototype drilling program described in the previous paragraphs.

During this reporting period, an action plan was developed to verify field locations for surface-based site characterization activities. These field locations are expected to be established over the next reporting period and will be based on the preliminary coordinates presented in the Surface-Based Investigations Plan (SBIP) (DOE, 1988b). Adjustments in activity locations due to surface or testing considerations will be made, allowing site preparation specifications for surface-based testing to be determined and pre-activity archaeological and environmental surveys to be conducted well in advance of surface disturbances. Locations will be marked with aerial survey targets to allow coordinates to be determined from orthophotos. The orthophotos will be developed from information collected as part of a planned aerial survey of the Yucca Mountain site area. Activity coordinates will then be used to assist in developing construction and test control requirements for surface-based site characterization work. The orthophotos and digital elevation contour maps developed from the aerial survey will be used in updates of the SBIP and the Yucca Mountain Site Atlas (DOE, 1988c).

Prerequisites constitute a package of information requirements and checklists compiled by principal investigators that are designed to determine readiness to begin field work in a specific activity. Prerequisite review action plans have been developed for the following planned surface-based site characterization activities:

1. Site vertical borehole studies, SCP Activity 8.3.1.2.2.3.2.

2. Multipurpose borehole (MPBH) testing, SCP Activity 8.3.1.2.2.4.9.

3. Geologic mapping of zonal features within the Paintbrush tuff, SCP Activity 8.3.1.4.2.2.1.

4. Surface fracture network studies, SCP Activity 8.3.1.4.2.2.2.

5. Evaluation of past discharge areas, SCP Activity 8.3.1.5.2.1.3.

6. Calcite and opaline silica vein deposits, SCP Activity 8.3.1.5.2.1.5.

7. Location and recency of faulting near prospective surface facilities, SCP Activities 8.3.1.17.4.2.1 and 8.3.1.17.4.2.2.

8. Quaternary geology and faulting at Yucca Mountain, SCP Activity 8.3.1.17.4.6.1.

The major purpose of prerequisite action plans is to (1) assist Project management in integrating site characterization activities and prevent delays and interruptions that may impact personnel, schedule, cost, or licensability

of the site; and (2) ensure that these activities meet their technical objectives, as described in the SCP, and programmatic requirements. The prerequisite action plans will also be used for readiness evaluations and work authorization, and to status progress and trends of site characterization activities. The action plans call for statusing of prerequisite completion on a monthly basis.

Prototype testing activities to develop techniques and procedures in preparation for ESF testing continued in G-Tunnel on the NTS. During the reporting period, emphasis was placed on the development of equipment and techniques to perform dry overcoring in the ES for the Overcore Stress Test, the Intact Fracture Test, and the Diffusion Test. Emphasis was also placed on development of procedures for the collection of bulk-rock samples from the ESF for laboratory analysis. Facility expansion to provide space for the Engineered Barrier Prototype testing and Thermal Stress Test was started. The Optimum Rubble Prototype Test alcove mining was completed. As part of this test, controlled blasting techniques were used to evaluate practices for dry blast-hole drilling dust control and to obtain rubble sizes suitable for preparing samples for the Matrix Hydrologic Properties Test. Additional discussion of these activities is included under the appropriate activity in Section 2.2.

Planning for interpretative documents to supplement the ESF SDRD and SCP was initiated during this reporting period. Preliminary titles assigned to these early drafts are ESF Test Description Document and TSRD.

2.1.4 Permits

Environmental regulatory compliance activities continued in an effort to obtain environmental regulatory approvals for site characterization at Yucca Mountain. On July 24, 1989, the U.S. Fish and Wildlife Service (USFWS) announced its intention to list the desert tortoise, which inhabits the desert Southwest (including the Yucca Mountain area), as "endangered." On August 9, 1989, the Project consulted with the USFWS concerning the Project's potential effect on the species. As a result, a Biological Assessment is being prepared to evaluate the Project's potential effects on the tortoise and alternatives available to the Project for mitigation strategies to avoid or minimize impacts to the tortoise. The Yucca Mountain site is not expected to be determined a critical habitat for the desert tortoise. However, in the interim, access to the Yucca Mountain site has been restricted until consultations with the USFWS are concluded.

The Nevada Division of Environmental Protection (NDEP) continues to withhold the Project's air quality permit for land disturbance and to take no action on the NTS air quality operating permit modification request for prototype activities. On July 11, 1989, a letter was sent to the NDEP strongly stating that the application for an air quality permit for land disturbance was complete and that no legal basis exists for not approving the application. However, the NDEP stated in a telephone conversation on that same day that Nevada State Bill A.B. 222, effective July 1, makes the repository unlawful in the State of Nevada. Therefore, consultation between

the NDEP and the State Attorney General is necessary to determine if the application or the permit modification request can be issued.

On June 27, 1989, a Resource Conservation and Recovery Act Identification Number was received from the U.S. Environmental Protection Agency (EPA) for the handling and management of hazardous waste. Any solid and hazardous wastes that are generated during the course of site characterization will be stored, transported, and disposed of in accordance with the Project Hazardous Materials Management and Handling Plan. A draft of this plan is scheduled for completion in October 1989.

The State Engineer continues to process the Water Appropriation Permit application. Protests to the permit have been received from the National Park Service (NPS), the Nevada Nuclear Waste Project Office (NWPO), and the State of Nevada, which filed as a formal party to the proceedings on March 15, 1989. The State Engineer plans to hold a public hearing on this issue, but to date no schedule has been established for the hearing.

Discussions continue with the NPS to address its concern that Project water use during site characterization may affect ground-water resources in Death Valley National Monument and Ash Meadows. The NPS is protesting all new applications in the region, but has said that establishing a monitoring program would satisfy its concerns. Consequently, a water monitoring program is being developed, in consultation with the NPS, to satisfy this suggested permit condition. Work has begun on the monitoring program, and a draft is scheduled for completion in October 1989.

On February 9, 1989, DOE published a Federal Register notice stating that the DOE proposes to construct facilities in a floodplain. The NWPO provided comments on the notice on March 31, 1989. A Floodplain Assessment, required by 10 CFR Part 1022, is currently in review. The Floodplain Assessment is scheduled for release in October 1989.

In May 1989, the Free Use Permit application for sand, gravel, and fill material to be used during site characterization was reviewed by DOE. The application was filed with the U.S. Bureau of Land Management (BLM) on July 11, 1989. On August 29, 1989, the BLM toured the gravel pit location. Permit approval is expected as soon as consultations with the USFWS are complete.

On April 6, 1989, an Underground Injection Control permit application was filed with the NDEP for tracer tests in the unsaturated zone. On June 27, 1989, the NDEP notified the DOE Nevada Operations Office Environmental Compliance Division, which, in turn, notified the Project Office on July 20, 1989, that the application was incomplete. The NDEP has requested additional information about the injection wells and an abandonment plan. These items are being prepared and are expected to be submitted to the NDEP in October 1989.

A worker environmental protection and awareness training film for field activities was completed during the reporting period, and the lesson plan necessary to implement the training program is currently being developed. The film, to be viewed by each Project worker, emphasizes the importance of

protecting archaeological, biological, and cultural resources. However, due to the recent development with the desert tortoise, the worker training film will be revised.

DOE initiated a program to review proposed site characterization activities for compliance with land access requirements, environmental regulatory compliance requirements, environmental monitoring and mitigation program requirements, and archaeological and terrestrial ecosystems pre-activity survey requirements. Each Project participant responsible for a site disturbing activity is required to request a compliance review before site activities may begin. During this reporting period, 22 activity requests were processed. Of these, nine were approved in total. The remaining 13 requests were partially approved; all had some activity identified on the Nellis Air Force Base Range (NAFBR).

2.1.5 Land Acquisition

During this reporting period, two quarterly consultation meetings were held with the Las Vegas District and Stateline Area Resource Offices of the BLM concerning Right-of-Way Reservation (ROWR) N-47748. ROWR N-47748 was granted to DOE by the Nevada State Office of the BLM in February 1988 for access to the public lands at Yucca Mountain. The process to gain Project access to the NAFBR is continuing. It is expected that an ROWR will be issued by the BLM in October.

During this reporting period, a case file was developed in accordance with 43 CFR Part 2300, Land Withdrawals, for the land withdrawal application for approximately 4,300 acres of public land on Yucca Mountain that was filed with the BLM by the Project Office in early 1989. Portions of 43 CFR Part 2300 require that a land withdrawal case file be developed. As part of this case file, a draft Land Withdrawal Report has been prepared and transmitted to the Las Vegas District Office of the BLM for review. In addition, a draft Mineral Resource Analysis, which is also required for the case file, has been prepared by the Nevada Bureau of Mines and Geology and was entered into the review process.

A research proposal to conduct regional hydrologic studies in the Death Valley National Monument and the Desert National Wildlife Refuge was prepared and submitted by the Project Office to the NPS and the USFWS, respectively. The two necessary approvals for the proposal were received from these agencies in early June 1989.

The Barstow and Stateline Area Resource Offices of the BLM were both notified of casual access to public lands under their jurisdiction for conduct of regional hydrologic studies.

2.1.6 Public Outreach

In September 1989, three public information meetings were held in Nevada. The meetings discussed, in part, the status of the site characterization program. These three-hour Project Update Meetings were held the evenings of September 25, 26, and 28 in Pahrump, Henderson, and Carson City, respectively.

During the meetings, advance copies of the first Semiannual Site Characterization Progress Report were available for public review. In addition, the status of the DOE responses to the March 1989 SCP Public Hearings was discussed. The public was informed that, as DOE had promised, all comments will receive written responses. However, due to the volume of comments received, comment response packages are not expected to be issued until early 1990.

Project Update Meetings will continue to be held approximately every six months in various locations around Nevada. The meetings will continue to provide information on the status of site characterization activities, as well as various related topics currently of public interest. Summaries of the issues raised at all Update Meetings are prepared and reviewed by scientists who are planning the studies at Yucca Mountain to ensure that all technical concerns are appropriately addressed.

Additional information about site characterization activities is currently available at the Yucca Mountain Public Information Office in Beatty. A new Yucca Mountain Information Office is expected to open in Las Vegas in early 1990.

2.1.7 Interactions with NRC and Oversight Organizations

The Project Office committed a significant level of effort in support of briefings, technical exchanges, meetings, and site visits with the NRC and Project oversight groups. During the reporting period, the Project Office participated in four meetings with the NWTRB. The NWTRB was created by the Nuclear Waste Policy Amendments Act of 1987, and its members are appointed by the President to advise Congress and the executive office on the conduct and progress of the DOE high-level waste program. The full board contains several panels composed of experts that interface with various aspects of the DOE program. The four meetings held were: (1) a Risk and Performance Assessment Panel meeting on May 16-17, (2) a briefing on the Yucca Mountain Project that included a Yucca Mountain site visit on June 26-28, (3) a Container and Transportation Panel meeting on August 21-23, and (4) a meeting on September 14 on the status of environmental field programs and issues related to the 40 CFR Part 191 remand.

During the reporting period, the Project Office also participated in several meetings with the NRC, some of which involved site visits. Protocols for "technical exchanges" between DOE and NRC staff were instituted in July to enable less formal discussions on topics of limited scope; no policy is established during these exchanges. Technical exchanges conducted during the reporting period included (1) discussions of the definition and quantification of the "substantially complete containment" concept in 10 CFR 60.113, (2) a volcanism field trip to the Yucca Mountain site in May, (3) a hydrology field trip to the site in July, and (4) an August field briefing in Utah for NRC staff on prototype dry-drilling methods. "Meetings," on the other hand, are considered formal interactions between the DOE and NRC. Meetings held during the reporting period focused on (1) SCP study plan availability, (2) discussions of NRC objections and comments contained in the Site Characterization Analysis, and (3) tectonic and volcanic activity hazard assessment methodology.

In addition, the Project Office has supported several interactions with the Advisory Committee for Nuclear Waste (ACNW), an advisory body to the NRC. These interactions included (1) a late April DOE briefing to NRC staff on preliminary concerns with the SCP, (2) a June ACNW briefing to DOE staff on concerns with the SCP expressed in the Site Characterization Analysis, and (3) a September DOE briefing to ACNW staff on the availability of technical data generated by site characterization work.

In April, the DOE received a briefing in Las Vegas by staff from the Center for Nuclear Waste Regulatory Analysis (CNWRA). The briefing focused on the role of the CNWRA as a dedicated, federally funded research and development center for the NRC. The CNWRA will perform analysis and research to reduce regulatory uncertainties prior to the licensing process for a geologic repository for high-level waste.

2.2 SITE PROGRAMS

The site programs consist of the planned field and laboratory investigations that will be conducted to collect technical information on the Yucca Mountain site. The comprehensive site data collection activities will be integrated with repository, seals, and waste package design activities and activities associated with performance assessment to obtain the information needed to evaluate the suitability of Yucca Mountain for a mined geologic disposal system for high-level waste. The field and laboratory investigations have been organized into 16 distinct site programs (e.g., geohydrology, geochemistry, etc.). Site investigations are subdivided into studies and activities. Individual packages of work within an SCP study are termed activities. The status of these site studies is provided in this section. Activity status is included only if work was performed in that activity during the reporting period.

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

Study Plan 8.3.1.2.1.1 is currently being compiled. A draft for internal review is nearly complete.

Activity 8.3.1.2.1.1.1 - Precipitation and Meteorological Monitoring. Work continued on designing the precipitation monitoring network for Yucca Mountain and vicinity. Much of this work is part of the regional meteorology program.

Three new tipping bucket rain gages were purchased for evaluation of precipitation monitoring techniques, and tests were initiated to evaluate their performance. One gage is a 0.2 mm resolution, 8-inch orifice; the second is 0.2 mm resolution, 12-inch orifice; and the third is a heated snow gage with a 0.2 mm resolution, 12-inch orifice. It is believed that the 12-inch orifice will be shown to be superior to the 8-inch, which currently is installed in the field. It also is believed that 0.2 mm resolution rain gages will be easier to maintain and calibrate than those presently used.

Solar radiation data were collected with an Eppley precision spectral pyranometer located at weather stations 1 and 2 at the NTS. These data will be used to verify and, if necessary, recalibrate the LiCor pyranometers currently in operation on those weather stations.

On July 13, USGS staff met with personnel from the DOE Weather Service Office (WSO) in Las Vegas to discuss final details for setting up ALERT-type technology at the NTS for monitoring activities and establishing a DOE meteorological data base for the southern Nevada area. The system was installed on July 18 and serves as an automatic flood warning system activated by either rainfall at a precipitation station or runoff at a stream gaging station. The system also provides the Las Vegas WSO with NTS weather forecasts and near real-time data and graphics on precipitation, temperature, wind, lightning, and radar.

An abstract on verification and calibration of tipping bucket rain gages by W. Davis et al. (approved) was submitted to the DOE for approval for presentation at the annual meeting of the Soil Science Society of America (SSSA), to be held October 15-20, 1989, in Las Vegas, and for publication in the proceedings.

2.2.1.2 Study 8.3.1.2.1.2 - Characterization of Runoff and Streamflow

Study Plan 8.3.1.2.1.2 was submitted to DOE/HQ for review on May 11, 1989.

Activity 8.3.1.2.1.2.1 - Surface-Water Runoff Monitoring. Routine operation of the streamflow and precipitation monitoring networks continued throughout the reporting period. Upgrading of crest-stage gages and minor repairs were made at stations at Fortymile Wash near Lathrop Wells, well J-13, and the Narrows in April. In June, a routine check of sites in the current surface-water network was made. The crest-stage site on Topopah Wash was investigated as a potential candidate for the surface-water prototype gage.

In early May, USGS staff visited the area surrounding Yucca Mountain to reassess proposed sites for stream gages that will comprise the Yucca Mountain intensive streamflow network. The channel that drains Crater Flat to the Amargosa Valley was briefly checked for the feasibility of a stream gage monitoring system for Crater Flat; this drainage basin receives runoff from the west-facing slopes of Yucca Mountain, including Solitario Wash. In late August, the drainage outlet of Crater Flat was re-examined in an effort to complete selection of a future streamgaging site. An examination was also made of the hydrologic character of the Amargosa River channel in the Amargosa Farms area.

Preliminary tests were performed on calibration tubes used for surface-water runoff. Initial tests of the system and instrumentation were successful, but indicated several minor modifications were needed in the plumbing configuration.

On June 14-15, USGS staff visited the experimental watershed project at Walnut Gulch near Tombstone, Arizona. The purpose of the trip was to

investigate flumes used for runoff studies in channels that are similar to channels found at Yucca Mountain.

Rainfall was reported on April 26 and observed on April 27 at higher elevations near Pahute Mesa and Upper Fortymile Wash. Fieldwork in Fortymile Wash on April 27 and field reconnaissance in and around the Yucca Mountain area indicated no runoff in the Yucca Mountain area.

Significant storm activity occurred during the week of August 7-11, causing spotty rainfall over most of the Mojave Desert and the Great Basin. All of the observed runoff events were the result of small cells (about 10 miles in diameter) of intense precipitation. In one case, no rainfall was observed 4 miles from a center of intense rainfall. However, several areas experienced rainfall that was intense enough to cause notable runoff, specifically in tributaries to Topopah Wash from the southern part of the Calico Hills. Upon further investigation, runoff was also found to have occurred in the following locations (peak discharges given in parentheses): Windy Wash in Crater Flat (130 cfs); Crater Flat Wash above Highway 95 (20 cfs); Topopah Wash at Jackass Flats (35 cfs); and an unnamed tributary to Amargosa River No. 2 near Johnnie (50 cfs). Approximately 1 inch of rain fell on Yucca Mountain during the early morning of August 11; however, no runoff other than road runoff was observed or reported for washes on Yucca Mountain or in Fortymile Wash. Land-surface evidence of runoff in Crater Flat was photographed from the air on August 31.

Evidence of minor flooding of an unnamed tributary to the river from the Funeral Mountains was noted during a field inspection in late August, but the date of this flooding is unknown. An examination at Mesquite Springs in northern Death Valley disclosed evidence of apparent recent runoff in Death Valley Wash; flow appeared to be slight, but the site was noted as an excellent surveillance point to evaluate floods originating in the Grapevine Canyon and Oriental Wash drainages. The area may become a crest-stage-gage candidate site as the regional streamflow network evolves.

A program of quarterly QA testing of unknown water samples for pH, conductivity, and alkalinity was arranged with the USGS laboratory in Ocala, Florida.

USGS staff participated in the NRC hydrology field trip at the NTS on July 25 and 26. The review included a visit to the Fortymile Wash gage at the Narrows and a discussion of streamflow measurement and data-reduction techniques.

Activity 8.3.1.2.1.2.2 - Transport of Debris by Severe Runoff. Debris flows that resulted from precipitation in 1984 on Skull Mountain and Jakes Point were evaluated. Monitoring of debris transport continued. A survey was conducted of heavy runoff from the west-facing slopes of the southern Sierras, south of Bishop and Independence, California, where heavy debris movement from Olancha Creek disrupted the Los Angeles water supply aqueduct. It was concluded that this runoff and debris flood would require extensive effort to adequately document and evaluate, and follow-through studies will be conducted during the next few months. Information gained from these studies can be applied to debris movement studies to be conducted at Yucca Mountain. The Wren Wash area at Yucca Mountain was investigated for evidence of debris flows

resulting from the storm activity on August 7-11. Evidence of runoff and sediment transport were found, but both were minor. All observed runoff on the east-facing slopes of Yucca Mountain was the product of road runoff, runoff from man-disturbed sites, or both.

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

Various activity sections and illustrations for Study Plan 8.3.1.2.1.3 were completed. The study plan is currently in internal technical review at the USGS.

Activity 8.3.1.2.1.3.1 - Assessment of Regional Hydrologic Data Needs in the Saturated Zone. Data collected at Franklin Lake Playa and elsewhere in the regional ground-water flow system are being examined to determine if the data may be qualified and used to support site characterization.

Activity 8.3.1.2.1.3.2 - Regional Potentiometric-Level Distribution and Hydrogeologic Framework Studies. Routine operation of the periodically and continuously measured potentiometric-level networks continued throughout the report period. A report on water levels in periodically measured wells in the Yucca Mountain area in 1988 is in review at the USGS.

Locations, depths, potentiometric data, lithologic data, and hydrologic analyses for water wells and drillholes within the regional ground-water flow system have been compiled for use in potentiometric and flow analyses. A hydraulic and hydrochemical testing procedure for testing in 2-inch diameter piezometers constructed as part of ongoing Project activities in the Amargosa Desert has also been developed.

USGS and Battelle/Chicago staff made a site visit to Franklin Lake Playa and vicinity, the principal discharge area of the Alkali Flat - Furnace Creek Ranch ground-water system, to inspect various well sites for deployment of a multilevel hydrochemical sampler for obtaining stratified hydrochemical samples. Prototype testing of this equipment is tentatively scheduled for late 1989.

A reconnaissance was made of new private water wells drilled in Crater Flat and the site for a monitoring well as part of the Bond Gold Bullfrog Project, located in the Grapevine Mountains on the southwest flank of the Amargosa Desert.

USGS staff conducted a review of geophysical surveys planned or proposed for specific problem resolution in the regional ground-water flow system. Of particular importance is the resolution of the distribution and cause of the large hydraulic gradient north of Yucca Mountain. Additional discussions were held regarding methods of exploring the gradient, including the possibility of using geostatistics to assess data uncertainty associated with the planned piezometers. Further discussion of this large gradient occurs under Activity 8.3.1.2.1.4.1.

An abstract by C. Savard (approved) discusses potentiometric and hydrochemical data to support the boundary between the Oasis Valley and Alkali

Flat-Furnace Creek Ranch ground-water flow systems. The abstract will be presented at the Fall 1989 America Geophysical Union (AGU) meeting and published in EOS.

Oatfield and Czarnecki (approved) made final revisions to a paper on hydrogeologic inferences that can be drawn from driller's logs and geophysical surveys in the Amargosa Desert, Southern Nevada prior to submission of the paper to Journal of Hydrology.

Czarnecki and Luckey (1989) prepared an introduction to the regional and local groundwater systems section of the Geological Society of America (GSA) 1989 Field Trip Guidebook.

Activity 8.3.1.2.1.3.3 - Fortymile Wash Recharge Study. A reconnaissance field trip of Fortymile Wash was made to determine (1) potential locations for performing infiltration testing, (2) sites for construction of piezometer/unsaturated zone monitoring holes, and (3) location of existing "infiltration" ponds. Neutron holes UZN 85, 91, and 92 were found to be suitable (as to location) for infiltration testing. No sites for construction of piezometer/unsaturated zone holes were found. Existing ponds were all found to be unsuitable for infiltration studies.

A seminar was given by Battelle/Chicago to about 20 USGS and Los Alamos National Laboratory (LANL) staff on the use of multilevel, in situ hydrochemical samplers in the unsaturated and saturated zones. Plans are in preparation to use these instruments in boreholes at Fortymile Wash and Franklin Lake Playa. A follow-up briefing on the use of these instruments was given to a USGS training class on hydrochemical modeling.

USGS staff toured the Agricultural Research Service's (ARS's) Walnut Gulch Experimental Watershed near Tombstone, Arizona, and visited the ARS staff in their Tucson offices. The purpose of the tour was to review instrumentation that has been used in arid environments to determine streamflow transmission losses in an effort to quantify recharge. Information from this trip will be directly transferable to efforts directed at estimating recharge at Fortymile Wash, located 3 km east of Yucca Mountain.

Activity 8.3.1.2.1.3.4 - Evapotranspiration Studies. Findings related to phreatophyte distribution at Franklin Lake Playa were reviewed as part of the characterization of evapotranspiration within the ground-water flow system of Yucca Mountain and vicinity.

USGS staff attended a seminar by M. Parlange (Cornell University Ph.D candidate) on estimating regional evapotranspiration by measuring temperature and humidity gradients in the atmospheric boundary layer (located about 1 km above land surface). It is believed that the method might have applicability for regional hydrology studies in the vicinity of Yucca Mountain.

2.2.1.4 Study 8.3.1.2.1.4 - Regional Hydrologic System Synthesis and Modeling

Development of Study Plan 8.3.1.2.1.4 has been completed, and it is currently in internal review at the USGS.

Activity 8.3.1.2.1.4.1 - Conceptualization of Regional Hydrologic Flow Models. USGS Project staff and USGS staff of other regional ground-water investigations of the Great Basin participated in a seminar to discuss alternate conceptual models. Findings of the studies unrelated to the Yucca Mountain Project are consistent with the hydrogeologic concepts that are currently applied in Project modeling of the regional flow system.

A more focused workshop by USGS Project geologists, geophysicists, and hydrologists was held on May 5 to discuss alternative causes and preliminary simulations of the large horizontal gradient beneath northern Yucca Mountain. The possibility of fracture response to local differences of in situ stress was discussed. However, most of the discussion centered on hydrogeologic controls resulting from stratigraphic, structural, and secondary-alteration features associated with the Timber Mountain - Claim Canyon caldera complex. Analyses of core from drillhole USW G-2, which is within the area of the large gradient, indicates substantial alteration to zeolites and clays; this may have reduced the effective transmissivity, contributing to the steepening of the potentiometric surface.

At the Spring 1989 AGU meeting in Baltimore, Maryland, Sinton (1989) and Czarnecki (1989) presented talks, respectively, on the characterization and preliminary simulation of the large hydraulic gradient beneath northern Yucca Mountain. USGS staff plan to present updated results of recent work on the preliminary simulations to a group of researchers at Lawrence Berkley Laboratory (LBL) for critical review. The results of this work are targeted for presentation at an upcoming session on large hydraulic gradients in the saturated zone at an AGU meeting and as a paper in Water Resources Research.

An abstract by Czarnecki et al. (approved) addresses the identification of recharge areas and flow paths of ground water toward Yucca Mountain, and will be presented at the Fall 1989 AGU meeting in San Francisco, California.

Final revisions were completed to a paper on conceptual models and site characterization of the subregional ground-water flow system (Czarnecki and Wilson, approved) prior to submission to Groundwater.

Activity 8.3.1.2.1.4.2 - Subregional Two-Dimensional Aereal Hydrologic Modeling. A paper on characterization of the subregional ground-water flow system of Yucca Mountain and vicinity (Czarnecki, approved) was prepared for submittal to the Journal of Radioactive Waste Management and Nuclear Fuel Cycle.

Activity 8.3.1.2.1.4.4 - Regional Three-Dimensional Hydrologic Modeling. A report was completed on the status of three-dimensional, steady-state modeling of the ground-water flow system at Yucca Mountain (Sinton et al., approved).

2.2.1.5 Study 8.3.1.2.2.1 - Characterization of Unsaturated Zone Infiltration

Study Plan 8.3.1.2.2.1 is currently being revised to incorporate USGS internal technical review comments.

Activity 8.3.1.2.2.1.1 - Characterization of Hydrologic Properties of Surficial Material. Infiltrometer measurements were made in the Topopah Wash to characterize stream-channel hydraulic characteristics, and laboratory tests were conducted to define the physical characteristics of the channel sediments.

Infiltration tests on a wide variety of surfaces were performed in connection with the prototype infiltrometer evaluations and prototype surficial materials characterization. Application, with bounding calculations that assess potential for impacts, was made to the DOE for permission to perform these prototype tests at Yucca Mountain. Initially, however, infiltrometer evaluation is being done in areas that have already been cleared near Test Cell "C" and north of the Hydrologic Research Facility in Area 25 at the NTS. Additional soil physical measurements will be combined with the prototype tests to develop a statistically-based sampling program and infiltration-runoff map for surficial units, and to determine if geologic and geomorphic surficial map units can be used to delineate infiltration-runoff map units.

Vegetation and soils mapping were performed as part of the prototype surficial materials characterization and prototype remote-sensing studies. Prototype infiltrometer measurements were made in connection with the mapping work, all of which will be entered as data layers in the Geographic Information System (GIS), a data base and graphics system. Laboratory analyses of the hydraulic and physical properties of the soils from the mapped areas were performed in parallel with the mapping and infiltrometer work.

Progress was made on calibration of the time domain reflectrometry system. The initial laboratory calibrations, the field calibration site, and the experimental design have been completed, and the final environmental approval for the evaporation station was obtained. A ground-penetrating radar (GPR) investigation, using two different systems, was conducted in several locations on Yucca Mountain with very little success. It appears that the high amount of radiofrequency interference from U.S. Air Force and NTS activities may render GPR unusable. Additional testing will be done with other antennas.

Activity 8.3.1.2.2.1.2 - Evaluation of Natural Infiltration. Natural infiltration on and around Yucca Mountain continues to be monitored as part of the neutron monitoring program. A 1-inch rainfall occurred in mid-August and neutron logging was initiated to determine the impacts on natural infiltration. Preliminary indications are that all of the water evaporated into the atmosphere and did not have any influence at depth. One notable exception is 5 feet of water that entered into wellbore UE-25 N#2. Fracture flow is most likely responsible for this large volume of water. Several ideas have emerged on ways to identify the pathways and source of the water. Following study plan approval and DOE authorization to continue field work, some of these ideas can be investigated.

A draft report on geohydrologic data from shallow neutron-access holes at Yucca Mountain was completed and submitted for internal technical review at the USGS. Work is underway to develop a better calibration equation for the neutron moisture meter. Data from Activity 8.3.1.2.2.3.1, Matrix Hydrologic Properties Testing, will be used in revision of the calibration equation.

Because of the complex interactions between neutron counts, determining density and water content will be a difficult process. Several ideas are being pursued.

Progress was made in development of the cross-hole gamma system. A series of tests on the high-voltage radiation threshold and window for the gamma source has provided a working knowledge of the use and limitations of the equipment. Temperature compensation has been used for the first time and appears to work well. The new, small diameter crystal has not yet been received, but it is expected that it will work adequately. When completed, the cross-hole gamma system will provide the ability to simultaneously measure bulk density and water content to a resolution of 0.01 g/cm^3 and 0.01 cm^3/cm^3, respectively.

Work continued on modeling the spatial variability of solar radiation over Yucca Mountain using a clear-sky solar radiation model. Half of the expected number of computer simulations and some preliminary geostatistical analyses of this modeled data have been completed. There has been a more thorough evaluation of the influence of ridges that block direct beam and circumsolar diffuse radiation. The influence of the ridges had to be specifically evaluated for the atmospheric conditions present at the NTS for the evapotranspiration studies and the regional meteorology studies.

A section on characterizing infiltration was prepared by Flint (1989) for the GSA 1989 Field Trip Guidebook.

Drafts of four abstracts were prepared by USGS staff for presentation at the SSSA annual meeting, to be held October 15-20, 1989, in Las Vegas, Nevada. Klenke et al. (approved) discusses drilling methodology, with minimum disturbance, for the emplacement of small diameter access tubes in soil containing rock fragments; Kingery et al. (approved) discusses temperature effects on a hand-held neutron moisture meter; Richards et al. (approved) discusses the influence of scale on calculating sorptivity values from imbibition experiments on nonwelded tuff; and Flint et al. (approved) discusses the spatial variability of solar radiation in mountainous terrain.

Activity 8.3.1.2.2.1.3 - Evaluation of Artificial Infiltration. Steady-state and falling-head permeameter construction was completed. Testing of this equipment and determination of the hydraulic conductivities of the various sample holding screens is currently underway. The permeameter, which can be used for both soil and rock samples, was designed in support of the artificial infiltration program, but will also support the surface mapping program.

2.2.1.6 Study 8.3.1.2.2.2 - Water Movement Tracer Tests

Study Plan 8.3.1.2.2.2 was approved by the DOE and sent to the NRC in February 1989. NRC comments on the study plan have not been received to date.

Activity 8.3.1.2.2.2.1 - Chloride and Chlorine-36 Measurements. A suite of core samples has been analyzed for chlorine-36 at the University of Rochester's accelerator mass spectrometer. Samples from borehole USW UZ-1 and G-Tunnel indicate high values of chlorine-36 at depth. In G-Tunnel, there is

a visible fault near the sample collection points. The relationship between this fault and high chlorine-36 values will be investigated.

Norris (approved) presented an abstract on the use of chlorine isotope measurements to trace water movements at Yucca Mountain at the American Nuclear Society (ANS) topical meeting FOCUS '89: Nuclear Waste Isolation in the Unsaturated Zone, which was held in Las Vegas, Nevada, September 18-21, 1989.

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

Revisions to sections of this study plan on in situ pneumatic tests, water injection tests, and tracer tests in surface-based boreholes are underway in response to Project Office and DOE/HQ comments.

Activity 8.3.1.2.2.3.1 - Matrix Hydrologic Properties Testing. Eight core samples were selected and plans finalized for prototype testing of the core by the Institute of Gas Technology (IGT) laboratory in Chicago. Most of the core is from G-Tunnel at the NTS; the rest is from nonwelded units of Yucca Mountain. The core will be run through a series of tests to determine the best methods of handling core from the drill rig to the laboratory. Methods of processing core will also be examined.

The core from the nonwelded units has been processed for water content, porosity, and bulk density. These data are being combined with the neutron logs to determine a calibration equation to help evaluate water content changes in the formation over time. The welded core samples are currently being processed. Those data will also be used to determine an appropriate calibration equation for the neutron moisture meter.

Holmes and Narver (H&N) laboratory results from matrix hydrologic testing are currently being combined with data generated from USGS matrix hydrologic testing at the Hydrologic Research Facility laboratory.

Imbibition tests on core samples were completed. During the first part of the test, evaporation studies were made to determine how long core samples can be out of the Lexan liner before significant loss of water occurs. This information was presented at the Project Office's Sample Overview Committee meeting in May.

Imbibition tests were also conducted in the two dry-drilled boreholes in G-Tunnel. The experiment worked satisfactorily in the nonwelded tuff. However, water could not be supplied fast enough to the borehole in the welded tuff to measure imbibition; the fracture network in the welded tuff is too extensive. Initial results for nonwelded tuff indicate, however, that the rock surrounding the borehole imbibed water slower than air-dried rock core from the borehole. This is probably due to the increased degree of saturation of the rock around the borehole. An experiment to determine the dependence of imbibition on water content was conducted. A 2.4-inch core was undercored to 1 inch, and all experiments were repeated to determine the influence of the smaller scale test. These data are being compared to the data collected

during the field experiment in G-Tunnel. Scoping is underway for a professional paper to discuss the results.

Thermocouple psychrometry, using the Richards psychrometer, was performed on all cuttings obtained from the G-Tunnel wet- versus dry-drilling project to evaluate the use of this method for obtaining moisture content. Samples were obtained from holes WD-1, WD-2, DD-1, and DD-2. Water characteristic curves, using submersible pressurized outflow cells are being run in the laboratory. Imbibition methodology is currently being developed.

The NRC technical staff and DOE representatives were given a tour of the USGS Hydrologic Research Facility laboratory at Area 25 of the NTS in late July.

Three abstracts from the Yucca Mountain Project have been prepared for presentation at the SSSA annual meeting, to be held in Las Vegas, Nevada, in October. The abstracts discuss modeling infiltration from imbibition, the applicability of the van Genuchten equation for unsaturated flow, and methods for determination of water characteristic curves. Abstracts for these papers will be published in the SSSA proceedings.

Activity 8.3.1.2.2.3.2 - Site Vertical Borehole Studies. Progress in borehole instrumentation and data acquisition during the reporting period included installation of the prototype instrument package in test hole USW UZ-4, wiring of sensors and solenoids, and testing of the primary and backup power-supply systems at both USW UZ-4 and the long-term archiving site, USW UZ-1. Also at both sites, electronically-keyed entry systems were installed and tested, and a nearly complete complement of software was installed in the computers and partly debugged. Additional work included design of the next prototype shelter and resolution of IDS problems with synchronous communications.

Martin Marietta Data Systems (MMDS) completed final testing of Phase I IDS software, and coding and debugging of most Phase II software. MMDS also transferred IDS source code and documentation to the USGS.

Other calibration and instrument-testing work included development of a calibration equation for the Druck PDCR 930 pressure transducers that contains total error to within ± 0.0005 lb/in^2; near-completion of the first thermocouple psychrometer calibration apparatus to be used in the laboratory facility at the USGS Hydrologic Research Facility at the NTS; and initiation of tests to evaluate the effects of long electrical lead wires on performance of superstable thermistors. A presentation on the results of laboratory thermocouple psychrometer calibration and G-Tunnel underground facility field applications was made by the USGS at the April ESF Testing Committee meeting, held in Pleasanton, California.

During the NRC staff visit at the NTS during the week of July 24, USGS staff made presentations on the IDS, instrument shelter design, prototype drillhole instrumentation program, laboratory calibration facility, and pressure-transducer calibration program. Reports by Kume and Rousseau (1989) and Rousseau (1989) document the status of investigations to characterize percolation by means of vertical boreholes.

During the reporting period, significant progress was made in modeling and data processing software for vertical seismic profiling (VSP). Progress was made with the program to image reflecting and diffracting surfaces in a variable-velocity medium using reverse time migration. The problem of errors in calculating travel time from the source to every point in the medium has been solved by modifying the program to eliminate refraction. A sample data set was prepared to test the migration program, but the sampling interval was inadequate (as is the case for most actual data sets), so an interpolation process was designed to resample the data. The modified imaging package was tested on the sample data set with results that were only partially satisfactory. It was observed that some reflections or diffractions from the synthetic model arrive at times close to first arrivals, tending to "smear" the image. The imaging program is being redesigned to remove these events, which should produce sharper images. The imaging package has also been supplied with a new forward travel time module. The module calculates travel time from an arbitrarily located source to any point in the medium, and eliminates head wave travel paths from consideration.

To demonstrate the VSP migration algorithm and programs, a simple physical model was created, consisting of a rectangle with a tunnel placed near the center. Synthetic and laboratory data were generated using a simple common-source gather configuration, and imaged using the migration program. Images of the tunnel and the boundaries of the model are clearly visible and in the correct position. Artifacts in the image were produced by interference believed to result from direct and reflected shear waves, and P-S mode conversion. These artifacts can be suppressed by preprocessing, and should also be attenuated when as many as 30 to 60 source points are considered together.

Examination continued of additional multichannel filtering schemes to separate compressional and shear waves. Multi-component VSP and cross-hole data sets are being acquired with physical models to test mode separation algorithms. Two approaches to separation are being used: (1) multichannel velocity filtering and data rotation; and (2) multichannel velocity filtering, eigenmatrix analysis, and subsequent data rotation. Only the first approach has been applied to the data thus far, with acceptable results. The second approach, which is more theoretically rigorous, may produce better results.

Program documentation and users' guides for the VSP migration program are currently in development.

2.2.1.8 Study 8.3.1.2.2.4 - Characterization of Percolation in the Unsaturated Zone -- Exploratory Shaft Facility Study

Study Plan 8.3.1.2.2.4 was submitted to the NRC for review in February 1989. NRC comments on the study plan have not been received to date.

Activity 8.3.1.2.2.4.1 - Intact-Fracture Test in the Exploratory Shaft Facility. In preparation for prototype testing, work continued on (1) instrumentation/equipment procurement, (2) resistivity experimentation on nonwelded core samples, (3) construction of the ventilation duct and hood for the exhaust system, (4) drilling the oven and mounting hardware to outfit the oven for the vacuum phase, (5) design of the Woods metal small chamber for

prototype testing of core, and (6) design of the frame for the vacuum chamber and pump cart.

Initial testing of G-Tunnel prototype equipment was completed. Axial sampling in welded and nonwelded tuff was attempted in the tunnel. Preparation continued for the Prototype Sampling Methods test to be conducted in G-Tunnel. The weeks of July 17 and July 23 were spent working on methods to retrieve radial fractures from the Grouse Canyon member of the Belted Range tuff, and resulted in the first successful nonwelded radial fracture sampling in G-Tunnel. A wedge tool was used to break the core loose beyond the fractured area.

The design of the projection Moire setup was completed, and an additional list of the equipment required to implement the setup was prepared. The literature survey of projection Moire continued. Preliminary experimentation proceeded with well-defined geometrical objects, including a flat surface that can be tilted and a cube. The results are currently being analyzed and will help in better defining a standard to assess the sensitivity of the system. Images of the Moire fringes were digitized and stored in the computer.

Experimentation with various grating densities to assess the resolution limits of the current experimental Moire setup was also performed. The computer program that allows the evaluation of the sensitivity of the projection Moire system for different configurations was completed. Work also continued in defining and implementing a calibration target for the lower resolution levels.

Work in assisting the laboratory experimentation effort continued with (1) sealing samples and making pressure transducer mountings for the imbibition tests, (2) making jigs for testing conductivity of different solutions during resistivity experiments, and (3) coring the coranite slab for the buoyant scale setup.

Activity 8.3.1.2.2.4.2 - Percolation Tests in the Exploratory Shaft Facility. Technical support was provided for the detailed design and implementation of laboratory tests for prototype percolation tests. Matrix properties and fracture flow experimentation continued. Activities included (1) running small-core imbibition and air-entrapment tests on nonwelded and welded core samples using gravimetric measurements; (2) design and fabrication for a new packer prototype for 1/2-inch holes that will accommodate tensiometers; (3) construction and testing of tensiometers; (4) plotting and analyzing data from fracture location tests and single-hole nitrogen injection tests on tuff sample blocks; (5) plotting and analyzing imbibition data on welded tuff samples; (6) installation of the drill frame for large sample block testing; (7) cutting new blocks for fracture testing; (8) reviewing draft papers on the subjects of imbibition, air entrapment, and air permeability analysis; (9) calculating the pressure drop through the packer system, and constructing the new packer systems; (10) drilling boreholes in a block for emplacement of tensiometers and psychrometers; and (11) setting up the ponding experiment.

Air permeability studies also continued. Activities associated with these studies include drilling and fracture location testing, drilling and

testing in tuff sample block E, and data analysis of single-hole and cross-hole tests conducted in tuff sample block D.

As part of drilling and fracture location testing of two boreholes in block D, (1) pressure transducers were wired and calibrated; (2) a series of steady-state, single-hole nitrogen injection tests at 5, 10, 15, and 20 psi pressures for boreholes 1 and 2 in block D were completed; (3) a series of steady-state cross-hole nitrogen injection tests at 800, 1,000, 3,000, and 5,000 sccm flow rates for borehole 1 in block D were completed; and (4) single-hole nitrogen injection test results were analyzed.

As part of drilling and testing in block E, one borehole was completed following the process of drilling and nitrogen injection testing at each 0.5-inch increment to locate the fracture. After the fracture was located, four constant pressure-variable flow tests were conducted at intervals of 5, 7, 10, and 12 psi pressure. Evaluations are continuing.

Fracture flow experiments in small tuff blocks continued. Related activities completed include (1) procuring additional equipment needed for the experiments; (2) design, construction, and testing of a new, improved tensiometer system; (3) setting up and running imbibition tests on nonsealed, nonwelded core and sealed, nonwelded core; and (4) setting up and running a ponding imbibition test in a nonwelded block, including the drilling of three boreholes, dam construction, assembly of mariotte reservoir, and calibration/insertion of thermocouple psychrometers in the boreholes to measure potential before and during wetting.

Activity 8.3.1.2.2.4.3 - Bulk-Permeability Test in the Exploratory Shaft Facility. Preparation for prototype testing continued. Related activities completed include (1) procurement of instrumentation/equipment, (2) detailed design of the packer injection manifold, (3) review of air permeability analysis techniques, and (4) design modifications to the packer system.

Activity 8.3.1.2.2.4.4 - Radial Borehole Tests in the Exploratory Shaft Facility. Work was completed on the straddle packer system, which was successfully implemented in the field near Superior, Arizona. The injection and monitoring strings were placed in separate holes, and saturated gas was injected into the formation at prescribed flow rates. Shut-in tests were performed with instrument readouts providing acceptable values. This work culminates 1-1/2 years of development.

Eight constant flow rate tests were performed, along with four shut-in tests. The air permeability testing tools, data acquisition system, gas saturation unit, and related accessories performed well. Regressions were performed on calibration data to define the relation between the output of pressure transducer (mV) and pressure (pascals). Data (pressure and time values) have been plotted for flow test No. 8 for subsequent type curve analysis.

A pressure transducer calibration manifold for simultaneous calibration of six Druck pressure transducers using one dead-weight tester has been built, and calibration is underway using the Cosa dead-weight tester and CR7 data logger.

Modifications have been completed to the computer program that determines the best estimates of permeability and wellbore storage using a nonlinear regression algorithm called the Levenberg-Marquardt method. The changes allow output of the correlation matrix, Eigen, values and singular values, and also provide confidence intervals and standard deviations for permeability and storage.

Drawings for the assembly of the packer string and fabrication drawings for interval pipes were completed.

Activity 8.3.1.2.2.4.5 - Excavation Effects Test in the Exploratory Shaft Facility. Revisions to a section of the Prototype Test Report Review that describes the blast effects/blast characterization investigation have been completed.

Activity 8.3.1.2.2.4.7 - Perched-Water Test in the Exploratory Shaft Facility. Layout of proposed prototype boreholes was begun at the G-Tunnel underground facility. Revision to some of the perched-water technical procedures for the prototype G-Tunnel work got underway.

In preparation for prototype testing in G-Tunnel, work continued on (1) instrumentation/equipment requisition, (2) calibration of pH/condensation/temperature probes, (3) plans for logging core during drilling of the prototype boreholes, (4) construction of packers and manifold systems for testing, (5) calibration of Sensotec and Microswitch pressure transducers, (6) construction of thermocouples and suction lysimeters, (7) plotting calibrations and preliminary data from borehole U12g-PW2, (8) drafting the schematic for the instrument systems, (9) monitoring instrumentation that is installed in borehole U12g-PW2 and downloading/plotting of data, and (10) reviewing options for pumping/injection test analyses. USGS site support was provided in drilling the borehole (U12g-PW3) in the Laser drift.

Prototype borehole drilling of four test holes in the G-Tunnel underground facility was completed. This is significant, because the boreholes will allow prototyping of the two types of instrumentation that will be used. Core samples for gravimetric water contents were collected and processed, packer and instrument string for borehole U12g-PW2 was installed, and collection of pressure and temperature data from two instrument stations began. Televideo and neutron moisture meter logs were run in the completed perched water boreholes U12g-PW3 and U12g-PW4 prior to emplacement of instrument systems. The results of these activities will be used to compare the two multiport packer/instrument systems being tested. Borehole U12g-PW4 is in the welded, fractured Grouse Canyon and will be used in the prototype perched water test. Preliminary compilation of drilling data and geologic descriptions for boreholes U12g-PW1, -PW2, -PW3, and -PW4 was also completed.

Tensiometer systems were constructed and pressure transducers were calibrated to monitor matric potential profiles in the vicinity of perched water zones.

Activity 8.3.1.2.2.4.8 - Hydrochemistry Tests in the Exploratory Shaft Facility. Fabrication of spare components for the one-dimensional compression cell continues. Assembly of the second pore-water extraction vessel was completed. Using the one-dimensional compression vessel, pore water was

successfully extracted from welded G-Tunnel tuff through a combination of compression to saturation and subsequent carrier-gas injection.

Dry coring and optimal rubble prototype test analysis continued. Thirteen rubble samples have been collected as a result of blasting in the alcove in G-Tunnel. Uniaxial compression testing of welded tuff also continued. Tests on four nonwelded tuffs and one welded tuff were conducted. Two of the nonwelded tuff tests are the first of a group of tests to investigate the effects of rubble coring on the chemistry of pore water. Nine uniaxial compression water samples were collected and sent to Rocky Mountain Analytical Laboratory for compression water analysis. A summary of compression methods testing was prepared by the USGS.

Work continued on literature research into bound water/crystal water properties of clay and zeolite minerals for application to interpretation of compression water analysis results.

The experimental series of boron adsorption on tuff was started, comparing reactions on conditioned versus non-conditioned tuff, with and without silica solution. A kinetic analysis was performed on silica data from an earlier tuff dissolution test. The sensitivity study continued on the MINEQA2 model, using literature values for boron adsorption on soil to compare modeled boron adsorption by amorphous iron oxide.

The second dissolution test continued on grounded tuff and deionized water; pH was initially adjusted to 10.0. Analysis of results from the second detailed dissolution test of G-Tunnel tuff continued, including determining the rate of dissolution. The analysis of initial data from the third detailed dissolution test of G-Tunnel tuff also began. The fourth detailed dissolution test of G-Tunnel tuff was completed. The information collected will help determine dissolution of the third type of tuff and allow examination of boron adsorption by the tuff at different preconditioned intervals.

Regression analysis of intrinsic constants used in the Constant Capacitance model continued to improve predictive ability.

An abstract on the applicability of simple and complex models of tracer absorption in water-rock systems (Lewis-Russ et al., approved) was completed and will be presented at the Association of Ground Water Scientists and Engineers annual meeting, to be held October 31 through November 1, 1989, in Houston, Texas. A proceedings paper will be published in Groundwater.

An abstract on compression methods testing (Mower and Higgins, approved) was presented at the ANS topical meeting, FOCUS '89: Nuclear Waste Isolation in the Unsaturated Zone, which was held in Las Vegas, Nevada, September 18-21, 1989.

Activity 8.3.1.2.2.4.9 - Multipurpose-Borehole Testing Near the Exploratory Shafts. During the reporting period, prerequisite reviews of documentation continued. Existing technical procedures for MPBH testing were reviewed, and additional technical procedures were identified for development.

The first phase of equipment development and testing at the prototype site near Tooele, Utah, was completed. This work is necessary to evaluate methods for dry drilling and dry coring.

2.2.1.9 Study 8.3.1.2.2.5 - Diffusion Tests in the Exploratory Shaft Facility

Development of Study Plan 8.3.1.2.2.5 was completed by LANL. The study plan was submitted for review on April 18, 1989.

Activity 8.3.1.2.2.5.1 - Diffusion Tests in the Exploratory Shaft Facility. Prototype diffusion tests in G-Tunnel are ongoing.

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

Study Plan 8.3.1.2.2.6 was revised to incorporate technical review comments and extensive changes from a USGS internal review. The revised document was submitted to the DOE for review on May 26.

2.2.1.11 Study 8.3.1.2.2.7 - Hydrochemical Characterization of the Unsaturated Zone

Study Plan 8.3.1.2.2.7 was revised to include sampling strategy and discussion of possible interpretations based on parameters measured in the hydrochemical analysis. The study plan is currently in review.

Activity 8.3.1.2.2.7.1 - Gaseous-Phase Chemical Investigations. Research was initiated on heat tape and O-ring-type tubing connectors. Work also began on the setup of an 8-inch-diameter simulated, vertical drillhole to be used in the laboratory.

Gas and water vapor sampling continued quarterly at test hole USW U2-1. Downhole packer systems are currently being built for future gas sampling at UZP-1 and two prototype holes.

Trautz and Weeks (1989) prepared a section on gaseous phase flow and transport for the GSA 1989 Field Trip Guidebook.

Activity 8.3.1.2.2.7.2 - Aqueous-Phase Chemical Investigations. The design of the packer inflation manifold and flow controller panel was completed.

Literature research into bound water/crystal water properties of clay and zeolite minerals was conducted for application to interpretation of compression water analysis results. A paper on the conceptual model of unsaturated-zone ground-water flow at Yucca Mountain based on geochemical-isotopic data was drafted. The paper is currently in internal review at the USGS.

2.2.1.12 Study 8.3.1.2.2.8 - Fluid Flow in Unsaturated, Fractured Rock

Development of Study Plan 8.3.1.2.2.8 continued. Work on the study plan currently includes incorporation of generic changes and technical revisions to text, tables, and figures.

Activity 8.3.1.2.2.8.1 - Development of Conceptual and Numerical Models of Fluid Flow in Unsaturated, Fractured Rock. The status of work on unsaturated zone hydrology was reviewed at a meeting at the USGS-Denver on June 12. It was decided to summarize the current status of the work on the fault model and to stop any further work during this fiscal year.

A review was made of the hydrologic literature on transport modeling in dual-porosity media with the intent of adapting an existing finite element code to handle this phenomena.

An LBL report on air compression effects during infiltration into enclosed unsaturated media is currently in internal review at the USGS. A paper by LBL staff pertaining to an approximate solution for one-dimensional absorption in unsaturated porous media (Zimmerman and Bodvarsson, 1989) was published.

The program for evaluating film flow over fault surfaces is being modified because of convergence problems. Preliminary analytical models for channel flow in faults are being developed.

A paper on absorption of water into finite-size blocks was reviewed internally at LBL, and sent to the USGS for review. The main result of the study was a scaling law for prediction of absorption into blocks of irregular shapes. Some further study of shape effect will be conducted on nonconvex blocks. Different closed-form fractal representations for the surface roughness are being numerically simulated, the goal being the simulation of isotropic surfaces. Work on the effect of airflow on imbibition is continuing with calculations of air flow effect on water absorption using the characteristic curves for Yucca Mountain.

A paper on the effect of the asperities on fracture permeability (Kumar et al., 1989) was completed by LBL staff, reviewed internally, and submitted to Physics of Fluids. It was found that asperities cause an appreciable reduction in permeability below the parallel plate value. A preliminary draft of the current status of the fault model has been written by LBL staff.

2.2.1.13 Study 8.3.1.2.2.9 - Site Unsaturated-Zone Modeling and Synthesis

Development of Study Plan 8.3.1.2.2.9 continued. Work currently includes incorporation of generic changes and technical revisions to text, tables, and figures.

Activity 8.3.1.2.2.9.1 - Conceptualization of the Unsaturated-Zone Hydrologic System. A Performance Assessment/Technical Integration Group (PA/TIG) meeting was held on July 26-27 in Las Vegas, Nevada. A primary focus of the meeting was the development of performance assessment test case

problems dealing with ground-water travel time for examination over the next year.

Numerical simulations were run to test the scaling law for absorption into irregular blocks, using a block with a partially penetrating fracture of varying length. A stochastic analysis of spatial variability and spatial correlation of unsaturated flow through fractured rock was initiated by USGS staff.

Two abstracts were submitted to the DOE for approval for presentation at the first International Radioactive Waste Conference, to be held in Las Vegas, Nevada, in April 1990. The abstracts are reviews of work on fracture-matrix flow interactions and fractal analysis of rough surfaces and flow of fluid over them.

A paper on fractal analysis of fracture roughness and aperture distribution was written and is being reviewed internally at the USGS.

D. Hoxie (approved) presented a talk on the development of numerical hydrogeologic models related to siting of a high-level nuclear waste repository at the Transportation Issues Management System/Operations Research Society of America Joint National Meeting in Las Vegas, Nevada, on May 7-9, 1989.

Activity 8.3.1.2.2.9.2 - Selection, Development, and Testing of Hydrologic Modeling Computer Codes. USGS staff participated in a Validation Oversight Group (VOG) meeting held in Las Vegas, Nevada, on July 25. The primary purpose of the meeting was to resolve available VOG review comments on the draft "Model Validation Methodology" document. This document pertains to the validation of numerical models used in performance assessment analyses. A final draft version of the document was submitted in September for formal review.

Incorporation of source/sink terms in the two-phase flow code, TOUGH, is proceeding.

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

Study Plan 8.3.1.2.3.1, Activity 7, was submitted for review on May 2, 1989. A revision of the study plan has been completed, and it was resubmitted to the Project Office in August.

Study Plan 8.3.1.2.3.1, Activities 1-6, was submitted for review on June 20, 1989.

Activity 8.3.1.2.3.1.2 - Site Potentiometric-Level Evaluation. Monitoring of water levels continued. Transducers were replaced and calibrated as necessary. All periodic water-level measurements and instrument calibrations were brought up to date. A USGS report on water levels in periodically measured wells at Yucca Mountain was completed and is being revised following internal review.

Automated first-level filtering of all transducer output through 1988 was completed. Special manual filtering that still must be performed was documented. A systematic evaluation of transducer signals was completed through 1988 for all wells in the continuous water-level network to determine which periods of record were reliable. Evaluation of wells USW WT-2, -3, and -6 was completed in May. Evaluation of wells UE-25 WT #11, #13, #15, b#1, p#1, and USW G-3 was completed in June. The evaluations have been merged for four water table wells so the signal from these wells can be processed into water levels. Final processing will be lengthy, since there are more than 700,000 points in the data set.

The data collections platforms and data loggers at wells USW H-5 and G-3 have been programmed to reduce interference between the two data collection systems so prototype testing may begin.

Data on magnetic storms was collected to determine if the large-scale anomalies in the continuous water-level network might correlate with such storms. A prototype mechanical device to detect anomalous water-level rises was built. The device will be unaffected by electrical interference and will be tested in one or more wells in the continuous water-level network.

A dummy bridge circuit was placed on one tube of well USW H-5 in May. This circuit emulates a transducer/cable/data-logger system, but should not respond to water-level changes. No "spikes" were observed with this system in June, but the system did exhibit drift. The cause of the drift has not been determined. This system will be left in the well for at least several months, and another system will be installed in well USW H-3. The system also will be tested in the laboratory.

Progress was made in the deployment of satellite data collection platforms for the water-level network. Necessary electronics to monitor panel temperature were obtained and a barometric pressure transducer was added to the system. Preliminary tests indicated that the platform could read output from the depth-measuring transducer. A voltage divider still needs to be built to measure excitation voltage, and the program needs to be refined.

A wide area water-level anomaly that occurred in late March 1989 was identified. Work began to acquire lightning strike, barometric pressure, precipitation, and temperature data for this period and another period in 1988 to investigate possible causes of the apparently spurious data.

Barometric pressure data from Brown's Room in Devils Hole was acquired and analyzed for use in evaluating water-level fluctuations in the Paleozoic aquifer system. Results showed a time lag of barometric changes and rapid propagation of changes into the room.

A 1,000-foot well sounder was delivered for use in measuring water levels in a monitor well drilled by Bond Gold in the Funeral Mountains.

An abstract was completed regarding water levels measured in well PM-3 on Pahute Mesa and their implications for further delineating flow system boundaries between the Oasis Valley flow system and the Alkali Flat (Franklin Lake Playa)-Furnace Creek Ranch ground-water flow systems. The abstract was prepared for an upcoming AGU meeting.

A presentation on the site saturated-zone studies, with emphasis on the water-level network, was made to the NWTRB during its visit to the NTS on June 28 and to the NRC during its visit to the NTS on July 26.

Activity 8.3.1.2.3.1.3 - Analysis of Single- and Multiple-Well Hydraulic-Stress Tests. Work continued on development of a program that will allow computerized curve matching to analyze hydraulic and pneumatic stress tests. The driver program was completed and tested. More than 100 individual solutions eventually will be included in the system, which is being used to analyze previously conducted hydraulic-stress tests for the C-hole complex.

A first draft of a report documenting the preliminary hydrogeologic assessment of the C-hole complex was completed. The report presents geohydrologic data and a conceptual model for use in interpreting previously conducted hydraulic-stress and tracer tests. An internal USGS technical review of the report was completed and revisions are currently being made.

Analysis of the previously conducted C-hole intraborehole flow surveys was completed. This includes pumping and nonpumping tracejector and temperature surveys. Work began on preparation of an interpretative report to document the surveys.

Activity 8.3.1.2.3.1.4 - Multiple-Well Interference Testing. Instrumentation needs for conducting the planned hydraulic and tracer tests at the C-hole complex were reviewed. Preliminary design specifications for the multiple-packer system were completed in cooperation with the U.S. Bureau of Reclamation (USBR).

Three zones in wells UE-25c#2 and UE-25c#3 were equipped with electronic pressure transducers and data aquisition systems to begin collection of hourly water-level data. These data are needed to establish background hydraulic conditions and document high-frequency water level fluctuations prior to the conduct of additional hydraulic-stress tests in the C-holes.

Activity 8.3.1.2.3.1.5 - Testing of the C-Hole Sites with Conservative Tracers. Packer testing instrumentation needs for testing of C-hole sites were reviewed. A draft of a report documenting the preliminary hydrogeologic assessment of the C-hole complex was completed and reviewed internally at the USGS, and is currently in revision.

Activity 8.3.1.2.3.1.7 - Testing of the C-Hole Sites with Reactive Tracers. Major efforts have been made to complete detailed technical procedures referenced in the study plan for this activity. Work was completed on the characterization of lithium as a potential tracer for the proposed field tests.

Development and verification of the computer code FEHMN (Finite Element Heat-Mass) continued in cooperation with Activity 8.3.1.3.7.1.3. The code will be used for porous media continuum and dual porosity models.

2.2.1.15 Study 8.3.1.2.3.2 - Characterization of the Saturated-Zone Hydrochemistry

Development of Study Plan 8.3.1.2.3.2 continued. The study plan is currently undergoing revisions based on internal USGS comments.

Activity 8.3.1.2.3.2.1 - Assessment of Saturated-Zone Hydrochemical Data Availability and Needs. Between June 5 and 26, meetings were held in Canada and Sweden with technical investigators of the Canadian Atomic Energy Commission, Limited (AECL) and Swedish Nuclear Fuel Supply Company (SKB) repository programs. An examination of hydrochemical experimental and mobile-laboratory facilities was included to assist in development of the technical strategy for characterizing saturated-zone hydrochemistry at Yucca Mountain. A particular focus of the meetings was to initiate discussions pertinent to the possible application of the Swedish in situ hydrochemical-sensor system for studies at Yucca Mountain.

Planned acquisition and use of the Swedish downhole hydrochemical tool necessitates a demonstration of tool performance at temperatures and pressures anticipated at and in the vicinity of Yucca Mountain. For this reason, a joint Project-AECL proposal is being prepared for field testing of the instrument at the AECL Borehole Test Facility at Whiteshell, Canada. The work is proposed for inclusion within the DOE-AECL cooperative program.

In accordance with a DOE/SKB bilateral agreement on exchange of technical information, a draft of Study Plan 8.3.1.2.3.2 (Characterization of Saturated-Zone Hydrochemistry) was sent to the SKB for informal technical review.

A draft journal article, coauthored by USGS and Desert Research Institute (DRI) staff, which describes the Spring 1988 hydrochemical sampling of water-table wells at Yucca Mountain by the DRI, is in review at the USGS.

Preliminary design work was performed with respect to packer systems and equipment to be used for future hydrochemical sampling of the saturated zone.

A preliminary examination was begun of an extensive data base of comprehensive hydrochemical analyses of waters in southern Nevada compiled by the USGS Nevada District Office in Carson City.

A September USGS workshop was held on the potential applications of heavy radiogenic isotopes in geohydrologic investigations at Yucca Mountain. The workshop was attended by technical staff of the USGS, DOE, LANL, LBL, and AECL, and by scientists from several European scientific agencies.

Activity 8.3.1.2.3.2.3 - Regional Hydrochemical Characterization. Hydrochemical data collected and processed as part of ongoing and past Project activities were compiled. This compilation is part of a larger effort to consolidate Project data in compliance with QA requirements.

A description of the sample tracking system used for Project hydrochemical sampling was prepared and reviewed at the USGS.

Efforts are underway to coordinate the moving and preparation of the field/laboratory trailer for hydrochemical sampling in the Amargosa Desert. As part of the sampling effort, current mining company drilling and hydrochemical sampling opportunities were checked in Crater Flat, Beatty Wash, and the Amargosa Desert.

A manuscript prepared by the USGS on ground-water chemistry at selected sites in the Yucca Mountain area is currently in internal review.

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

Development of Study Plan 8.3.1.2.3.3 has been completed. The study plan is currently in internal review at the USGS.

Activity 8.3.1.2.3.3.2 - Development of Fracture Network Model. Efforts are underway to make the finite element flow and transport code, TRINET, run more efficiently. A conjugate gradient solver for symmetric matrices that saves the decomposition steps for later use was tested successfully in TRINET, and the time-dependent boundary condition option was incorporated. The TRINET user's manual continued to be revised as the code was modified.

As part of the effort in developing a fracture network model, LBL staff have been working on statistics to represent the variation over space of the conducting elements in the network model. They are also developing a volume fraction statistic, as well as researching some representations of connectivity in flow geometry.

A six-element borehole seismic receiver string was fabricated for use in an environment similar to that of the C-hole complex.

A parametric investigation of the fracture geometry in the saturated zone at the C-hole complex was outlined by LBL. In this study, the importance of fracture intersection on overall fluid flow will be investigated. Project participants concur that a fault is very likely intersecting the C-holes. A fault may explain some of the anomalous hydrologic behaviors observed in the past C-hole hydraulic tests.

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

Study Plan 8.3.1.3.1.1 is currently in development at LANL.

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

Study Plan 8.3.1.3.2.1 was revised by LANL, incorporating Project Office review comments, and was resubmitted to the Project Office on May 25, 1989. The study plan is awaiting final approval by DOE.

Activity 8.3.1.3.2.1.1 - Petrologic Stratigraphy of the Topopah Spring Member. Moore et al. (1989) published the results of an operator variance test for modal point counts of the Topopah Spring Member of the Paintbrush tuff. Independent point counts were made by two petrographers for samples representing the lower nonlithophysal zone, the lower lithophysal zone, the middle nonlithophysal zone, and the upper lithophysal zones of the Topopah Spring Member. The point counts included analysis of cryptocrystalline, spherulitic, and granophyric devitrification textures as well as phenocrysts. The results of the operator variance tests indicated that operator differences significantly affect the results of petrographic modal analysis of thin sections. However, the individual petrographers were able to reproduce point count results within random error.

The prototype test to develop procedures for collecting bulk-rock samples in the ES focused on laboratory studies of outcrop samples collected from the west face of Yucca Mountain. Matrix variability of the devitrified Topopah Spring Member was studied by a combination of petrographic, x-ray diffraction, x-ray fluorescence, and automated neutron activation analysis methods. Collection of textural, mineralogic, and chemical data was completed and the information submitted for statistical analysis of sample-size effects and vertical and lateral variability effects within the Topopah Spring Member. Upon completion of the statistical analyses, a report outlining a methodology for sampling the Topopah Spring Member in the ES will be prepared.

An abstract on the mineralogy-petrology studies and natural barriers at Yucca Mountain was presented by S. Bolivar (approved) at the ANS topical meeting FOCUS '89: Nuclear Waste Isolation in the Unsaturated Zone, which was held in Las Vegas, Nevada, September 18-21, 1989.

Activity 8.3.1.3.2.1.2 - Mineral Distributions Between the Host Rock and the Accessible Environment. Preliminary work began to identify trace minerals that could be important in retarding the movement of radionuclides, particularly actinides, in ground water. To characterize the minerals of high specific gravity in the Topopah Spring Member, a heavy liquid mineral separation was made. Constituents of the high-density fraction ($p > 2.77$) included biotite, hematite, allanite, and an isometric oxide (possibly maghemite). Additional studies of iron- and manganese-bearing trace minerals were made using image analysis of backscatter electron intensities generated by a scanning electron microscope.

Quantitative x-ray diffraction analyses of samples used for batch sorption experiments were published by Chipera and Bish (1989a). These analyses support the effort to understand how radionuclides will interact with tuff at Yucca Mountain.

Activity 8.3.1.3.2.1.3 - Fracture Mineralogy. Manganese-oxide minerals from fractures in the Crater Flat tuff in USW G-4 were studied using optical, scanning electron microscopic, electron microprobe, and x-ray powder diffraction methods to determine their distribution, mineralogy, and chemistry. A report describing this work is in review.

Work continued on the study of fractures in the Topopah Spring Member from drillholes USW G-1, G-2, and GU-3.

A report describing the occurrence and distribution of erionite at Yucca Mountain (Chipera and Bish, 1989b) was published.

The procedure on sample collection of muck from excavations in the ESF for mineralogy-petrology studies was prepared. This procedure describes the frequency, methods, and criteria to be used for sampling bulk-rock material removed during the excavation of the ESF. This procedure was based on past sampling experience at Yucca Mountain and applies to all mineralogy and petrology studies in the ESF.

2.2.2.3 Study 8.3.1.3.2.2 - History of Mineralogic and Geochemical Alteration at Yucca Mountain

Project Office and DOE/HQ comments on Study Plan 8.3.1.3.2.2 were received at LANL on May 25, 1989. A meeting to resolve these comments was held on May 31, 1989. The study plan is currently in revision based on the results of this meeting.

Activity 8.3.1.3.2.2.1 - History of Mineralogic and Geochemical Alteration. The origin or origins of authigenic mineral deposits and breccias along the Bow Ridge and other faults in the vicinity of Yucca Mountain have been studied as part of this activity. This work was part of a cooperative effort between the alteration history study at LANL and the hydrogenic deposit activity of the USGS. Samples from Trench 14 at the NTS have been analyzed by scanning electron microscope image analysis and by electron microprobe to determine the major modes of calcium, silicon, and magnesium elemental distributions resulting from authigenic mineral growth in the hydrogenic deposits. These three elements are most important because they are the major constituents in the only authigenic minerals (i.e., calcite, opal, and sepiolite) identified in abundance within Trench 14. Natural radiation dosimeters were placed in bedrock at Trench 14 and at Busted Butte as part of the electron spin resonance dating, which was begun in collaboration with a visiting scientist from Japan. The electron spin resonance dating technique is being used to determine the timing of secondary mineral alteration at these sites. Access to a third proposed site in the Calico Hills was denied because of a perceived threat to archaeological remains in the area.

Work was initiated to investigate radiometric dating of zeolites, clays, and authigenic feldspars at Yucca Mountain by the potassium/argon (K/Ar) method. A number of illite samples have already been dated by this technique. In this new study, dates will be compared with those from clays and illites from the same or equivalent samples when possible. The feasibility of dating authigenic minerals by $^{40}Ar/^{39}Ar$ techniques will also be examined.

Prototype tests to develop detailed procedures for collecting alteration history samples in the ES have been delayed due to land access problems.

Activity 8.3.1.3.2.2.2 - Smectite, Zeolite, Manganese Minerals, Glass Dehydration and Transformation. X-ray diffraction heating experiments were conducted with commercial samples of chabazite and heulandite as part of a study to characterize the thermal properties of these minerals. Enhanced data reduction was made possible by the use of Rietveld refinement techniques so

that the loss of water from particular structural sites during heating could be characterized.

2.2.2.4 Study 8.3.1.3.3.1 - Natural Analog of Hydrothermal Systems in Tuff

No progress was made in this study during the reporting period. This is an out-year study.

2.2.2.5 Study 8.3.1.3.3.2 - Kinetics and Thermodynamics of Mineral Evolution

Study Plan 8.3.1.3.3.2/3 (see Section 2.2.2.6) was submitted to DOE/HQ for review in March 1989. Review comments were received on June 1, 1989, and are being addressed at LANL.

Activity 8.3.1.3.3.2.1 - Kinetic Studies of Zeolite and Related Framework Silicates. Scoping studies of the kinetics of the cristobalite transforming to quartz reaction were conducted. It appeared that pressure greatly affects the rate of transformation; however, there was significant scatter in the data. Further experiments are needed before this issue can be resolved. Technical procedures have been written for this work.

Scheetz and Roy (1989) published the results of reactivity tests of tuff-bearing concrete as part of the investigation of the effects of concrete grouts on water chemistry.

2.2.2.6 Study 8.3.1.3.3.3 - Conceptual Model of Mineral Evolution

See Section 2.2.2.5 for study plan status.

Work was completed on the smectite to illite transition, and the report has been written and submitted for review. The transformation of smectite to illite may be a largely equilibrium process, or it may be kinetically controlled. This report examined the effects of temperature, activity of aqueous silica, and activity of water on possible intermediate illite/smectite (I/S) compositions. The ordering phenomenon in intermediate I/S compositions was discussed.

2.2.2.7 Study 8.3.1.3.4.1 - Batch Sorption Studies

During the reporting period, Study Plan 8.3.1.3.4.1/3 (see Section 2.2.2.9) underwent Project Office and DOE/HQ review. Scheduling for a comment resolution meeting is pending.

Activity 8.3.1.3.4.1.1 - Batch Sorption Measurements as a Function of Solid Phase Compositions. Batch sorption experiments with neptunium, americium, and technetium on pure minerals were begun. The minerals used included synthetic and natural calcite, hematite, goethite, cryptomelane, romanechite, montmorillonite, and clinoptilolite. The initial experiments showed strong absorption of neptunium onto the iron and iron-manganese oxides and oxyhydroxides.

Activity 8.3.1.3.4.1.2 - Sorption as a Function of Sorbing Element Concentrations (Isotherms). A numerical method of regularization has been used to effect the deconvolution of isotherms obtained from the literature describing the exchange of Li^+, K^+, and Rb^+ into the synthetic faujasites NaX and NaY. This work was described by Triay and Rundberg (1989a). The obtained selectivity coefficient distributions fit the univalent isotherms used for deconvolution. The relative number of K^+ cations undergoing exchange with the obtained selectivity coefficients has been compared with published cation-site populations in K-X and K-Y, which are determined crystallographically.

Triay and Rundberg (1989b) also used this method of deconvolution to determine the site-specific selectivity coefficients for divalent and trivalent exchange in relatively rigid exchangers. The technique involved the measurement of ion-exchange isotherms and the application of the numerical approach of regularization to effect deconvolution. The method has been designed and extensively tested with computer-generated isotherms. The results of these numerical studies are being evaluated to determine if this approach can successfully recover selectivity coefficient distributions from divalent and trivalent isotherms. If a careful accounting of the exchanging cations is maintained, this method can be applied to systems undergoing ion exchange by different mechanisms.

Activity 8.3.1.3.4.1.3 - Sorption as a Function of Ground-Water Composition. A report was completed that discusses the sorption of nickel and neptunium in tuff using ground waters from wells J-13, UE-25p #1, and USW-H-3 (Knight and Lawrence, approved). The USW-H-3 and UE-25p #1 waters represented extremes in water composition found at Yucca Mountain, each showing higher cation concentration than well J-13 water. Sorption was least in the UE-25p #1 water, except for a devitrified sample, a finding consistent with previously reported results for strontium (Sr), cesium (Cs), and barium (Ba). The sorption for nickel on the zeolitized samples was much less than that exhibited by Sr and Ba.

Investigations of sorption as a function of water to rock ratios using Cs, Sr, Ba, and zeolitic tuff have been undertaken. Preliminary results indicate increasing sorption with increased water-to-rock ratios; however, the results appeared to be very sensitive to experimental procedure. Work continued to develop these experimental procedures.

Activity 8.3.1.3.4.1.5 - Statistical Analysis of Sorption Data. Statistical support of the sorption effort is described in Activity 8.3.1.3.7.1.2 as part of the 3-D transport calculation. Sorption data were related to a 3-D statistically produced mineralogic model of Yucca Mountain.

2.2.2.8 Study 8.3.1.3.4.2 - Biological Sorption and Transport

Screening review comments were incorporated into Study Plan 8.3.1.3.4.2 by LANL, and the study plan was submitted to DOE for review on June 15, 1989.

Two experiments were performed to determine the ability of siderophore to bind $^{59}Fe^{3+}$. Buffering systems and oxidizing agents were modified to enhance binding. Repetition of the experiments is required to confirm the initial

results. The experiments were performed as precursors to $^{239}Pu^{4+}$ binding experiments. Work continued on colloidal agglomeration of the microbiological byproducts.

2.2.2.9 Study 8.3.1.3.4.3 - Development of Sorption Models

No progress was made in this study during the reporting period. (See Section 2.2.2.7). Scheduling for a comment resolution meeting for the study plan is pending.

2.2.2.10 Study 8.3.1.3.5.1 - Dissolved Species Concentration Limits

During the reporting period, Study Plan 8.3.1.5.1 underwent internal technical review at LANL.

Activity 8.3.1.3.5.1.1 - Solubility Measurements. A summary progress report on the solubilities of neptunium (Np), plutonium (Pu), and americium (Am) in well J-13 ground water from Yucca Mountain at three temperatures (25°, 60°, and 90°C) and hydrogen ion concentrations (pH of 5.9, 6.0. and 8.5) was given by Nitsche et al. (1989) on work conducted from October 1, 1985, to September 30, 1987. The solubilities were studied from oversaturation. The neptunium solubility decreased with increasing temperature and with increasing pH. The soluble neptunium did not change oxidation state at steady state. Plutonium concentrations decreased with increasing temperature and showed no trend with pH. Pu(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. Steady-state concentrations for the 60°C americium experiments were not obtained within five months. The high specific alpha activity of the americium solution probably caused this problem. The americium supernatants did not change oxidation state.

Currently, a suite of experiments to determine the solubility concentration limits for Np, Pu, and Nd^{3+}/Am at 25°C in well UE-25p #1 ground water have been completed. Solution species of NpO^{2+} and NpO_2CO_3 at pH 7 and all NpO_2CO_3 at pH 8.5 were identified.

Activity 8.3.1.3.5.1.2 - Speciation Measurements. The integrated photoacoustic/photothermal deflection spectroscopy system was assembled and underwent testing. Tests were conducted using Nd^{3+} in several different aqueous solutions. Nd^{3+} was used because of its analogous chemistry to the actinides without the inherent problems associated with radioactive materials. Refinements to this system are planned.

2.2.2.11 Study 8.3.1.3.5.2 - Colloid Behavior

Activity 8.3.1.3.5.2.1 - Colloid Formation Characterization and Stability. A paper on the formation, characterization, and stability of plutonium (IV) colloid was presented by D. Morris (approved) at the ANS topical meeting FOCUS '89: Nuclear Waste Isolation in the Unsaturated Zone, held in Las Vegas, Nevada, September 18-21, 1989. Results were presented that provide further evidence that colloidal plutonium(IV) is structurally similar

to plutonium dioxide and that colloidal plutonium(IV) is electrochemically reactive. Voltametric studies of the redox reactivity of plutonium(IV) colloid were also discussed as part of the presentation.

2.2.2.12 Study 8.3.1.3.6.1 - Dynamic Transport Column Experiments

Study Plan 8.3.1.3.6.1 was completed by LANL and submitted to DOE for review on August 18, 1989.

Activity 8.3.1.3.6.1.1 - Crushed Tuff Column Experiments. Twenty-millimeter columns made of polycarbonate have been fabricated to study transport of radionuclides in crushed pure minerals, including synthetic calcite and hematite; natural cryptomelane; and purified clinoptilolite, calcite, and romanechite. The ability of polycarbonate columns loaded with these pure minerals to prevent leakage was studied.

Activity 8.3.1.3.6.1.5 - Filtration. The ability of Yucca Mountain tuff to act as a natural filter for particulate matter continues to be studied using Calico Hills and Topopah solid rock columns. Two columns each of Calico Hills tuff and Topopah tuff were used. The elution of 0.09-micrometer fluorescent colloids through the columns continued, and the amount of colloid eluting was analyzed using quantitative fluorometric analysis. A calibration curve using standards with known concentration of the 0.09-micrometer colloid was obtained.

The validation of the autocorrelation photon spectroscopy techniques for analyzing colloid size was completed. National Institute of Standards and Technology (NIST) standards were used.

Birdsell (approved) presented a paper on laboratory studies of radionuclide migration in tuff at the ANS topical meeting FOCUS '89: Nuclear Waste Isolation in the Unsaturated Zone, held in Las Vegas, Nevada, September 18-21, 1989.

2.2.2.13 Study 8.3.1.3.6.2 - Diffusion

Study Plan 8.3.1.3.6.2 was completed by LANL and submitted to DOE/HQ for review on August 18.

Activity 8.3.1.3.6.2.1 - Uptake of Radionuclides on Rock Beakers in a Saturated System. The study of the sorption of radionuclides as a function of time using beakers made of Yucca Mountain tuff is currently in progress.

2.2.2.14 Study 8.3.1.3.7.1 - Retardation Sensitivity Analysis

Comments from the Project Office review of Study Plan 8.3.1.3.7.1 were received at LANL on June 28, 1989. Comments from DOE/HQ have not yet been received. The study plan is currently in revision based on Project Office comments.

Activity 8.3.1.3.7.1.1 - Analysis of Physical/Chemical Processes Affecting Transport. Code development work was completed on computer codes FEHMN (Finite Element Heat-Mass) and FEHMSN (Finite Element Heat-Mass-Stress). For FEHMN, unsaturated zone flow and heat transfer capabilities were added and verified; a multiple tracer capability and a reactive tracer capability were added; a zoning capability that allows for irregularly shaped zones within the grid was added; and an adaptive solution strategy for multiple degree of freedom problems was developed. For FEHMSN, the fully coupled 2-D stress and mass transport module was implemented and compared with analytic solutions of hydraulic fracturing. A report on FEHMS, a finite heat-mass-stress code for coupled geologic processes (Zyvoloski and Kelkar, approved), was completed.

A 2-D version of the colloid transport code (CTCN) was developed, and most of the modules have been finished. The code was tested against solutions to problems with analytic solutions and against solutions obtained by similar codes.

Activity 8.3.1.3.7.1.2 - Geochemical/Geophysical Model of Yucca Mountain and Integrated Geochemical Transport Calculations. A set of preliminary 3-D forward calculations of the transport of technetium and cesium from the repository to below the water table was completed. The calculations were run with the radionuclide transport code, TRACRN, using a grid with 30,870 zones. Transport was studied at three recharge rates--0.1 mm/yr, 0.5 mm/yr, and 4.5 mm/yr. The effects of dispersivity length scale on the calculated results was also studied. The results were presented at the ANS topical meeting FOCUS '89.

An updated conceptual model of the site was developed to perform these calculations. The model includes a 3-D representation of the tilted stratigraphic beds, with offset along the Ghost Dance fault zone and spatially distributed sorption coefficients that are functions of mineral assemblage. Results from sensitivity studies based on this model will be used to guide the geochemical site characterization of Yucca Mountain. The model will be updated to integrate new data as they become available from the mineralogy/petrology work, sorption studies, radionuclide solubility studies, and ground-water chemistry studies.

Activity 8.3.1.3.7.1.3 - Transport Models and Related Support. A non-vertical gravity vector option was added to TRACRN. This option simplifies the grid set-up for systems with tilted beds or non-vertical boreholes. The report on TRACRN 1.0, a model of flow and transport in porous media for the Yucca Mountain Project (Travis and Birdsell, approved), was completed.

A double precision version of TRACRN was developed that will run on 32-bit machines. This version was tested and has become the baseline version of the code. A Cray version is now generated by transforming the baseline version with an editing file. The code was recently put under configuration management.

The verification plan was written for FEHMN, and many problems have been run. A verification structure was set up in FEHMN for comparing the numerical solutions with analytic solutions.

Verification of the method of lines code, which is the solution routine in CTCN, was implemented properly.

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

Study Plan 8.3.1.3.7.2 is currently in development.

2.2.2.16 Study 8.3.1.3.8.1 - Gaseous Radionuclide Transport Calculations and Measurements

No progress was made in this study during the reporting period. This is an out-year study.

2.2.3 Rock Characteristics (SCP Section 8.3.1.4)

2.2.3.1 Activity 8.3.1.4.1.1 - Development of an Integrated Drilling Program

No progress was made in this activity pending results of the prototype drilling program.

2.2.3.2 Activity 8.3.1.4.1.2 - Integration of Geophysical Activities

A paper on geophysical activities for the Yucca Mountain Project has been completed. The paper summarizes past geophysical work performed for the Project, and integrates and prioritizes new geophysical work to be conducted as part of site characterization. Currently, the paper is in revision.

A USGS field workshop was held at Yucca Mountain to discuss the potential applicability of various geophysical surveys (e.g., gravity, seismic reflection) and to help answer questions regarding the cause of the large hydraulic gradient at Yucca Mountain and other hydrologic issues.

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

Development of Study Plan 8.3.1.4.2.1 continued during the reporting period.

A base map has been prepared for use in Study Plan 8.3.1.4.2.1 (Vertical and Lateral Distribution of Stratigraphic Units), which is to provide the location of existing and planned drillhole sites.

Activity 8.3.1.4.2.1.1 - Surface and Subsurface Stratigraphic Studies of the Host Rock and Surrounding Units. A field trip was conducted at Yucca Mountain to orient Project personnel and support technical staff in the stratigraphic and structural characterization of Yucca Mountain. Staff attended a field seminar as part of the geophysical integration meeting held

in Mercury, Nevada, on May 17-19. Geophysical methods proposed to resolve geologic and hydrologic problems were discussed.

Muller and Spengler (approved) examined bulk porosity above the static water level in lithophysal zones calculated with borehole gravity and gamma-gamma density log data from drillholes in densely welded tuff at Yucca Mountain. A talk will be presented on this information at the Mineral and Geotechnical Logging section of the Society of Professional Well Log Analysts (SPWLA) meeting, to be held in Las Vegas October 2-4, 1989.

Project participants attended a meeting to coordinate surface geophysical studies with drillhole data and hydrologic studies. As a result, a revised list of core requirements was prepared at the request of the DOE.

A two-day field trip to Coyote Wash and nearby areas was conducted on June 7-8 with the TAR committee. The purpose of the trip was to field-check geologic mapping and trace contacts between zones in the Tiva Canyon Member of the Paintbrush tuff to ascertain whether a fault could be identified between proposed locations of ES-1 and ES-2. Results of the trip will be documented in a Review Record Memorandum currently in preparation by the TAR committee.

USGS staff discussed planned petrologic studies at Yucca Mountain with other Program investigators, including LANL, Michigan State, the Lunar Planetary Institute, and the University of Colorado at Boulder, and prepared a proposal for these studies to characterize the Paintbrush tuff.

Work continued on a paper that discusses the stratigraphic and structural framework for Yucca Mountain.

Responses were prepared to review comments on a report on the compilation of model analyses of volcanic rocks from the NTS area. In a related action, plots were made of whole rock geochemical properties for samples from drillholes USW-G1 and USW GU-3/GD-3.

Digitizing was completed on a map on lateral variations in the tuffs of the Calico Hills.

An abstract was completed on element mobility in Miocene tuffs at Yucca Mountain (Spengler and Peterman, approved). The abstract was prepared for a poster session to be presented at the International Conference on Chemistry and Migration Behavior of Actinides and Fission Products in the Geosphere, to be held in Monterey, California, November 6-10, 1989.

USGS staff attended a meeting with the NWTRB June 26-28 and led a portion of the field trip for the NWTRB to Yucca Mountain on June 28.

A USGS bulletin titled "Granitic Rock Masses in the State of Nevada" (Maldonado et al., 1989) was published.

Activity 8.3.1.4.2.1.2 - Surface-based Geophysical Surveys. The remote sensing and magnetic studies sections of a draft report on the geophysical activities to be conducted as part of site characterization were revised. The report is currently in revision by Project staff as part of Activity 8.3.1.4.1.2, Integration of Geophysical Activities.

USGS staff met to discuss the geology of the eastern Amargosa Desert in preparation for developing a manuscript that describes seismic reflection line AV-1.

Activity 8.3.1.4.2.1.3 - Borehole Geophysical Surveys. The Campbell Pacific Nuclear DR-501 neutron moisture and gamma density gauge was run in the NTS G-Tunnel wet- and dry-drilled boreholes. The information obtained on the rock properties will help to determine the usefulness of this combination tool for borehole geophysical logging at Yucca Mountain.

A short oral presentation on the status of Project well logs was given by P. Nelson, USGS, at the research logging session of the annual SPWLA meeting, held in Denver, Colorado, on June 11.

USGS staff met with NTS contractors and national laboratory staff to discuss density logs at the NTS and Yucca Mountain. Work continued on improving density log readings in air-filled boreholes.

A revised report summarizing information on geophysical logs and core measurements from 40 boreholes at Yucca Mountain is in review. The manuscript was revised to accommodate DOE comments resulting from an earlier review in June.

Activity 8.3.1.4.2.1.5 - Magnetic Properties and Stratigraphic Correlations. Interpretations of rock paleomagnetic data began for a report dealing with the magnetic properties of Tiva Canyon Tuff.

A paper on the paleomagnetic investigation of tertiary structural rotation at Yucca Mountain (Rosenbaum and Hudson, approved) was presented at the ANS topical meeting FOCUS '89: Nuclear Waste Isolation in the Unsaturated Zone, held in Las Vegas, Nevada, on September 18-21, 1989.

A manuscript for the Journal of Geophysical Research on the paleomagnetic constraints on the geometry and timing of deformation at Yucca Mountain was completed and is currently in internal review at the USGS.

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

Study Plan 8.3.1.4.2.2 was approved by the DOE and submitted to the NRC in February 1989.

Activity 8.3.1.4.2.2.2 - Surface-Fracture Network Studies. Modifications to a stereonet plotting program for fracture analysis were completed. Development of directional statistics for fracture studies continued. A report on the program that computes fractal dimension of lines or points is in review.

A report prepared by USGS staff on fractures in outcrops in the vicinity of drillhole USW G-4 has been completed. The report, by Barton et al. (1989), has been published as a USGS Open-File Report.

All activity-specific prerequisite requirements for the uncleared outcrop studies for this activity have been completed. A management review of the prerequisite package is tentatively scheduled for October.

Activity 8.3.1.4.2.2.3 - Borehole Evaluation of Faults and Fractures. A manuscript on fracture characteristics in core from drillhole USW G-4 was completed for publication in the open-file series. (See Activity 8.3.1.4.2.2.2.)

Activity 8.3.1.4.2.2.4 - Geologic Mapping of the Exploratory Shaft and Drifts. The ES mapping test fixture has been completed. The fixture, with the photogrammetry control targets in place, was photographed, and the photogrammetry laboratory has begun analyzing the templates. The photograph templates (stereophotograph strips printed on 8- by 10-inch film positives for use in the analytical plotter) will be used to test shaft photogrammetry procedures. A report on photogrammetric tunnel mapping is in preparation, as is one on geologic photogrammetry.

Modifications to the prototype shaft mapping platform were completed, and the platform has been reassembled at the Fran Ridge Test Pits in preparation for prototype shaft wall mapping. As-built drawings and design calculations for the platform were provided to the DOE. Work continued on calculating camera and target positions for ES mapping.

Generic bundle adjustment computations to determine the ideal "surveyed" control configuration for ES drift mapping were completed. Work continued on an article describing the ES drift control configuration experiment and recommendations. Work also continued on preparation of the technical procedure for drift mapping.

Work is continuing at the USGS on a report discussing a close-range photogrammetric technique for mapping neotectonic features in trenches, which will be submitted to the Bulletin of the American Association of Engineering Geologists.

Planning is underway for trench mapping prototype tests to be conducted at Yucca Mountain.

Activity 8.3.1.4.2.2.5 - Seismic Tomography/Vertical Seismic Profiling (VSP). Implementation of true vertical boundary capability by integrating the displacement discontinuity conditions into the 3-D anisotropy program continues. The anisotropy program was modified to allow this integration for all nine components of the seismic waves. Calculations were carried out to determine the effect of anisotropic boundaries on the displacement discontinuity regions. It was determined that the solution for a displacement discontinuity in a homogeneous medium could be used in the implementation of the displacement theory into an anisotropic background.

A report on the feasibility of VSP/cross-hole methods for fracture detection is in final revision and is expected to be submitted to the DOE for review during the next reporting period. Preparations are in progress for prototype fieldwork to be carried out at the USW G-4 site.

2.2.3.5 Study 8.3.1.4.2.3 - Three-Dimensional Geologic Model

No progress was made in this study during the reporting period. This is an out-year study.

2.2.3.6 Study 8.3.1.4.3.1 - Systematic Acquisition of Site-Specific Subsurface Information

Study Plan 8.3.1.4.3.1 is currently in internal review at Sandia National Laboratories (SNL).

Activity 8.3.1.4.3.1.1 - Systematic Drilling Program. A one-day workshop was held in Albuquerque, New Mexico, on July 27 to discuss the technical approach of the systematic drilling program. The workshop was attended by representatives of other, related site characterization studies and by representatives of design and performance assessment activities that will rely on data from integrated drilling activities.

A paper that discusses estimates of spatial correlation in volcanic tuff entered SNL peer review. This document supports drillhole and sample spacing concepts for the systematic drilling program.

2.2.3.7 Study 8.3.1.4.3.2 - Three-Dimensional Rock Characteristics Models

No progress was made in this study during the reporting period. This is an out-year study.

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

Development of Study Plan 8.3.1.5.1.1 continued during the reporting period.

2.2.4.2 Study 8.3.1.5.1.2 - Paleoclimate Study: Lake, Playa, Marsh Deposits

Planning is underway for development of Study Plan 8.3.1.5.1.2.

A 10-day scoping field trip was held in June to determine which paleolake, marsh, and playa deposits should be cored to obtain maximum data for paleoclimate and paleohydrology studies. Samples were collected in southern Nevada, California, northwestern Arizona, and southwestern Utah.

Activity 8.3.1.5.1.2.1 - Paleontologic Analysis. Following internal technical training on the preparation of Quaternary palynomorphs, USGS staff reorganized and began cataloging collections of modern botanical-type materials for paleontologic analysis.

Over 100 references pertaining to modern or fossil mollusks (terrestrial and aquatic) from southern Nevada were assembled. Modern biogeographic data

for taxa known to have lived in this region during the isotopic stage are currently being compiled to provide baseline data for paleohydrologic interpretations. Samples collected during the June scoping field trip, as well as ostracode taxa collected from springs in Arkansas, were prepared for analysis. Curation of samples examined during the past five years as part of the Project has been completed.

Investigations of modern ostracode taxonomy and distributions continued, as did the collection and identification of ostracode taxa from particular localities in the Menlo Park area on a time series basis. A time series basis examination will provide information on the influence of seasonality and temperature correlation to the abundance of ostracodes. Work is also continuing on the development and updating of data bases concerned with ostracode ecology.

A paper on ostracodes as a source of quantitative paleohydrologic and paleohydroenvironmental information (Gutentag et al., approved) was prepared for presentation at the 1989 AGU Fall meeting, to be held in San Francisco on December 4-8, 1989. The abstract will be published in the AGU publication EOS.

Efforts to improve the methods to be used in chryophyte cyst sample preparations continued.

A report (Bradbury et al., 1989) on late Quaternary paleolimnology of the Walker Lake, Nevada, has been published.

A bibliographic search was made on the ecology of modern charaphytes and an examination/evaluation of the paleoenvironmental potential of diatoms preserved in spring deposits was initiated.

2.2.4.3 Study 8.3.1.5.1.3 - Climatic Implications of Terrestrial Paleoecology

Work is continuing on the development of Study Plan 8.3.1.5.1.3. Work began on the bibliographic data bases in support of the climate program.

Activity 8.3.1.5.1.3.2 - Analysis of Pollen Samples. Work continued on the comparison of several different methods of palynological processing. Bibliographic investigations were conducted on palynological extraction methods not previously considered and on late Quaternary Pacific sea-surface temperatures.

Activity 8.3.1.5.1.3.3 - Determination of Vegetable-Climate Relationships. Collections of modern botanical-type materials were catalogued, and a bibliographic research was conducted on modern plant distributions. Development of a reference data base for soil/plant relationships and the hydrologic role of vegetation in central and southern Nevada was initiated.

2.2.4.4 Study 8.3.1.5.1.4 - Analysis of the Paleoenvironmental History of the Yucca Mountain Region

Development of Study Plan 8.3.1.5.1.4 continued during the reporting period.

Activity 8.3.1.5.1.4.1 - Modeling of Soil Properties in the Yucca Mountain Region. A draft report on the morphology and genesis of soils on the Kyle Canyon alluvial fan was completed by USGS staff and is in internal review. A proposal for completion of soil studies in the Yucca Mountain analog study areas, the Kawich and Stewart Creek drainage basins, was completed.

Two reports on development and morphology of Quaternary soils in the Yucca Mountain region were published (Reheis et al., 1989; Reheis, 1989).

Activity 8.3.1.5.1.4.2 - Surficial Deposits Mapping of the Yucca Mountain Area. Several workshops were held at the NTS on stratigraphy and mapping criteria for Quaternary surficial deposits in southern Nevada.

Activity 8.3.1.5.1.4.3 - Eolian History of the Yucca Mountain Region. Revisions of a manuscript being prepared on the use of immobile element geochemistry in the identification of eolian additions to soils were completed.

2.2.4.5 Study 8.3.1.5.1.5 - Paleoclimate-Paleoenvironmental Synthesis

No progress was made in the development of this study plan during the reporting period.

E. Taylor (1989) published a report on late Quaternary paleoclimate problems and geologic questions.

Activity 8.3.1.5.1.5.1 - Paleoclimate-Paleoenvironmental Synthesis. Evaluation began of alternative/additional sources of paleoclimatological information, including vertebrate faunas, acid-resistant algae, and Pacific sea-surface temperature estimates.

A paper on reconnaissance Delta 13-C and Delta 18-O data from Trench 14, Busted Butte, and drillhole G-4 at the NTS is being prepared by USGS staff for presentation at the International High-Level Radioactive Waste Management Conference in Las Vegas during April 1990.

2.2.4.6 Study 8.3.1.5.1.6 - Characterization of the Future Regional Climate and Environments

No progress was made in development of this study plan during the reporting period.

2.2.4.7 Study 8.3.1.5.2.1 - Characterization of the Quaternary Regional Hydrology

Study Plan 8.3.1.5.2.1 was approved by the DOE and submitted to the NRC in July 1989. Land access permits needed to start hydrogenic deposit studies and paleodischarge studies on BLM, NTS, and NPS land were obtained in July. These permits are for non-surface disturbing activities. The prerequisite packages for Activities 8.3.1.5.2.1.3 and 8.3.1.5.2.1.5 were prepared.

Activity 8.3.1.5.2.1.1 - Regional Paleoflood Evaluation. A USGS workshop was held in April and included classroom and field exercises at Bare Mountain, Crater Flat, and Yucca Mountain. The workshop focused on Quaternary geology field techniques and mapping.

Activity 8.3.1.5.2.1.3 - Evaluation of Past Discharge Areas. USGS staff served as field trip leaders during a July 24-28 briefing trip to Amargosa Valley, Death Valley, and Yucca Mountain for technical personnel from the Hydrologic Section of the NRC.

A reconnaissance trip was conducted in April by USGS staff to locate two possible discharge deposits south of Yucca Mountain, at the south end of Crater Flat. These areas were previously sampled by W. Carr and dated as being anomalously young with respect to their current position relative to the present ground-water table.

Ostracode data from samples collected in Kansas, Colorado, and New Mexico are being organized as a prototype test activity within paleohydrology. A report will be prepared that contains all physical and chemical data, ostracode occurrences, plates, and site descriptions. Modern and fossil locality data sheets were revised based on field experience to date.

Efforts to improve the methods to be used in chryophyte cyst sample preparations continued.

Project participants worked on creating a macrofossil data base for use with other paleoclimate indicators.

Work began on a report that summarizes applications of ostracode studies to hydrology.

Literature searches and modern mollusk biogeographic data are being organized to provide baseline data for paleohydrologic interpretations.

Activity 8.3.1.5.2.1.4 - Analog Recharge Studies. During the reporting period, USGS staff spent two weeks at the analog recharge sites collecting biologic and hydrologic data. USGS staff completed a reconnaissance of the Rattlesnake Ridge area along Rainier Mesa and located two areas for weather monitoring stations. This site will extend the range of climates being investigated by the analog recharge activity to a climate that is only slightly wetter than that existing at Yucca Mountain today. An environmental assessment is underway for the permits required for these two weather monitoring stations. Permits are pending for access to Nellis Air Force Base and the springs controlled by the USFWS in the Amargosa region.

The data collection systems at the analog recharge sites of Kawich Creek and Stewart Creek in central Nevada were serviced. Work continued on a new sample tracking system and software for the Leavesley precipitation-runoff model. Data analysis for chloride leaching experiments on tuff samples and for flume calibration data was begun.

Procurement of instruments and other equipment needed for the arid zone geochemistry activity has begun. Currently, work is underway to prepare an Environmental Impact Statement (EIS) for installation of an instrument tower at Organpipe Cactus National Monument, Arizona. Contract negotiations are underway with the New Mexico Institute of Mining and Technology for geochemical and soil surveys to be performed in the study area.

Design of experiments aimed at quantifying evapotranspiration losses from effective moisture was initiated. Soil samples from the analog recharge sites were prepared for grain-size distribution analysis, and data reduction was begun.

Work continued on the development of a computer program for an isotope diffusion model for light-stable isotopes in snow.

Activity 8.3.1.5.2.1.5 - Studies of Calcite and Opaline Silica Vein Deposits. Strontium isotope analyses and x-ray diffraction trace element analyses of carbonates and spring waters continued as part of scoping studies around Yucca Mountain.

DOE personnel and Project participants held discussions on the deepening of Trench 14 at the NTS. Tentative plans call for a small trench within the existing trench to avoid further surface disturbance and a fence around the east end of the existing trench as a safety precaution.

U-series analyses of calcite vein and soil K horizon carbonates from Trench 14 continued. Preliminary results indicate that the calcite veins may range in age from about 232 ka to greater than 350 ka. Experiments on the use of mass spectrometry for U-series dating continued. The development of a carbonate rock standard for U-series dating also continued.

USGS staff attended an American Society for Testing and Materials (ASTM) meeting in St. Louis, Missouri, and collected samples from springs in the Hot Springs, Arkansas, area. The hot springs in Arkansas are a possible analog for those in Nevada; the trip was used to test various collection methods that might be used for work to be conducted in Nevada.

Project participants continued to run standards for fission track dating. ^{205}Pb spike calibrations were run for future Pb isotope work.

Project review of a draft DOE report by J. Szymanski titled "Conceptual Considerations of the Yucca Mountain Groundwater System with Special Emphasis on the Adequacy of this System to Accommodate a High-Level Nuclear Waste Repository" was completed in July. The review includes a compilation of existing evidence pertaining to the origin of Ca-Si vein deposits at and near Yucca Mountain.

2.2.4.8 Study 8.3.1.5.2.2 - Characterization of the Future Regional Hydrology Due to Climate Changes

No progress was made in this study during the reporting period.

2.2.5 Erosion (SCP Section 8.3.1.6)

No progress was made in the Erosion Program during the reporting period.

2.2.6 Postclosure Tectonics (SCP Section 8.3.1.8)

On July 26, the Project Office released the technical review report, "Review of a Conceptual Model and Evidence for Tectonic Control of the Ground-Water System in the Vicinity of Yucca Mountain, Nevada." The report was compiled from the comments of 24 Project scientists on the November 1987 draft manuscript by J. S. Szymanski, entitled "Conceptual Considerations of the Death Valley Groundwater System with Special Emphasis on the Adequacy of this System to Accommodate the High-Level Nuclear Waste Repository." Both the manuscript and the review report encompass considerations of several studies and activities within SCP Investigation 8.3.1.8, Postclosure Tectonics. Reviewers concluded, though not unanimously, that (1) the tectonic processes and geomechanical models that Szymanski proposed dominantly influence the hydrologic system are described with insufficient rigor for testing or further analysis; (2) although stress and geothermal heterogeneities in the earth's shallow crust probably influence the hydrologic system, the scale and duration of their effects is greatly overstated in the manuscript; (3) the geologic and hydrologic field data claimed to support Szymanski's theory, particularly when supplemented by other available evidence, are more readily and consistently explained by traditionally accepted geologic and hydrologic processes; and (4) Szymanski's recommendations for testing his hypothesis lack valid diagnostic criteria. The review recommends some additions and modifications to existing plans that have not yet been fully evaluated for possible incorporation into the SCP and study plans.

Also on July 26, the Project Office released a final version of J. S. Szymanski's November 1987 manuscript, retitled "Conceptual Considerations of the Yucca Mountain Groundwater System with Special Emphasis on the Adequacy of this System to Accommodate a High-Level Nuclear Waste Repository," and announced plans for its review by the National Academy of Science and another independent peer panel. Efforts are currently underway to form these panels and define review criteria for the report.

2.2.6.1 Study 8.3.1.8.1.1 - Probability of a Volcanic Eruption Penetrating the Repository

DOE review of Study Plan 8.3.1.8.1.1 began on April 27, 1989.

It was proposed in the study plan review that the title of Study Plan 8.3.1.8.1.1 be changed to "The Probability of Magmatic Disruption of the Repository" to more properly reflect the scope of the study. However, the revised study plan has not received approval to effect such a change.

Activity 8.3.1.8.1.1.1 - Location and Timing of Volcanic Events and Activity 8.3.1.8.1.1.4 - Probability Calculations and Assessment. Crowe (approved) presented a talk on the estimation of rates of volcanic activity for probability calculations at the ANS topical meeting FOCUS '89, held in Las Vegas, Nevada, on September 18-21, 1989.

A paper titled "Volcanic Hazard Studies for the Yucca Mountain Project" by Crowe at al. (1989) was presented in May at the Waste Management '89 Symposium and published in the proceedings.

Activity 8.3.1.8.1.1.2 - Evaluation of the Structural Controls of Basaltic Volcanic Activity. Conjecture on the structural controls of basaltic volcanic activity were made during the paper presentation at the ANS topical meeting FOCUS '89. Work will continue to evaluate pertinent geophysical data.

2.2.6.2 Study 8.3.1.8.1.2 - Effects of a Volcanic Eruption Penetrating the Repository

Study Plan 8.3.1.8.1.2 is currently in development.

2.2.6.3 Study 8.3.1.8.2.1 - Analysis of Waste Package Rupture Due to Tectonic Processes and Events

Study Plan 8.3.1.8.2.1 is currently in development.

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

No progress was made in this study during the reporting period. This is an out-year study.

2.2.6.5 Study 8.3.1.8.3.2 - Analysis of the Effect of Tectonic Processes and Events on Changes in Water-Table Elevation

Study Plan 8.3.1.8.3.2 is in the planning stage.

Activity 8.3.1.8.3.2.3 - Assessment of the Effect of Strain Changes on Water-Table Elevations. Analysis of water-level data from Devils Hole continued based on the theoretical stress-strain relations for various fault orientations.

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

Study Plan 8.3.1.8.3.3 is currently in development.

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 was made in this study during the reporting period. This is an out-year study.

2.2.6.8 Study 8.3.1.8.5.1 - Characterization of Volcanic Features

Project Office and DOE/HQ review comments were received at LANL on June 9, 1989. A comment resolution meeting was held on July 11-12. The study plan is currently being revised.

Activity 8.3.1.8.5.1.2 - Geochronology Studies. Developmental work continues on the noble gas mass spectrometer system. System development is sufficiently complete to begin analysis of the first basalt samples. Mineral separation techniques are being optimized to separate course-fraction olivine grains to minimize loss of helium by diffusion. The first analytical runs for uranium (U)-thorium (Th) disequilibrium measurements of three samples from volcanic units of the Lathrop Wells volcanic center have been completed. The analyses were successful; however, the mineral separations for each sample did not have sufficient variance in U and Th contents to establish an isochron. Work continued in developing more efficient separation techniques using magnetic and heavy liquid separations.

Additional sampling of surface core from volcanic centers for paleomagnetic studies was completed. Sampling sites included Lathrop Wells center, Little Black Peak and Hidden Cone of the Sleeping Butte centers, and Red Cone and Black Cone of the 1.2 Ma volcanic centers.

Potassium-argon age determinations were completed for 11 sample sites in the Yucca Mountain region, including the 1.2 Ma volcanic centers of Crater Flat and the 3.7 Ma centers of southeast Crater Flat and Buckboard Mesa. The data were evaluated.

An addition to the geochronology studies was made: application of the thermoluminescence (TL) dating technique was evaluated for the Lathrop Wells and "A" Cone volcanic centers. The TL dating technique has been added to geochronology dating sections described in the study plan. The addition was considered minor and had the approval of the DOE review teams. Preliminary results appeared promising in applying the TL technique to dating material less than 40,000 years old.

Rock-varnish studies continued. The studies involve rock-varnish dating of geomorphic surfaces on and around Yucca Mountain (including alluvial fans, fluvial terraces, hillslope deposits, lava flows, and pediments) to determine the time of surface stabilization (since stable surfaces formed on lava flows) and to constrain the timing of geologic events that have formed, deformed, or modified these surfaces. Rock varnish studies support not only volcanism geochronology but also tectonic/neotectonic, erosion, and paleoclimate/paleoenvironment studies. Rock-varnish geochemistry studies to determine the chemical basis and processes operative in rock-varnish formation and in cation depletion within rock varnish through time continued.

Activity 8.3.1.8.5.1.3 - Field Geologic Studies. A possible new tephra-fall unit was recognized at the Lathrop Wells volcanic center. This unit was inferred to represent the youngest eruption from the center. Five samples from the Lathrop Wells volcanic center and three from the "A" Cone of the Cima volcanic center were collected for TL dating.

Field evaluation of rhyolite domes dated at 2.9 Ma was completed in the Mount Jackson area, located 100 km northwest of the Yucca Mountain site. These rhyolite domes represent the youngest silicic volcanism in the region. Sections of this activity have been modified from the planned work of the SCP to include an increased level of study of the distribution of Pliocene silicic volcanic centers in the Yucca Mountain region. This work is described in Study Plan 8.3.1.8.5.1, Characterization of Volcanic Features.

Activity 8.3.1.8.5.1.4 - Geochemistry of Scoria Sequences. Lava and scoria samples were collected from the Lathrop Wells and "A" Cone volcanic centers. The samples were crushed and submitted for major element chemical analysis; analysis has been completed for about half the samples.

Activity 8.3.1.8.5.1.5 - Geochemical Cycles of Basaltic Volcanic Fields. Study Plan 8.3.1.8.5.1, Characterization of Volcanic Features, describes plans for a more comprehensive evaluation of the evolution of basaltic volcanic fields of the southwest United States than that presented in the SCP. Revised plans include an evaluation of the time-space trends in vent locations, volume, effusion rate, and geochemistry.

It has been proposed in Study Plan 8.3.1.8.5.1 that the title of this activity be changed to "Evolutionary Patterns of Continental Basaltic Volcanic Fields." The study plan, however, has not yet received final approval.

2.2.6.9 Study 8.3.1.8.5.2 - Characterization of Igneous Intrusive Features

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. Efforts to acquire land access to log test holes USW G-4, G-3, and UE-25p#1 continued, as did activities related to calibration of logging instruments. A revised technical procedure on measurement of subsurface temperatures was submitted for internal approval.

2.2.6.10 Study 8.3.1.8.5.3 - Investigation of Folds in Miocene and Younger Rocks of the Region

No progress was made in this study during the reporting period.

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

No progress was made in this study during the reporting period. This is an out-year study.

2.2.7.2 Study 8.3.1.9.2.1 - Natural Resource Assessment of Yucca Mountain

Study Plan 8.3.1.9.2.1 is currently in development. Input from LANL was provided to the USGS for development of the study plan.

Activity 8.3.1.9.2.1.1 - Geochemical Assessment of Yucca Mountain in Relation to the Potential for Mineralization. Collection and examination of published data for geochemical studies continued.

Activity 8.3.1.9.2.1.2 - Geophysical/Geologic Appraisal of the Site Relative to Mineral Resources. Collection and examination of published data for geophysical and geological studies continued.

Activity 8.3.1.9.2.1.3 - Assessment of the Potential for Geothermal Energy at Yucca Mountain. Collection and examination of published data for geothermal studies continued.

Activity 8.3.1.9.2.1.4 - Assessment of Hydrocarbon Resources At and Near the Site. Collection and examination of published data for hydrocarbon studies continued.

Activity 8.3.1.9.2.1.5 - Mineral and Energy Assessment of the Site, Comparison to Known Mineralized Areas, and the Potential for Undiscovered Resources and Future Exploration. Discussions were held to review existing data and to determine further data required to prepare a report on resource assessment and resource potential in support of DOE's application to the BLM for land withdrawal.

The USGS geostatistical subactivity plan that is part of this activity was returned to the author for modification and reformatting.

2.2.7.3 Study 8.3.1.9.2.2 - Water Resource Assessment of Yucca Mountain

Development of Study Plan 8.3.1.9.2.2 continued during the reporting period.

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

No progress was made in this study during the reporting period. 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 was made in this study during the reporting period. 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

Meteorological monitoring at the NTS in support of site characterization is ongoing.

2.2.8.2 Study 8.3.1.12.1.2 - Plan for Synthesis of Yucca Mountain Project Meteorological Monitoring

A draft plan for the synthesis of meteorological monitoring data was prepared. The plan provides for coordination of meteorological monitoring efforts proposed during site characterization by various participating organizations.

2.2.8.3 Study 8.3.1.12.2.1 - Meteorological Data Collection at the Yucca Mountain Site

Activity 8.3.1.12.2.1.1 - Site Meteorological Monitoring Program. Drafts of the first, second, and third annual meteorological monitoring data reports have been prepared. The reports cover the period from December 1, 1985, through November 30, 1988.

2.2.8.4 Study 8.3.1.12.4.1 - Characterize the Potential Extreme Weather Phenomena and their Recurrence Intervals

Compilation of meteorological and climatological data from the NTS and other local and regional sources was initiated to quantify the extreme weather phenomena that may be expected at the Yucca Mountain site.

2.2.9 Offsite Installations and Operations (SCP Section 8.3.1.13)

2.2.9.1 Activity 8.3.1.13.1.1 - Identification of Near-Site Activities

A report that includes the characterization and identification of the preliminary impacts of air traffic in the Yucca Mountain area is currently in preparation. A study to identify other near-site activities (industrial-, transportation-, and military-related) is in the early planning stages.

2.2.9.2 Activity 8.3.1.13.1.3 - Characterization of All Nuclear Facilities Not Associated with the Nuclear Fuel Cycle near Yucca Mountain

The Radiological Monitoring Plan for the NNWSI Project (DOE, 1988d), issued in March 1988, is currently in the preliminary stages of being implemented. The implementing procedures for the program are either being revised to ensure consistency with the latest revision of the Project QAPP (DOE, 1989a), or in development. As part of this process, analytical methods are being identified or developed to evaluate the impacts of offsite nuclear facilities. This effort will include the documentation, verification, and validation of these analytical methods.

A limited amount of QA Level III radiological monitoring data has been collected to date. Data was reported in the 1987 Environmental Monitoring Program Summary (DOE, 1988e) and will be reported in the 1988 and 1989 Environmental Monitoring Program Summary reports.

The QAPP for the analytical laboratory (EPA/Las Vegas) that will be used to analyze samples collected as part of the radiological monitoring program is in the final stages of development.

2.2.10 Surface Characteristics (SCP Section 8.3.1.14)

2.2.10.1 Study 8.3.1.14.2.1 - Exploration Program

Development of Study Plan 8.3.1.14.2.1 was initiated.

2.2.10.2 Study 8.3.1.14.2.2 - Laboratory Tests and Material Property Measurements

No progress was made in this study during the reporting period. This is an out-year study.

2.2.10.3 Study 8.3.1.14.2.3 - Field Tests and Characterization Measurements

No progress was made in this study during the reporting period.

2.2.11 Thermal and Mechanical Rock Properties (SCP Section 8.3.1.15)

An SNL paper is currently being drafted on the application of models for jointed rock to the analysis of prototype testing. The paper will be submitted to the 31st U.S. Symposium on Rock Mechanics, to be held at the Colorado School of Mines on June 18-20, 1990. An SNL report on the estimates of rock mass deformability was submitted to the Project Office for review. The report outlines a method to estimate rock mass deformability using a combination of field measurements and finite element analyses.

Work supporting a Problem Definition Memo (a QA implementing instruction used to control analyses) titled "Analyses to Support Development of Slot Cutting Methods for ESF Thermomechanical Testing" was submitted for SNL peer

review. The set of analyses described evaluated the potential effect of slots cut by the chain saw on the experimental results obtained by the heated block, and potentially on other experiments using similar slot cutting methods. In addition, parametric studies were performed to determine the depth of slot necessary to ensure adequate measurement of stresses and displacements in the block. A nonlinear jointed rock mass model, along with thermal and mechanical loading, was used in these analyses. The results indicate that to get representative measurements of load versus deformation at a 1.0-meter depth in the block, the slots must be cut at least 2.5 meters deep, with the flatjacks applying load to the upper 2.0 meters. Slot depths beyond 3.0 meters resulted in only marginal changes in the results.

As part of the prototype activities conducted to support studies to examine spatial distribution of thermal and mechanical properties, a high pressure flatjack test was completed in G-Tunnel at the NTS. Flatjacks will be used in several ESF experiments. The experiment used displacement measuring instruments, and the results can be used to evaluate jointed block models as well as flatjack designs. A high pressure flatjack was placed in a 1-meter-deep slot cut in the rib of the demonstration drift. Linear variable displacement transducers, cable-actuated wire displacement gages, and sliding micrometers were installed across the slot at various gage lengths. Displacement measurements were also made across the drift to measure the "heave" of the rock on either side of the slot as the flatjack pressure was increased. Acoustic emission sensors were installed to monitor fracturing events within the rock as pressure was increased. Flatjack pressure was increased to 2,500 psi and cycled down to 0. Pressure was subsequently increased to about 4,500 psi, at which point a large piece of rock on the right side of the slot failed, exposing a portion of the flatjack. The part of the flatjack that was exposed inflated to about two inches, but did not fail. Pressure was reduced slowly to zero and the experiment concluded. The 4,500 psi pressure attained is the highest pressure achieved in any of the flatjack or pressurized slot tests to date.

The G-Tunnel Data Acquisition System (DAS) for prototype testing is nearly complete. The software for the G-Tunnel DAS is complete enough to allow data acquisition, although several of the algorithms must still be written.

A 1-meter-deep slot was cut in the rib of the demonstration drift in densely welded tuff in G-Tunnel. A new technique involving drilling a 4-foot horizontal, 8-inch diameter starter hole was employed to accomplish the cutting. The starter hole allows a uniform number of cutters under constant pressure to bear on the cutting surface. This is the first successful slot cut in the densely welded tuff using a hydraulic control system.

The new modular hydraulic chain saw, which will eventually be capable of cutting 1-meter- and 2-meter-deep slots, was set up at Building 851 in Area I at SNL. The saw is being operated to determine the effectiveness of the design and what alterations, if any, must be made. The design of the bar-chain interface must be evaluated to minimize friction between these two components. The problems encountered with the chain and bar of the new hydraulic modular chain saw may impact the conduct of the rock mass response experiment and other experiments in G-Tunnel.

A preliminary draft of a report evaluating the various instruments proposed for the ES geomechanics experiments has been completed by Science Applications International Corporation (SAIC).

A six-member Rock Mechanics Review Panel was organized by SNL to provide guidance on the Thermal and Mechanical Rock Properties Program. The panel met in Albuquerque, New Mexico, the week of June 5, 1989. Project staff working on the analytical and experimental portions of the program made presentations to the panel.

The high-pressure flatjack test frame delivered from Westinghouse/ Richland Operations was transferred to Area III at SNL, where high-pressure flatjack demonstrations are being planned. These demonstrations are necessary because the test frame allows much more controlled conditions than those in the field. To support this testing, a new operating procedure is being prepared to detail the potential safety concerns for high-pressure flatjack testing using this test frame.

SNL staff met with the Rock Mechanics Review Panel in Mercury, Nevada, in August, to tour G-Tunnel and the Yucca Mountain area, consider the design methodology for constructing stable openings, and discuss the upcoming thermal stress experiment planned for G-Tunnel.

Evaluation of gages that measure stress in a transient, elevated temperature environment continued. Configuration work continued on the Sandia Data Acquisition and Reduction System (SANDARS), to be used in future G-Tunnel and ESF experiments. A preliminary draft of a document that describes the design of SANDARS was prepared.

Plans were developed and implemented to expand the G-Tunnel Underground Facility (GTUF) to make more space in welded tuff available for prototype testing. Two new drifts totaling about 150 feet in length are being mined. One drift will be dedicated to the prototype thermal stress test, and the other will be used in a vertically-oriented engineered barrier test.

Analyses of jointed-rock response in the vicinity of flatjacks placed in thin slots cut in the walls or floors of drifts were completed. This is discussed in Section 2.2.10.3.

2.2.11.1 Study 8.3.1.15.1.1 - Laboratory Thermal Properties

During the reporting period, Study Plan 8.3.1.15.1.1 was revised based on Project Office review comments and resubmitted to the Project Office on June 27, 1989. The study plan was submitted to DOE/HQ for review on May 3.

The technical procedure titled "Procedures for Laboratory Sample Bulk Chemical Determination" was issued as a controlled document.

Activity 8.3.1.15.1.1.1 - Density and Porosity Characterization. A report on physical properties data for tuffs from the unsaturated zone at Yucca Mountain (Schwartz, approved) was completed. The report documents all SNL-generated data for the density and porosity of tuffs in the unsaturated zone at Yucca Mountain.

Activity 8.3.1.15.1.1.2 - Volumetric Heat Capacity Characterization. A report on the calculation of heat capacities for tuffaceous units from the unsaturated zone at Yucca Mountain was completed and transmitted to the Project Office for review. This report documents the calculations used to estimate heat capacities in the absence of experimental values.

Activity 8.3.1.15.1.1.3 - Thermal Conductivity Characterization. A report on the thermal conductivity of seven thermal/mechanical units at Yucca Mountain was completed and submitted to the Project Office for review. This report documents the data analysis used to obtain some of the recommended Reference Information Base (RIB) values for thermal conductivity.

2.2.11.2 Study 8.3.1.15.1.2 - Laboratory Thermal Expansion Testing

A comment resolution meeting for Study Plan 8.3.1.15.1.2 was held August 1-2 in Washington, D.C. The study plan is currently in revision at SNL.

2.2.11.3 Study 8.3.1.15.1.3 - Laboratory Determination of Mechanical Properties of Intact Rock

Study Plan 8.3.1.15.1.3 is currently in revision based on QA and management concerns expressed from the DOE review.

A paper on the relevance of partial saturation to the mechanical properties of tuff (Nimick and Peters, 1989) was presented at the 30th U.S. Symposium on Rock Mechanics on June 19, 1989, in Morgantown, West Virginia. F. B. Nimick also made a presentation on the status of the laboratory testing program (thermal and mechanical rock properties) to the NWTRB on June 28, 1989. The presentation was part of three days of briefings held for the NWTRB at the Project Office.

Activity 8.3.1.15.1.3.1 - Compressive Mechanical Properties of Intact Rock at Baseline Experiment Conditions. A report on the tensile strength of Topopah Spring tuff was completed and submitted for SNL review. This report documents a comparison of two methods of determining tensile strength.

Activity 8.3.1.15.1.3.2 - Effects of Variable Environmental Conditions on Mechanical Properties. In preparation for low strain rate and creep experiments, several scoping experiments were completed and the appropriate technical procedures written.

2.2.11.4 Study 8.3.1.15.1.4 - Laboratory Determination of the Mechanical Properties of Fractures

Work continued on the development of Study Plan 8.3.1.15.1.4.

In preparation for characterization of natural fracture surfaces from Yucca Mountain, a laboratory profilometer was fabricated and is being tested.

A preliminary investigation of two techniques for studying the mechanical properties of fractures was initiated. The study compares the rotary shear and triaxial compression techniques.

Activity 8.3.1.15.1.4.1 - Mechanical Properties of Fractures at Baseline Experiment Conditions. In support of ESF Title II work, a working group of RIB values for soil properties and joint characteristics is being reviewed.

2.2.11.5 Study 8.3.1.15.1.5 - Excavation Investigations

Study Plan 8.3.1.15.1.5 was approved by the DOE and sent to the NRC in February. Comments on the study plan have not been received to date.

A report describing the pretest analyses supporting the three excavation investigation experiments for the ESF (Costin and Bauer, 1989) was published.

SNL management review of a report on MRS system studies for the repository was completed, and the document was submitted to the Project Office for review on April 28.

Activity 8.3.1.15.1.5.2 - Demonstration Breakout Rooms. Requirements for orientation and scheduling of the demonstration breakout rooms with respect to the rest of the ESF were refined.

Activity 8.3.1.15.1.5.3 - Sequential Drift Mining. Preliminary analyses of the G-Tunnel mining evaluations experiment at SNL (Johnson and Bauer, approved) were documented.

The results of thermal analysis as part of the first benchmark exercise for Project thermal and mechanical codes (Costin and Bauer, approved) were documented by SNL.

SNL reports on the documentation and verification of the shaft code, the documentation of the finite element heat transfer analysis program, and the joint empirical model completed technical review and were submitted for SNL management review.

2.2.11.6 Study 8.3.1.15.1.6 - In Situ Thermomechanical Properties

Revised and more detailed analyses of the three major thermal experiments in the ESF are being planned. These include the canister-scale heater experiment, the heated room experiment, and the thermal stress experiment. More analyses are required because the geometry and thermal loadings proposed for the experiments are different from those previously analyzed. The results of these analyses will be used to better define the experiment. The estimated zones of influence will provide a means of developing the proper standoff distance requirements for Appendix B of the ESF SDRD (DOE, 1989b) and assessing the ESF design with regard to test-to-test interference concerns.

Pretest analyses for three in situ thermomechanical experiments planned to be conducted in the ESF have been detailed in an SNL report by Bauer et al. (1989).

Activity 8.3.1.15.1.6.4 - Thermal Stress Measurements. Analyses in support of the prototype thermal stress test were performed to assess new designs for the experiment. New experiment configurations were discussed with the experiment designers and builders. These configurations were analyzed to provide optional locations for instrumentation. Once a final design is agreed upon, another series of analyses will be performed.

Measurements using ultrasonic equipment for rock mass characterization are being considered for incorporation into the thermal stress experiment.

A location off the EV-6 incline above the laser drift was identified for the drift to house the thermal stress experiment. The strata in this location afford the possibility of a 20-foot thick, structurally undisturbed block of welded tuff. Alternative approaches to mining the new drift were investigated. The procedure currently used for drift mining includes blasting combined with the use of an Alpine miner.

The initial meeting of the Rock Mechanics Review Panel, organized by SNL, was held in Albuquerque, New Mexico, the week of June 5, 1989. The panel urged that alternatives to the currently configured thermal stress test be considered. Their suggestions included scaling down the drift size to decrease the time required for results or placing heaters in the floor or rib. Project staff involved with the thermal stress experiment are in the process of assessing the panel's recommendations.

At the second meeting of the Rock Mechanics Review Panel, the rationale and layout for the prototype thermal stress test were discussed. A consensus was reached that it would be valuable for this test to be a thermal overdrive experiment above the roof of a drift, despite the considerable logistical difficulties.

Progress was made in mining the thermal stress drift. This work should be completed by mid-October. Details in procedures and equipment for data acquisition were worked out, and procurement of necessary equipment was started. Research into appropriate instruments for measuring stress changes continued. Investigations were also directed toward high-temperature grouts and a more efficient installation method for the insulation that must be held in place against the roof of the drift.

The SMF will receive approximately 150 feet of core from the multiple-point borehole extensometer (MPBX) instrumentation holes associated with the prototype thermal stress experiment. Arrangements for processing the core have been made.

2.2.11.7 Study 8.3.1.15.1.7 - In Situ Mechanical Properties

Activity 8.3.1.15.1.7.1 - Plate Loading Tests. The Rock Mechanics Review Panel recommended that the planned plate loading tests incorporate modifications based on experience that the European rock mechanics community has had with such tests. Standards of the International Society of Rock Mechanics and the American Society for Testing Materials for plate loading tests will be modified slightly to address the specific application and needs of the Project.

Activity 8.3.1.15.1.7.2 - Rock-Mass Strength Experiment. The experiment procedure for the rock mass response experiment was approved. This experiment will be conducted in G-Tunnel and is intended to provide information for a similar experiment that will be conducted in the ESF. A criteria letter that details the support requirements from NTS contractors was drafted. The support work includes joint surface profiling, drilling coreholes for comparative laboratory fracture testing, and drilling instrument holes. Preliminary work for instrument modification and design of a reaction frame for this experiment was started. Related work being performed in G-Tunnel includes flatjack construction and demonstration, and modification and demonstration of the modular hydraulic chain saw that will be needed to cut slots for this experiment. The DAS that will be used to support this and other experiemnts in G-Tunnel is nearly complete. The room that will house the DAS is also nearly complete.

2.2.11.8 Study 8.3.1.15.1.8 - In Situ Design Verification

Study Plan 8.3.1.15.1.8 has been completed and is currently in management review at SNL.

2.2.11.9 Study 8.3.1.15.2.1 - Characterization of the Site Ambient Stress Conditions

Study Plan 8.3.1.15.2.1 was approved by the DOE and sent to the NRC in February 1989. NRC comments on the study plan have not been received to date.

All work of the Problem Definition Memo (a QA implementing instruction used to control analyses) titled "In Situ Stress Analysis for the ESF" was completed. The analysis file was reviewed and subsequently closed. The results of the analysis were submitted to the RIB for use in ESF design.

Activity 8.3.1.15.2.1.2 - Overcore Stress Experiments in the Exploratory Shaft Facility. Prototype overcore stress testing was begun at G-Tunnel; two stress measurements were obtained. Several types of drill bits are being tested for efficiency and cost.

Work continued in excavating non-welded tuff in G-Tunnel. Drilling and loading of four designed blast charges was documented, and this information will be combined with vibration data to refine the prototype controlled blasting fieldwork planned for the summer of 1990.

Compressive testing of strain instrumented grout specimens from the USBR borehole pressure gauge construction was completed. The modulus of elasticity and Poisson's ratio will be used for comparison with the welded tuff values where the gages will be placed.

Compressive strength tests were performed on three 3-inch diameter by 6-inch high grout samples cast the previous week from the Bureau of Mines borehole pressure cell construction material. Core bit requirements for stress meter holes were reviewed.

Initial prototype field testing of the NQ size (3 inch) borehole dilatometer in G-Tunnel was successfully completed. Preliminary interpretation of the data indicates that the rock modulus measurements are sensitive to joints, faults, and probably differences in lithology.

Laboratory testing and calibration of the NQ size borehole dilatometer has been completed successfully. Electrical wiring of the cubical stress cell is nearly complete. When hydraulic connections have been made, anisotropy testing will begin on cubical samples from oriented cores of welded tuff. Drilling experience in G-Tunnel has indicated that water drilling is three to four times faster than air drilling, and bit life is much longer using water. Other testing confirmed that careful borehole TV camera surveys are superior to core analyses for identification of natural fractures.

As a result of prototype testing, several changes have been made in the standard overcore stress relief method that will increase the speed and success of measurements as well as reduce the costs of the stress measurement program in the ES.

2.2.11.10 Study 8.3.1.15.2.2 - Characterization of the Site Ambient Thermal Conditions

No progress was made in this study during the reporting period.

Activity 8.3.1.15.2.2.1 - Surface-Based Evaluation of Ambient Thermal Conditions. Activity concerned with instrument calibration continued. Technical procedures were reviewed in preparation for making additional measurements at test hole USW G-4. Planning for thermal measurement activities continued.

2.2.12 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

Study Plan 8.3.1.16.1.1 was submitted for review on May 9, 1989.

Activity 8.3.1.16.1.1.1 - Site Flood and Debris Hazards Studies. A written summary of the surface-water investigative program with an emphasis on flood studies at Coyote Wash for the ES was completed (Glancy, approved).

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

Study Plan 8.3.1.16.2.1 is currently in development.

2.2.12.3 Study 8.3.1.16.3.1 - Determination of the Preclosure Hydrologic Conditions of the Unsaturated Zone at Yucca Mountain

No progress was made in this study during the reporting period. This is an out-year study.

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

No progress was made in this study during the reporting period.

2.2.13.2 Study 8.3.1.17.2.1 - Faulting Potential at the Repository

No progress was made in this study during the reporting period.

2.2.13.3 Study 8.3.1.17.3.1 - Relevant Earthquake Sources

Development of Study Plan 8.3.1.17.3.1 began. Compilation of existing fault and seismicity map data for the NTS area continued.

Activity 8.3.1.17.3.1.1 - Identify Relevant Earthquake Sources and Activity 8.3.1.17.3.1.2 - Characterize 10,000-year Cumulative Slip Earthquakes for Relevant Seismogenic Sources. A paper on regional termination and segmentation of Quaternary fault belts in the Great Basin, Nevada and Utah (Thenhaus and Barnhard, 1989) was published.

2.2.13.4 Study 8.3.1.17.3.2 - Underground Nuclear Explosion Sources (UNEs)

A meeting was held at SNL on May 17-18, 1989, to review a draft of Study Plan 8.3.1.17.3.2 and portions of Study Plan 8.3.1.17.3.3 (Empirical Models for UNEs) prepared by SNL. These documents are being revised as a result of this meeting.

2.2.13.5 Study 8.3.1.17.3.3 - Ground Motion From Regional Earthquakes and Underground Nuclear Explosions (UNEs)

Development of Study Plan 8.3.1.17.3.3 continued. Work on the prototype stochastic model for strong ground motion also continued.

Seismic wave transmission modeling efforts continue to develop the capability of predicting amplitudes and acceleration from UNE events at Pahute Mesa.

A report on the ES seismic design basis (Subramanian, approved) was completed.

Review comments were received on a draft report on UNE seismic ray path studies, and work to address these comments has begun. The draft of a report

on the tunnel dynamics experiment was completed and is in internal review at SNL.

Ground motion data from UNEs Amarillo and Contact are currently being digitized. Work on the stochastic model for strong ground motion continued.

2.2.13.6 Study 8.3.1.17.3.4 - Effects of Local Site Geology on Surface and Subsurface Motions

Development of Study Plan 8.3.1.17.3.4 continued. An evaluation of UNE data to ascertain the effects of local site geology on attenuation also continued during the reporting period.

2.2.13.7 Study 8.3.1.17.3.5 - Ground Motion at the Site from Controlling Seismic Events

No progress was made in this study during the reporting period.

2.2.13.8 Study 8.3.1.17.3.6 - Probabilistic Seismic Hazards Analysis

Development of Study Plan 8.3.1.17.3.6 continued. Work also continued on the prototype stochastic model for strong ground motion.

2.2.13.9 Study 8.3.1.17.4.1 - Historical and Current Seismicity

Development of Study Plan 8.3.1.17.4.1 continued and is near completion.

Activity 8.3.1.17.4.1.1 - Compile Historical Earthquake Record. Data on smoked-paper seismograms from the Boulder City temporary array were analyzed.

Activity 8.3.1.17.4.1.2 - Monitor Current Seismicity. Operation of the Southern Great Basin seismographic network continued.

The automatic clock turn-on system for the SGE-III seismographs was successfully tested on June 27. The system adds significantly to the seismic (earthquake monitoring) capability of the Project and to the quality of the data that can be collected by the Project in support of site characterization.

2.2.13.10 Study 8.3.1.17.4.2 - Location and Recency of Faulting Near Prospective Surface Facilities

Study Plan 8.3.1.17.4.2 was approved by the DOE and submitted to the NRC on June 10, 1989. Comments on the study plan have not been received to date.

Activity 8.3.1.17.4.2.1 - Identify Appropriate Trench Locations in Midway Valley. Five potential sites for surface disturbance studies (possible trench and test pit locations) were selected; archaeological and environmental compliance reviews for those sites were completed.

The contract for geotechnical support of the Midway Valley study was awarded to Geomatrix Consultants of San Francisco, California. Many of the Geomatrix staff members involved in the Midway Valley study completed Yucca Mountain Project orientation, were trained in the applicable department operating procedures (DOPs) and the experiment procedure (EP), and participated in an orientation trip to Midway Valley at the NTS. Geomatrix staff also reviewed geologic references and will compile existing geologic data for the Midway Valley area in accordance with the procedures outlined in the EP.

Subcontractor staff visited the NTS and participated with the USGS in prototype testing for the photogrammetric technique used to log trenches. Results will be reviewed to evaluate the technique for the Midway Valley study.

The EP for this study was approved by SNL on May 15, 1989. An operations and safety plan, which will be included as an appendix to the EP, was approved by SNL effective April 5, 1989. This operations and safety plan is currently being reviewed by the Project Office. The EP must be approved 30 days before initiation of field work.

2.2.13.11 Study 8.3.1.17.4.3 - Quaternary Faulting within 100 Km of Yucca Mountain, including the Walker Lane

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. Interpretation of the geophysical setting of Yucca Mountain continued. Several newly published or preprinted manuscripts were consulted regarding the physical properties of crustal rocks that produce seismic reflections. In particular, there are clear cases where seismic reflections do not come from layer boundaries, but from metamorphic layering within deep rock bodies of a nearly uniform composition. The significance of these ideas relative to seismic data in the Yucca Mountain area was evaluated. A report documenting the results of a seismic reflection feasibility study is in review at the DOE.

USGS staff prepared for and participated in a technical planning meeting on May 17-19 in Mercury, Nevada, which included discussions on the results of geophysical investigations and plans for integration of future geophysical work at Yucca Mountain across the many studies calling for application of geophysical techniques. This meeting was held in preparation for a peer review of the seismic reflection method.

Seismic profiles in Crater Flat and over Yucca Mountain were reviewed in light of the proposal by USGS/Denver on May 17-19 that seismic reflection profiles be conducted in these areas. Aspects of the interpretations that were examined include the thickness of alluvial and other low-velocity deposits, thickness of volcanic cover, and distance of seismic energy propagation for different shot points used in 1985.

An abstract on the results of the seismic-refraction study of crustal structure in the southern Great Basin (Chang, approved) was completed for presentation at the AGU meeting to be held in San Francisco, California, on December 4-8, 1989.

Activity 8.3.1.17.4.3.2 - Evaluate Quaternary Faults within 100 Km of Yucca Mountain. A workshop was held in Mercury, Nevada, on May 17-19, 1989, on regional surficial geologic mapping and Quaternary stratigraphic nomenclature for arid regions.

A presentation was made on the applications of morphology and genesis of desert soils to Quaternary studies (Reheis, 1989) at the International Geological Congress meeting in Washington, D.C., in July 1989.

Following completion of a peer review, four 1:100,000 maps are currently in revision. These maps are for the following Quaternary faults and lineaments: Goldfield/Benton, Last Chance Range, Beatty, and Death Valley Junction. Air photos of Chloride Cliffs (southwest corner of the Beatty sheet) were studied for planning of field traverses.

Synthesis of data on Quaternary deposits for the Beatty 1:100,000 quadrangle and a revision of manuscript maps for the geologic map of the NTS continued.

A report (Reheis and Noller, 1989) on Quaternary faulting in the southern Walker Lane was published.

Activity 8.3.1.17.4.3.4 - Evaluate the Bare Mountain Fault Zone. USGS staff participated in a two-day field trip to Yucca Mountain to examine problems of Quaternary faulting on the Bare Mountain range front, where field evidence for and against late Quaternary faulting along the east base of Bare Mountain near Beatty, Nevada, was examined.

Activity 8.3.1.17.4.3.5 - Evaluate structural remains and characterize the Yucca Mountain region with respect to regional patterns of faults and fractures. Integration and concatenation of airborne synthetic-aperture radar flight strips over the Yucca Mountain region were carried out through cooperation with the National Mapping Division, USGS.

Using pre-existing data sets, map-controlled and optically corrected synthetic-aperture radar mosaics have been compiled as test products at 1:250,000 for the Death Valley, Goldfield, and Las Vegas quadrangles. Most of the Caliente quadrangle is also available in flight-strip format to avoid the positive terminal area in its southwestern part. High-gloss positive prints of these radar mosaics are sharp, clear, and well-suited for synoptic lineament or fracture-pattern analyses.

2.2.13.12 Study 8.3.1.17.4.4 - Quaternary Faulting Proximal to the Site within Northeast-Trending Fault Zones

No progress was made in this study during the reporting period.

2.2.13.13 Study 8.3.1.17.4.5 - Detachment Faults at or Proximal to Yucca Mountain

Development of Study Plan 8.3.1.17.4.5 continued and is near completion.

Activity 8.3.1.17.4.5.4 - Evaluate Postulated Detachment Faults in the Specter Range and Camp Desert Rock Areas. Work on the map and text of a report describing the Red Mountain detachment fault continued.

A report (Scott, 1989) on extensional detachment fault systems in southwestern Nevada was published.

Activity 8.3.1.17.4.5.5 - Evaluate the age of detachment faults using radiometric ages. Work continued on potassium-argon dating of samples from the northwest Spring Mountains and faulting in the Point of Rocks area.

2.2.13.14 Study 8.3.1.17.4.6 - Quaternary Faulting within the Site Area

During the reporting period, USGS staff participated in the comment resolution meeting for Study Plan 8.3.1.17.4.6 and began revising it based on review comments.

Activity 8.3.1.17.4.6.1 - Evaluate Quaternary Geology and Potential Quaternary Faults at Yucca Mountain. USGS staff attended workshops on southern Nevada surficial geology, and staked and flagged four potential trench sites near Yucca Mountain. A preliminary field examination of faults along the east side of Bare Mountain was also conducted.

Digitizing of existing fault data at Yucca Mountain and programming of translation software for trench mapping continued, as did fission track work on air fall tephra sediments.

Compilation of the geologic map for the Beatty 30- by 60-inch sheet continued.

Taylor et al. (1989) completed the explanation for the NTS field trip stop at Trench 14, which was published in the GSA Field Trip Guidebook for the St. Louis, Missouri, annual meeting.

A geologic map of the surficial deposits of the Topopah Spring quadrangle was published (Swadley and Hoover, 1989).

Activity 8.3.1.17.4.6.2 - Evaluate Age and Recurrence of Movement on Suspected and Known Quaternary Faults. Experiments on purifying desert carbonates for U-series dating were conducted. Work also continued on software for U-series and U-trend dating and background activity measurements of alpha detectors used for dating. A plan was generated by USGS staff to test the U-trend dating method in a climatic environment similar to that of Yucca Mountain (Cima volcanic field, California).

A new lead-205 standard was prepared and calibrated that will allow analysis of much smaller samples (especially water samples) for lead isotopes. Standards were run for fission track dating and stable isotope analyses.

USGS staff spent three days at the NTS with other Project Quaternary geologists discussing problems understanding the present stratigraphic framework for Yucca Mountain in a follow-through to comments on the Site

Characterization Plan/Consultation Draft (SCP/CD) provided by the State of Nevada.

2.2.13.15 Study 8.3.1.17.4.7 - Subsurface Geometry and Concealed Extensions of Quaternary Faults at Yucca Mountain

No progress was made in the development of this study plan during the reporting period.

Activity 8.3.1.17.4.7.2 - Detailed Gravity Survey of the Site Area. USGS staff participated in a technical workshop for integration of the Project's geophysical investigations, held in Mercury, Nevada, on May 17-19, 1989.

Work continued on isostatic gravity and aeromagnetic maps of the NTS and vicinity (scale 1:100,000) and the interpretative text to accompany the Las Vegas 1° to 2° gravity map. Data for about 300 gravity stations collected in the Timber Mountain area in 1979 have recently been incorporated into the gravity data files and the isostatic gravity map of the NTS.

Harris et al. (approved) summarized data contained in 15,355 gravity stations in the NTS and vicinity. Magnetic tape containing this data will be available from the Earth Resource Observatory System in Sioux Falls, South Dakota.

Activity 8.3.1.17.4.7.3 - Detailed Aeromagnetic Survey of the Site Area. A compilation of aeromagnetic data for the Beatty 1:100,000 quadrangle began.

A preliminary aeromagnetic map of the NTS and vicinity (Kirchoff-Stein et al., 1989) was published.

Saltus and Ponce (1989) published the Las Vegas sheet of the aeromagnetic map of Nevada.

Activity 8.3.1.17.4.7.4 - Detailed Ground Magnetic Survey of Specific Features within the Site Area. Work continued on interpretative text to accompany the Las Vegas 1° by 2° magnetic map.

Activity 8.3.1.17.4.7.5 - Evaluate Surface Geoelectric Methods and Plan Potential Applications of These Methods within the Site Area. Work continued on compilation of drillhole electric logs and surface geoelectric ground rigs for future comparison and for cataloging QA calibration documents for transmittal to the Local Records Center (LRC).

USGS staff tested Furgerson's (1982) one-dimensional, magnetotelluric interpretational composite section across the Walker Lane in the vicinity of Lathrop Wells. Staff used a two-dimensional interpretation approach that showed that the one-dimensional composite has a large-scale error in the vicinity of the Amargosa Desert and Syncline Ridge.

Progress continued on getting magnetotelluric calibration data ready to send to the USGS LRC. Evaluation of shallow geoelectric surveys on Yucca Mountain continued.

Development continued on alternate models for dipole-dipole resistivity in Coyote Wash that show the data are compatible with the geologic interpretation of conductive fault or fracture zone, or with more conductive lithological change in the Pah Canyon Member tuff and bounding beds.

Work performed by the TAR committee included evaluating the Dipole-Dipole Data 8 interpretation in the vicinity of the proposed ES, Coyote Wash, and Yucca Mountain. Original interpretation indicates that electrical contrast was inferred to be a fault (Smith and Ross, 1982). A meeting was held in Las Vegas on June 20 to discuss interpretations of the data. Analysis and modeling of this and related data are under consideration and will be contained in a report prepared by the TAR.

Activity 8.3.1.17.4.7.6 - Evaluate Methods to Detect Buried Faults Using Gamma-Ray Measurements, and Plan Potential Application of these Methods within the Site Area. The aerial gamma-ray radioactivity section of a draft report on the geophysical activities to be conducted as part of site characterization has been revised and expanded. The report is currently in preparation by Project Office staff as part of Activity 8.3.1.4.1.2 (Integration of Geophysical Activities).

Activity 8.3.1.17.4.7.7 - Evaluate Thermal Infrared Methods and Plan Potential Applications of these Methods within the Site Area. Compilation of existing Landsat multi-spectral scanner (MSS) digital tapes and limited feasibility testing of processed MSS digital mosaics (bands 4, 5, 7) was done for the following 2° quadrangles: Las Vegas, Caliente, Goldfield, and Death Valley. In addition, a concatenated mosaic has been prepared as a test product for all four quadrangles. Experimental image maps of color-infrared composites of the quadrangles were developed as feasibility test products.

2.2.13.16 Study 8.3.1.17.4.8 - Stress Field Within and Proximal to the Site Area

No progress was made in this study during the reporting period.

2.2.13.17 Study 8.3.1.17.4.9 - Tectonic Geomorphology of the Yucca Mountain Region

No progress was made in this study during the reporting period.

2.2.13.18 Study 8.3.1.17.4.10 - Geodetic Leveling

Development of Study Plan 8.3.1.17.4.10 continued during the reporting period.

2.2.13.19 Study 8.3.1.17.4.11 - Characterization of Regional Lateral Crustal Movement

Development of Study Plan 8.3.1.17.4.11 continued during the reporting period.

Activity 8.3.1.17.4.11.1 - Analyze Lateral Component of Crustal Movement Based on Historical Faulting, Seismicity, and Trilateration Surveys. USGS staff visited trenches in Ash Meadows to examine faults in a follow-through to comments on the SCP/CD by the State of Nevada.

2.2.13.20 Study 8.3.1.17.4.12 - Tectonic Models and Synthesis

Activity 8.3.1.17.4.12.1 - Evaluate Tectonic Processes and Tectonic Stability at the Site. USGS staff prepared and processed Fish Lake Valley tephra samples for background and program planning.

Revisions are currently being made to the manuscript for the geologic map of the NTS. Compilation of existing fault and seismicity map data for the NTS continued.

2.3 REPOSITORY DESIGN

The repository design program consists of the activities associated with designing both the surface and underground facilities of the proposed repository. These activities include the development of design criteria as well as design analyses. Status of the repository design program is provided in this section.

2.3.1 Configuration of Underground Facilities (Postclosure) (SCP Section 8.3.2.2)

2.3.1.1 Design Activity 1.11.1.1 - Compile a Comprehensive List of All Information Required from Site Characterization to Resolve this Issue

No progress was made in this design activity during the reporting period.

2.3.1.2 Design Activity 1.11.1.2 - Determine Adequacy of Existing Site Data

No progress was made in this design activity during the reporting period.

2.3.1.3 Design Activity 1.11.1.3 - Document Reference Three-Dimensional Thermal/Mechanical Stratigraphy of Yucca Mountain

No progress was made in this design activity during the reporting period.

2.3.1.4 Design Activity 1.11.1.4 - Preparation of Reference Properties for the Reference Information Base

No progress was made in this design activity during the reporting period.

2.3.1.5 Design Activity 1.11.2.1 - Compile Waste Package Information Needed for Repository Design

No progress was made in this design activity during the reporting period.

2.3.1.6 Design Activity 1.11.3.1 - Area Needed Determination

The Mine Ventilation Services (MVS) report on waste emplacement cooldown is undergoing revisions to reflect the specific initial conditions for the repository as noted in the Conceptual Design Report (SNL, 1987). Delays in finishing this work have been caused by the need to conform to QA procedures for generating basis documentation.

The report on the impact of fan reversibility was completed.

A table of design values for air velocities in the repository underground facilities and shafts was completed. This table will be submitted to the RIB as design information.

Documentation of the early work conducted on the impact of in situ moisture on the repository ventilation system was compiled into a letter report. A draft of this report is currently in review at SNL.

2.3.1.7 Design Activity 1.11.3.2 - Usable Area and Flexibility Evaluation

A draft report on alternative access methods to the proposed repository was completed and is currently in internal review at SNL.

Design alternative studies being prepared include alternatives for the location of the men-and-materials shaft, repository design for use of mechanical mining, and a plan for the modular development of the underground facility.

New coordinates with corresponding elevations were generated for all intersections in the repository. The new coordinate values and elevations are almost identical to the current data base.

A report discussing mined material handling at the prospective repository has been completed. Following SNL management approval, the report will be transmitted to the Project Office for review.

2.3.1.8 Design Activity 1.11.3.3 - Vertical and Horizontal Emplacement Orientation Decision

Reports on the statistical analyses of data related to decisions about the orientation of waste emplacement at Yucca Mountain and boring and lining horizontal emplacement holes were completed and submitted to the Project Office for review.

An SNL report on the waste package emplacement orientation recommendation has been completed and is in DOE review. An SNL report on the waste

emplacement borehole option study was completed and submitted in July to the Project Office for review.

2.3.1.9 Design Activity 1.11.4.1 - Chemical Changes Resulting from the Use of Construction Materials

No progress was made in this activity during the reporting period.

2.3.1.10 Design Activity 1.11.4.2 - Material Inventory Criteria

No progress was made in this activity during the reporting period.

2.3.1.11 Design Activity 1.11.4.3 - Water Management Criteria

No progress was made in this activity during the reporting period.

2.3.1.12 Design Activity 1.11.5.1 - Excavation Methods Criteria

Evaluation of proposed waste emplacement borehole drilling techniques continued. Currently, percussion drilling equipment is planned to be used; however, these systems emit a small amount of oil (used as lubricant) into the borehole. To date this has not been a problem, but, indications from waste package studies are that oil, even in trace quantities, cannot be tolerated in the repository. In addition to trying to quantify the amount of oil present, consideration is being given to supporting the development of a proposal for air turbine drilling equipment.

A design for demonstrating the applicability of mechanical mining for use in the repository was completed. This design will be reported in a letter report to be prepared.

The layout of the shafts and ramps for use with tunnel boring equipment was completed.

A presentation to SNL staff by personnel from Parsons, Brinckerhoff, Quade, & Douglas (PBQ&D) on tunnel boring machine (TBM) prototype tests at Fran Ridge and alternative repository emplacement drift layouts was made. This work is documented in several reports currently in development. TBMs could have a significant impact on the cost and quality of the mined repository.

2.3.1.13 Design Activity 1.11.5.2 - Long-Term Subsidence Control Strategy

No progress was made in this activity during the reporting period.

2.3.1.14 Design Activity 1.11.6.1 - Thermal Loading for Underground Facility

No progress was made in this activity during the reporting period.

2.3.1.15 Design Activity 1.11.6.2 - Borehole Spacing Strategy

A report on the preliminary examination of underground heat transfer in a Yucca Mountain repository and recommendations for thermal design approaches was completed and is currently in technical review.

In support of ESF Title II work, analyses to determine the predicted depth and extent of fracturing resulting from blasting for both the main pad and foreshaft are being planned. Current blast patterns are being reviewed in support of this analysis.

A report on the waste emplacement borehole option study was completed and submitted in July to the Project Office for review.

2.3.1.16 Design Activity 1.11.6.3 - Sensitivity Studies

No progress was made in this activity during the reporting period.

2.3.1.17 Design Activity 1.11.6.4 - Strategy for Containment Enhancement

Analyses to support this design activity are currently underway.

2.3.1.18 Design Activity 1.11.6.5 - Reference Calculations

No progress was made in this activity during the reporting period.

2.3.1.19 Design Activity 1.11.7.1 - Reference Postclosure Repository Design

No progress was made in this activity during the reporting period.

2.3.1.20 Design Activity 1.11.7.2 - Documentation of Compliance

No progress was made in this activity during the reporting period.

2.3.2 Repository Design Criteria for Radiological Safety (SCP Section 8.3.2.3)

No progress was made in the activities under Repository Design Criteria for Radiological Safety during the reporting period.

2.3.3 Nonradiological Health and Safety (SCP Section 8.3.2.4)

2.3.3.1 Design Activity, SCP Section 8.3.2.4.1.1 - Design Activity to Verify Access and Drift Usability

Work continued at SNL on documentation of the Problem Definition Memo (a QA implementing instruction used to control analyses) titled "Preliminary Benchmark Problem." A report is being prepared to document the results of the jointed mass model analyses. Meanwhile, participants are submitting analysis files for the work.

Four reports have completed technical review and are currently in management review at SNL. These reports cover (1) documentation and verification of the shaft code; (2) documentation of SPECTROM-41, a finite-element heat transfer analysis program; (3) the joint empirical model, an equivalent continuum model for jointed rock mass; and (4) the user's manual and guide for the boundary-element thermomechanical code (HEFF).

A report on SPECTROM-31, a finite-element computer program for the large deformation, static, and quasistatic response of planned and axisymmetric solids, continued in SNL peer review.

A report on SPECTROM 349, a three-dimensional linear superposition, heat-conduction computer program, also continued in SNL peer review.

A report on the documentation and verification of STRES30, Version 4.0, was completed and submitted for SNL peer review.

A report on an analysis of scenarios and potential radiological consequences for the Yucca Mountain repository associated with U.S. military aircraft crashes was submitted by Bechtel National, Inc. (BNI) to SNL for review.

A Problem Definition Memo titled "Scoping Studies to Investigate Two-Phase Flow Phenomena" was approved by SNL and submitted to RE/SPEC, Inc. for acceptance. This QA Level III task will investigate the phenomena of boiling heat transfer, two-phase flow, and capillary wicking in partially saturated porous tuff. Preliminary results are expected in October.

A Problem Definition Memo titled "A Preliminary Investigation of the Effects of Pore-Water Boiling, Temperature-Dependent Thermal Properties, and the Modeling of Air Spaces as Rock on Repository Heat-Transfer Calculations" was approved by SNL and submitted to RE/SPEC Inc. for acceptance. This QA Level III effort will investigate some of the common simplifying assumptions presently used in repository-scale thermal modeling. Preliminary results are expected in October.

A report on Part 2 of the first benchmark exercise for the Project thermal and mechanical codes, elastic rock mass analysis, was completed and entered into SNL management review. This report documents the results of the thermoelastic analyses performed during the second phase of the benchmark exercise. Part 3 of the exercise on jointed rock mass analysis was completed and submitted for SNL technical review. This is the last of three reports

documenting the results of the benchmarking exercise for the thermal and mechanical codes.

A report has been completed on computational models for jointed media with orthogonal sets of joints (Koteras, approved).

SNL technical review of a report on the constitutive model for jointed rock mass with two intersecting sets of joints was completed. The report is currently in SNL management review.

A report on the determination of equivalent thermal loadings as a function of waste age and burnup completed SNL management review and is being modified for submission to the Project Office.

A report on the location of the boiling isotherm and prediction of the water influx into a typical waste emplacement drift completed SNL management review.

A detailed outline was prepared by SNL staff for the preliminary design methodology for drift stability. The outline was submitted for SNL management review.

A Design Investigation Memo (a QA implementing instruction controlling an engineering design activity) titled "Repository Items Important to Safety" was initiated by BNI. This study will analyze repository systems and determine which, if any, are to be classified as "important to safety."

As part of testing to verify drift stability, simulated fractures will be made of refractory brick material to allow the length, geometry, and mechanical properties of the fractures and the mechanical properties of the matrix material to be controlled. These engineered materials will then be loaded through controlled stress and/or displacement paths and attendant deformations measured. The results provide a means to assess the mechanics, phenomena, and kinetics of the joint systems and thus provide a physical basis for understanding the constitutive behavior and the constitutive models applied to analyze the response. After development of procedures, refined methods will be applied to code validation.

2.3.3.2 Design Activity, SCP Section 8.3.2.4.1.2 - Design Activity to Verify Air Quality and Ventilation

No progress was made in this design activity during the reporting period.

2.3.4 Preclosure Design and Technical Feasibility (SCP Section 8.3.2.5)

As part of work being conducted under Information Need 4.4.7, Design Analyses, analyses to determine the predicted depth of fracturing resulting from blasting for both the main pad and foreshaft are being planned in support of ESF Title II work. Current blast patterns are being reviewed in support of this analysis.

As part of work being conducted under Information Need 4.4.10, Technology for Seals Emplacement, a comprehensive literature search on available sealing technologies was completed, and work was initiated on the evaluation of these technologies.

Other work to be conducted under this Issue is pending initiation of Title I design.

2.4 SEALS SYSTEM DESIGN

The seals system design program includes seals materials testing, design development, and design analyses. The DOE currently plans to seal all shafts, ramps, exploratory boreholes, and emplacement drifts for the permanent closure of the repository. Status of the seals program is provided in this section.

2.4.1 Shaft and Borehole Seals Characteristics (SCP Section 8.3.3.2)

2.4.1.1 Study 1.12.2.1 - Seal Material Properties Development

Work on Study Plan 8.3.3.2.2.1 will resume after the degradation model and ACD-related work are completed.

Activity 1.12.2.1.2 - Hydraulic Conductivity and Consolidation Testing of Crushed Tuff. Review of the interface concrete/grout study, the crushed tuff laboratory testing program, and the tuff concrete study for the ES were performed. The review included evaluation of the completeness of the data sheets and the results.

A draft technical procedure was prepared for consolidation and hydraulic conductivity testing of crushed tuff.

2.4.1.2 Design Activity 1.12.2.2 - A Degradation Model for Cementitious Materials Emplaced in a Tuffaceous Environment

An evaluation of the chemical compatibility of cementitious materials in a tuffaceous environment was completed using the geochemical modeling code EQ3/6. Interactions of either meteoric or ground water with four modeled cementitious materials in two tuff compositions at a range of temperatures were considered. The results show the dissolution and/or reaction of cement phases and changes in the ground-water chemistry. These changes in the ground-water chemistry further lead to the precipitation of materials either in the concrete or the surrounding tuff. These changes were examined along five specific water-flow paths which are representative of possible flow paths for water movement in shafts and boreholes. The results of these analyses provide specific amounts of precipitation and dissolution (per liter of ground water) on a phase-by-phase basis for each of the five flow paths. An objective of this work is to use these phase specific precipitation/ dissolution data to predict changes in the seal material porosity and, consequently, the seal permeability.

2.4.1.3 Study 1.12.2.3 - In Situ Testing of Seal Components

Initial concepts for in situ testing of sealing components were developed. These concepts included shaft seal testing, drainage testing, fracture grouting testing, backfill testing, and borehole seal testing.

2.4.1.4 Design Activity 1.12.4.1 - Development of the Advanced Conceptual Design (ACD) for Sealing

Design Subactivity 1.12.4.1.1 - Define Subsystem Design Requirements. A paper on the uncertainties in sealing a nuclear waste repository in partially saturated tuff was prepared for presentation at the Nuclear Energy Agency/Commission of European Communities (NEA/CEC) Workshop on Sealing of Radioactive Waste Repositories in West Germany. Two additional papers were prepared for the 30th Annual Meeting of the Institute of Nuclear Materials Management. These papers discussed the repository sealing program and the initial evaluation of sealing materials for the Project.

Work was performed on the TAR notice entitled "Geologic and Geophysical Evidence Pertaining to the Structural Geology in the Vicinity of the Proposed Exploratory Shafts." The purpose of this TAR was to clarify the implications to the performance of the repository if a fault intersected the exploratory shafts. As part of this TAR, documents that model the movement of water near a fault in the unsaturated zone were reviewed. These documents show that deep water movement in a faulted region is expected to be unsaturated for expected average flux rates at Yucca Mountain. For these unsaturated conditions, a shaft intercepting this region would tend to act as a barrier flow so that water would not be expected to enter the shaft. Under conditions of unexpectedly high fluxes at Yucca Mountain, zones of saturation near faulted regions were found to occur. For these saturated conditions, small amounts of water were predicted to enter the shafts. These amounts of water were much less than the storage and drainage capacity of the ESF so that this water could easily be contained within the ESF. It was concluded that there would be no performance impacts if a fault intercepted the exploratory shafts. This work will be published in the Review Record Memorandum for this TAR which is currently in preparation.

Design Subactivity 1.12.4.1.2 - Perform Trade-Off Studies to Support Advanced Conceptual Design Development. A comprehensive literature search on available sealing technologies was completed. A Design Investigation Memo to evaluate available sealing techologies was completed and approved, and work was initiated.

2.4.1.5 Design Activity 1.12.4.2 - Development of the License Application Design for Sealing

No progress was made in this design activity during the reporting period.

2.5 WASTE PACKAGE DESIGN AND PERFORMANCE ASSESSMENT

The waste package consists of the waste form and the container in which the waste form is placed. The waste package design program includes the development of waste package design bases, design analysis, container materials testing, the development of a reference design, waste form testing, and characterization of the waste package emplacement environment. Status of the waste package program is provided in this section.

2.5.1 Postemplacement Near-Field Environment (SCP Section 8.3.4.2)

2.5.1.1 Design Activity 1.10.1.1 - Consideration of 10 CFR 60.135 (a) Factors

No progress was made in this design activity during the reporting period. The information needed is being developed in other activities.

2.5.1.2 Study 1.10.4.1 - Characterize Chemical and Mineralogical Changes in the Postemplacement Environment

Activity 1.10.4.1.1 - Rock-Water Interactions at Elevated Temperatures. Rock-water interaction experiments continued. The purpose of these experiments is to determine how a steady-state tuff-water system responds to perturbations in fluid composition. The methodology to address this problem has been to allow tuff and fluid to approach equilibrium and then to inject into the reaction vessel an aliquot of fluid, which perturbs the steady-state system. Sampling of fluid after perturbation allows monitoring of the approach to a new steady state. The current runs replace those that were prematurely terminated by a power outage. A backup power supply was obtained in September to prevent further loss of experiments during power outages.

Solutions during the first phase of the approach to steady-state were collected and submitted for analysis. Injection of a new aliquot of fluid took place in April 1989, and samples have been taken periodically to monitor the approach to the new steady-state. Solution pH and dissolved carbonate are measured in the solution from the reaction vessel; inductively-coupled plasma (spectrometer)-auger electron spectroscope (ICP-AES), activation analysis, and ion chromatography measurements for cation and anion species are then conducted on the samples. Results to date indicate that the approach to a new steady-state is occurring at about the same rate as that seen for the initial phase of the experiment. Si, Na, and Al concentrations are approaching those values obtained during the pre-injection period, and Ca and Mg remain very low. The Si concentrations are considerably greater than expected for quartz saturation, but are lower than amorphous silica saturation values. However, the concentrations of the anions in solution are not following the trends observed before, indicating that the system is approaching a new steady state that is different from that initially attained by the system. Analysis of the solid phases and the analytical results will be completed when the run is terminated.

The technical implementing procedure for through-system calibration of the Dickson autoclave system was completed and submitted for review.

Activity 1.10.4.1.3 - Composition of Vadose Water from the Waste Package Environment. Work was still delayed due to the absence of appropriate sample material. Nevertheless, arrangements were made to begin reconnaissance experiments with high-G centrifuges.

Activity 1.10.4.1.4 - Dissolution of Phases in the Waste Package Environment. Dissolution and precipitation kinetics experiments were expanded to include studies of kaolinite, gibbsite, clinoptilolite, heulandite, and cristobalite over a range of pH and temperatures. After initial problems with the stability of vessels and flow rates, reaction progress was adequately controlled and the experiments are progressing normally.

Study of the dissolution and precipitation kinetics of cristobalite at 200°C continued. Steady-state concentrations of silica were achieved in the dissolution experiments that were consistent with predictions from other studies. Precipitation experiments proceeded normally. Amorphous silica, rather than cristobalite, has appeared in the run products. Investigation of this material continues.

2.5.1.3 Study 1.10.4.2 - Hydrologic Properties of Waste Package Environment

A paper on mathematical analysis of movement of a liquid front in an unsaturated, fractured porous medium was completed and sent to the Project Office for review. The paper is to be published in Water Resources Research.

An abstract by J. Nitao and T. Buscheck (approved) on the infiltration of a liquid front in an unsaturated, fractured porous medium was presented at the ANS topical meeting FOCUS '89, held in Las Vegas, Nevada, September 18-21, 1989.

D. Wilder (approved) presented an abstract on waste package interaction with unsaturated welded tuff environment at the Structural Mechanics in Reactor Technology Conference, held in Anaheim, California, on August 21, 1989.

Activity 1.10.4.2.2 - Two-Phase Fluid System Properties. As part of the fracture healing work being conducted, water permeability was measured in seven Topopah Spring tuff samples at a constant confining pressure of 5.0 MPa and at temperatures up to 150°C. One of the seven samples is intact; the others contain a longitudinal fracture almost dissecting the sample. Four of the six fracture samples contained a re-opened, naturally healed fracture. One of the remaining fractured samples contains an induced tensile fracture; the other contains a saw-cut. A dry gas (N2) permeability was also measured in a naturally fractured Topopah Spring tuff sample at the same conditions as the water permeability measurements. Conclusions are (1) fractures heal and water permeability decreases significantly at a pressure of 5.0 MPa and temperatures up to 150°C; (2) water is required for the fracture healing; (3) fracture surface condition, such as silica coating, does not affect the fracture healing; (4) fracture surface roughness has some effect on the fracture healing; and (5) thermal cycling and thermal gradient have little effect on the fracture healing.

An abstract by Daily and Lin (approved) on results of a laboratory study of fracture healing in Topopah Spring tuff and the implications for near-field hydrology was presented at the ANS topical meeting FOCUS '89, held in Las Vegas, Nevada, September 18-21, 1989.

As part of the work conducted on the suction potential of Topopah Spring tuff, the characteristic curves of suction potential vs. degree of saturation of intact Topopah Spring tuff samples were measured for both imbibition and drainage modes, at room temperature and 70°C. It was found that hysteresis exists between imbibition and drainage modes. The suction potential at 70°C is slightly lower than that at room temperature. A new constant humidity chamber with a capability up to 166°C has been acquired. The experiment will continue to higher temperatures.

A paper on the laboratory determined suction potential of Topopah Spring tuff (Daily and Lin, approved) was completed for publication in Water Resources Research.

An experiment to determine the imbibition speed and water front in a tuff sample was initiated.

2.5.1.4 Study 1.10.4.3 - Mechanical Attributes of the Waste Package Environment

Study Plan 8.3.4.2.4.3 was submitted to the Project Office for review on June 2, 1989. Revision of the study plan to incorporate comments received from the screening review is proceeding. Planning documents for activities described in the study plan have been initiated.

2.5.1.5 Study 1.10.4.4 - Engineered Barrier System Field Tests

Activity 1.10.4.4.1 - Repository Horizon Near-Field Hydrologic Properties. The first Prototype Engineered Barrier System Field Test (PEBSFT) at G-Tunnel continued during the reporting period. The test is a precursor to the Engineered Barrier Systems Field Tests (EBSFT) that will be conducted in the ESF.

The PEBSFTs are being conducted to evaluate the applicability of measurement techniques, numerical models, and procedures for future EBSFT investigations of the geohydrologic and geochemical environment in the near field (within a few meters) of heaters emplaced in welded tuff. The measurements made during the first prototype test included rock temperatures, changes in rock moisture content, air permeability of fractures intersecting the heater borehole, gas pressures, and rock-mass, gas-phase humidity.

The prototype (horizontal orientation) test also included an accelerated thermal cycle to examine the effects of the heating and cooling phases of a thermal pulse. The initial thermal loading for the 3-m (9.8-ft) heater was approximately 3 kW (1kW/m) and lasted 127 days. This initial thermal load per unit length of emplacement borehole was set higher than the loading expected for a typical spent fuel container (0.4 to 0.7 kW/m) in an attempt to increase the volume of rock to be disturbed in the relatively short period available

for prototype testing, and to create sufficiently high rock temperatures to drive two-phase fluid flow. The heat cycle created a region of boiling with a diameter of approximately 1.4 meters. The spatial extent of heating affected a volume of rock large enough to include several fractures. Subsequently, the heater power was gradually decreased to 0.0 kW over a 68-day period. The total duration of the heating cycle was 195 days.

Test results confirmed elements of the conceptual model of predicted environmental conditions. In particular, they confirm that a dry zone develops around the heater borehole and the degree of drying increases with proximity to the heater. A halo of increased saturation develops adjacent to the dry region and migrates away from the heater as rock temperatures increase. Some of the fractures intercepting the heater borehole increase the penetration of hot-dry conditions into the rock mass. A build-up of pore gas pressure develops in rock regions where vigorous evaporation is occurring. During the portions of the test when the heater power was gradually reduced (and eventually turned off), the dry region around the heater cooled off and slowly regained water. A suction pressure gradient formed between regions depleted of water and regions further from the heater that contained more water. The re-wetting rate is much slower than the initial drying rate. Measurements of air permeability made along the heater borehole prior to heating show that the fracture system exhibits a strong heterogeneity in fracture permeability. Measurements made after the heater was turned off show that there was a slight increase in air permeability for the rock adjacent to the heater.

The test results also yielded some surprises in terms of environmental conditions. The temperature above the heater container was approximately 30°C higher than below the container. This condition might be a consequence of hotter air accumulating at the top of the heater container. The amount of steam expected to invade the heater borehole based on scoping calculations greatly exceeded the measured value. The reason(s) for this discrepancy is not clearly understood; it might be a consequence of an inadequate system used to collect and condense the steam or an indication of invalid assumptions used in the scoping calculations.

The test results have also shown that some of the measurement techniques used during the test may have to be modified or replaced. The performance of the different sensors used exhibits considerable variability. Some of the sensors showed unacceptably high rates of corrosion, probably caused by inadequate installation procedures and materials not suitable for hot, humid environments.

Activity 1.10.4.4.2 - Repository Horizon Rock-Water Interaction. Pre- and post-heating tuff samples have been collected for analysis.

Abstracts on the progress of PEBSFTs (Ramirez, approved) and microwave measurements of water vapor partial pressure at temperatures up to 350°C (Latorre, approved) were presented at the ANS topical meeting FOCUS '89, held in Las Vegas, Nevada, September 18-21, 1989.

Activity 1.10.4.4.3 - Numerical Analysis of Fluid Flow and Transport in the Repository Horizon Near-Field Environment. Work continued on building the models for the vertical prototype heater test, including both the large and

small diameter heater borehole options. Both vertical cases were run for the simulation time of two years. A comparison of the two cases shows that the temperature and saturation fields are essentially the same. The small diameter case was rerun for two years at full power to determine how long it will take for the saturation fields of the central and two guard heaters to begin to coalesce. Consideration was given to the impact of the heater's heat generation rate on the fraction of energy available for boiling. With the heaters running at twice the nominal rate, the saturation fields coalesce in nine months.

Work continued on enhancements to the two-phase flowcode, TOUGH, to improve the code's performance. Verification runs were made to compare the new version of TOUGH with the preceding one. A new linear equation solver was installed that should be significantly faster than the current one. Several tests will be run to verify that the replacement of the solver has no impact on the code's results. Work is also underway to vectorize all computationally-intensive sections of the code.

Work continued on some discrete fracture/matrix modeling of hydrothermal flow around the prototype heater. In the most recent modeling effort, the impact of gridblock spacing transverse to the fracture is being examined.

2.5.2 Characteristics and Behavior of the Waste Form (SCP Section 8.3.5.10)

2.5.2.1 Activity 1.5.1.1 - Integrate Waste Form Data and Waste Package Design Data

Subactivity 1.5.1.1.1 - Integrate Spent Fuel Information. The Scientific Investigation Plans (SIPs) for Spent Fuel Waste Form Testing and Glass Waste Form Testing were revised to be consistent with requirements of the Lawrence Livermore National Laboratory (LLNL)/Project QA Program. These SIPs have been approved at LLNL and are currently in review at the Project Office.

LLNL staff met with staff of the Materials Characterization Center (MCC) to discuss approved testing material (ATM) selection criteria, spent fuel characterization parameters, and techniques to measure spent fuel characteristics. Also addressed were the problem of and possible solutions to analytically representing the data obtained from measurements on spent fuel waste forms so they are readily usable for model development and validation.

Subactivity 1.5.1.1.2 - Integrate Glass Waste Form Information. LLNL staff met with staff from the MCC to discuss glass waste form characterization parameters and techniques to measure glass waste form characteristics.

Subactivity 1.5.1.1.3 - Integrate Waste Package and Repository Design Information. Information on candidate container material for waste forms has been obtained and incorporated into tests.

2.5.2.2 Activity 1.5.2.1 - Characterization of the Spent Fuel Waste Form

Subactivity 1.5.2.1.1 - Dissolution and Leaching of Spent Fuel. Work continued on flow-through experiments using depleted UO_2 pellet fragments to

investigate the effects of water chemistry and other test parameters on the dissolution rate of UO_2. Calcium and silicon in the water appear to cause substantial reductions (i.e., orders of magnitude) in uranium concentrations measured in flow-through experiments, in comparison to measurements using deionized water or $NaHCO_3$ (171 mg/L) solutions that do not contain calcium or silicon. It appears that a thin secondary phase or adsorbed layer forms at the UO_2 surface in the experiment using well J-13 water or $NaHCO_3$ plus calcium and silicon, forming a barrier to UO_2 dissolution. Uranium concentrations measured in 25°C flow-through experiments, using either J-13 water or $NaHCO_3$/calcium/silicon solution at constant flow rates, decreased over a period of several weeks as the indicated surface layer was forming. The rate at which the surface layer formed appeared to be accelerated when the temperature was raised to 85°C.

The surfaces of UO_2 particles removed from flow-through columns at various times have been examined using an Auger microprobe. Auger examinations of particles from columns where uranium concentrations had dropped to the detection limit (~0.1 ng/mL) showed silicon and calcium to be present with uranium to a depth of ~100 angstroms. This thin surface layer was not visible during a scanning electron microscopy examination.

As part of the saturated tests with unirradiated UO_2, a task plan on the determination of the dissolution rate of the UO_2 matrix in well J-13 water by the isotope dilution technique was prepared by Argonne National Laboratory (ANL) and sent to LLNL for review and approval. This is a continuation of tests designed to investigate the feasibility of determining the dissolution rate of a UO_2 matrix in J-13 water. The initiation of this task is awaiting the arrival of UO_2 crystals from the MCC and completion of prerequisite planning.

As part of the unsaturated tests with unirradiated UO_2, a task plan on surface reactions between J-13 water and UO_2 pellets under unsaturated conditions at 90°C was prepared by ANL and sent to LLNL for review and approval. These tests are an extension of Series PMP8U parametric experiments that have already been performed. The principal objective of the new tests is to reproduce the results from the previous series with regard to uranium release and secondary phase formation during the water-UO_2 reactions. Most of the previous setup and procedures will be left unchanged, except for the replacement of Teflon™ by 304L stainless steel in fabricating the specimen support stands. These tests were initiated during the month of July.

Subactivity 1.5.2.1.2 - Oxidation of Spent Fuel. Test and activity plans for oxidation testing activities were prepared and approved at LLNL. Readiness reviews for the activities were also conducted during the month of September.

Both thermogravimetric analysis (TGA) and dry bath spent fuel oxidation tests were performed at Pacific Northwest Laboratories (PNL). The oxidation tests will provide data for the oxidation rate of and the oxidation state of spent fuel. The oxidation state may influence the dissolution radionuclide release rates.

TGA test BWR-9 was terminated on May 26 after 3,069 hours at 175°C. The sample was 197.5 mg of Cooper BWR fuel pulverized to -10/+24 Tyler mesh. The

final O/M was 2.19. Gas samples were drawn for Kr, Xe, O_2, and ^{14}C analyses. After completion of the test, sample BWR-9 was removed from the TGA and weighed.

As part of the dry bath oxidation tests, interim weight gain measurements were conducted during the months of June and August. No deviations from expected values were observed. During the June interim examination, the data acquisition system was calibrated and found to be within specifications. Also, an improved stability humidity probe was calibrated and installed.

An abstract on spent fuel oxidation testing (Einziger and Buchanan, approved) was presented at the ANS topical meeting FOCUS '89, held September 18-21, 1989, in Las Vegas, Nevada.

Subactivity 1.5.2.1.3 - Corrosion of Zircaloy. The corrosion and degradation test development and model development for Zircaloy cladding have resulted in (1) construction and preliminary operation of a new pressurized tube testing apparatus, (2) a preliminary model to describe the probable failure of Zircaloy cladding, and (3) construction and preliminary operation of a fluoride corrosion apparatus. The pressurized testing apparatus constructed at PNL incorporates acoustic emission monitoring for assessing the cladding degradation from oxide film fracture and plasticity, mounted surface strain gauges for monitoring cladding strains and inferring displacements, and through-thickness resistivity monitoring to infer fracture response. The apparatus was designed such that it could be used for future testing needs, such as hydride precipitation-induced failures that may be coupled with other degradation failure mechanisms. The preliminary model for corrosion cracking/degradation failure of Zircaloy cladding is based on a deformation-stress analysis of the Zircaloy cladding and its surrounding surface layer of zirconium oxide. The volume change during the zirconium transformation to zirconium oxide is very large and places the oxide film in a compressive state of stress. As long as the oxide film remains compressive, the probability is very low that radial surface cracks will form and propagate through the protective oxide film. Without a through-crack in the oxide film, the probable integrity of the cladding remains high. The model is considered conservative in the sense that at the first appearance of a through-crack, the cladding can be assumed to have failed. Physical and material properties for this preliminary model, as well as a validation procedure, will require the use of the pressurized tube testing apparatus. Finally, only preliminary results from the fluoride testing have been obtained. The results are still being interpreted, but indicate that low pH and high concentrated fluoride solutions are corrosive to unirradiated Zircaloy. Additional developmental testing is being planned.

An abstract on modeling of Zircaloy cladding degradation under repository conditions (Santanam et al., approved) was presented at the ANS topical meeting FOCUS '89, held September 18-21, 1989, in Las Vegas, Nevada.

Subactivity 1.5.2.1.5 - Evaluation of the Inventory and Release of Carbon-14 from Zircaloy Cladding. There was continued experimental development to study the thermally activated release of carbon-14 and tritium from irradiated, pressurized-water reactor (PWR) cladding to the environment. The controlled experiment parameters include temperature, atmosphere, oxide thickness, and cladding history. Information has been obtained on carbon-14

release in its various chemical species. A series of preliminary test experiments has been completed measuring the carbon-14 release from Zircaloy-4 samples with thin pre-transition and thick post-transition zirconium oxide films at four temperatures: 100, 200, 275, and 350°C, in air for 8 to 24 hours. Test experiments were repeated in argon carrier gas at 350°C. The data were examined in light of classic diffusion models, particularly diffusion from a semi-infinite plane and from a finite thickness plane. Diffusion coefficients were determined for pre- and post-transition oxide cladding. The diffusion coefficients for the pre-transition cladding range from 1×10^{-15} to 2×10^{-10} cm^2/sec, and the activation energy is -25/kcal/mole in the temperature range of 100-350°C. For the post-transition cladding, they range from 4×10^{-14} to 1×10^{-9} cm^2/sec, with an activation energy of -19/kcal/mole in the same temperature range. Carbon-14 release levels are higher and far more temperature-sensitive in air than in argon. The differences in release in air versus argon may be due to diffusional versus desorptive release. Carbon-14 release levels and rates also are significantly higher from post-transition oxide film than from the pre-transition oxide film, possibly due to a larger releasable reservoir. Porosity in the thick oxide film also may contribute to an altered release curve.

An abstract based on the results of an investigation of thermal release of carbon-14 from PWR spent fuel cladding (Smith and Baldwin, approved) was presented at the ANS topical meeting FOCUS '89, held September 18-21, 1989, in Las Vegas, Nevada. A proceedings paper is forthcoming.

2.5.2.3 Activity 1.5.2.2 - Characterization of the Glass Waste Form

Subactivity 1.5.2.2.1 - Leach Testing of Glass. New tests were initiated to provide input for a glass release model. The current glass release model is based on the EQ3/6 geochemical code, coupled to a dissolution rate "pre-processor" that describes glass dissolution in terms of transition-state theory. The dissolution rate model requires that the rate constant for the dissolution be known as a function of temperature, glass composition, and solution composition. To obtain rate constant data, flow-through leaching experiments are being conducted over a range of temperatures and solution pHs. Work to date is preliminary and has focused on a simplified glass composition analogous to the standard glass, SRL-165. Information on dissolution kinetics has been obtained up to 70°C for pHs between 2 and 13. The data indicate that the rate constant increases at extreme pH's. Characterization of the surfaces of the reacted glasses is underway, and preliminary results indicate that the surface chemistry of the glass may also be dependent upon solution composition. Additional static tests are underway to (1) test predictions of precipitate-solution equilibria, and (2) assess radionuclide release in the advanced stages of reaction. Both SRL-165 and simple analog glasses are being employed in these tests. These basic kinetics tests will be expanded to include a wider variety of possible glass compositions relevant to the Defense Waste Process Facility (DWPF) and West Valley Demonstration Project (WVDP). The data acquired will be incorporated into the release rate model.

Subactivity 1.5.2.2.2 - Materials Interactions Affecting Glass Leaching. Waste form characterization is continuing using three different types of site-specific tests: an unsaturated test that simulates intermittent contact

with liquid water and continual contact with water vapor; vapor phase tests in which the glass is exposed to water vapor at a variety of relative humidities and temperatures; and planned saturated tests in which the glass is in continual contact with static liquid water. The tests are being conducted to identify important chemical interactions between the waste form, water, and anticipated repository materials, and to provide a data base against which release rate models can be tested. The unsaturated tests have been performed in both a batch mode, in which the test is terminated at a predetermined time and the solution sampled; and a continuous mode, in which the sample is removed from the test assembly, the leachant sampled, and the sample is transferred to a new test assembly for continued exposure. Batch testing on both SRL-165 and ATM-10 glasses has been completed, and continuous mode testing will be continued for the duration of the Project. Vapor phase testing has been performed on a series of DWPF, WVDP, and natural glasses to assess the rate of vapor phase alteration and the nature of secondary minerals produced during such exposure. Once completed, this work will form the basis for saturated and unsaturated testing of vapor phase "aged" glasses. Activity and test plans are being developed for such tests, which are expected be initiated in fiscal year 1990.

2.5.2.4 Activity 1.5.3.1 - Integrate Scenarios for Release from Waste Packages

This activity is in the planning stages. The SIP for waste package performance assessment is being revised to incorporate new planning. The activity has been extensively expanded from that in the previous SIP to correspond to Section 8.3.5.10.3.1 of the SCP, which was expanded from the SCP/CD description in response to NRC comments.

2.5.2.5 Activity 1.5.3.2 - Develop Geochemical Speciation and Reaction Model

Subactivity 1.5.3.2.1 - Develop Data Base for Geochemical Modeling. A commercial relational data base program (INGRESS) replaced the inhouse LLNL data base handling programs for maintenance, development, and records-keeping of the geochemical modeling thermodynamic data base.

Work continued with scientists at the National Institute of Standards and Technology (NIST) to evaluate the consistency of the data base. As part of this effort, LLNL personnel started learning to use the CATCH program at NIST to understand how it works before transferring it to LLNL for detailed usage. The CATCH program will be used to analyze systems of elements for the Project's thermodynamic data base.

The sensitivity/uncertainty work for the data base was begun, including assessments of data needs and automated sensitivity/uncertainty analysis during EQ3NR analysis using the programs GRESS and ADGEN (from Oak Ridge National Laboratory).

Subactivity 1.5.3.2.2 - Develop Geochemical Modeling Code. The DOE-required LLNL Software Quality Assurance Plan (SQAP) was completed and submitted to the Project Office for review. Following a meeting with DOE

representatives to reconcile minor concerns, the plan was revised and resubmitted to the Project Office for approval.

Prototypes for additions to the solid solution models were completed. An initial version of the EQ3/6 Verification Library System package was constructed and the first stages of testing initiated. Also, various documents associated with the package, including the MCRT and draft EQ6 guides for users, programmers, and system administration, were completed.

Work continued on the prototyping of a new ideal site mixing model that will be incorporated in the EQ3/6 codes. The prototype of a model for ion exchange and a requirements document for its implementation in EQ3/6 were also prepared, and scoping work for adding a surface complexation (sorption) model to the EQ3/6 code was begun.

The program to plot aqueous species, including the code package, test cases, and user instructions, was completed. This package is used to create graphics output of changes in aqueous speciation as a function of EQ3/6 reaction progress.

2.5.2.6 Activity 1.5.3.3 - Generate Models for Release from Spent Fuel

Subactivity 1.5.3.3.1 - Generate Release Models For Spent Fuel Models. In a report on studies of spent fuel dissolution behavior under Yucca Mountain repository conditions (Wilson and Bruton, approved), the measured steady-state concentrations of U, Np, and Pu in solution were compared to predictions obtained from geochemical simulations of spent fuel dissolution. Comparisons showed that experimental results could be interpreted in terms of the precipitation of secondary phases and the changing composition and redox potential of the solution.

Further calculations explored the controls of water chemistry on radionuclide concentrations in solution in more detail. Concentrations of U in solution are kept at a minimum by maintaining sufficient quantities of Si in solution. Concentrations of the actinides U, Np, Pu, and Am vary as a function of redox potential and pH. In general, low redox potential and high pH tend to favor reduced actinide concentrations in solution. Oxidizing conditions and low pH tend to favor increased actinide concentrations in solution.

2.5.2.7 Activity 1.5.3.4 - Generate Models for Release from Glass Waste Forms

Subactivity 1.5.3.4.1 - Generate Release Models for Glass Waste Forms. Glass dissolution tests continued during the reporting period. Dissolution tests of a simple six-component waste glass analogue were made in flow-through cells at 25, 50, and 70°C. These tests were performed to determine the rate constant for glass dissolution as a function of pH and temperature. The run products were analyzed using scanning electron microscopy, infrared spectroscopy, and electron microprobe analysis. These techniques were used to determine the structure and composition of the surface alteration layer, which is important for developing a chemical model for glass dissolution.

Another set of experiments was performed in closed system Dickson vessels. Both SRL-165 and simple glasses were dissolved in a sodium bicarbonate solution having the same pH and concentration as well J-13 water. The results of these tests were used as input to regress rate constants and thermodynamic properties of glass alteration layers as part of the glass dissolution modeling work.

Work also continued on the development of a chemical model for glass dissolution that has been incorporated in the EQ3/6 geochemical modeling code. The current model assumes that the rate of glass dissolution can be predicted from the composition and structural state of an alteration layer that forms on the glass surface. Analysis of glass dissolution experiments using this model incorporated into EQ3/6 has yielded favorable results. Current experimental work is aimed at testing model predictions for the dependence of glass dissolution rates on solution composition. A report on this modeling work (Bourcier et al., 1989) was presented at the 6th International Symposium on Water-Rock Interaction, held in Malvern, England, in August 1989.

2.5.2.8 Activity 1.5.3.5 - Waste Package Performance Assessment Model Development

Subactivity 1.5.3.5.1 - Development of System Model. Prototype modeling for this activity is underway. The LLNL SQAP and the revised SIP for waste package performance assessment are being finalized. Work is also underway to provide more extensive identification of information transfers from other technical areas to waste package system model development.

A report on the completed first version of the system model, PANDORA-1.0, is being prepared. Example applications of PANDORA-1.0 have been carried out.

Subactivity 1.5.3.5.2 - Development of Uncertainty Methodology. Prototype development of uncertainty methodology is underway. The "uncertainty methodology" will be used both for uncertainty propagation (from input to output of the performance assessment models) and for numerical integration over all the waste packages to form the source term and the Engineered Barrier System (EBS) performance to be compared to NRC performance regulations.

Technical reports that clarify the uses and limitations of Latin hypercube sampling are currently being prepared. An improved sampling method has been developed and demonstration of the method completed.

During the reporting period, the ease-of-use of the test bed computer program set for testing and comparison of various sampling methods was improved.

2.5.2.9 Activity 1.5.4.1 - Deterministic Calculation of Releases from the Waste Package

This activity is currently in the prototype and planning stage. The LLNL SQAP and the revised SIP for waste package performance assessment are currently being finalized.

Results of prototype analyses have illustrated the potential importance of the degraded container condition and the local water contact mode (e.g., dry, water trickle-through, or water immersion), spent fuel matrix alteration rate, fuel-cladding gap and grain boundary inventories of radionuclides, and temperature cooldown. Conclusions from these illustrations, however, cannot be made at this time, given the present state of the data.

2.5.2.10 Activity 1.5.4.2 - Probabilistic Calculation of Releases from the Waste Package

This activity is currently in the planning stages. The LLNL SQAP and the revised SIP for waste package performance assessment are currently being finalized.

2.5.2.11 Activity 1.5.5.1 - Determine Radionuclide Transport Parameters

Subactivity 1.5.5.1.1 - Radionuclide Distribution in Tuff Wafers. The primary effort of this activity over the reporting period was in reducing and interpreting data acquired during the previous year from experiments that measured the transport rates of actinides in tuff. Measurements of U concentration vs. depth were obtained with the ion microprobe in tuff wafers that had been exposed to U-doped ground water in static experiments. It was determined that transport of U was faster and much less uniform than could be predicted by standard diffusion models, which assume a homogeneous porous medium with single, constant values for K_d, D_m, and tortuosity. Preliminary efforts to identify a model that could describe the observed distribution of the tracer U suggested that additional characterization of the heterogeneous tuff-ground water system was needed. Experimental and analytical efforts were made to determine (1) the heterogeneity of the tuff pore structure, which determines tortuosity; (2) major element and mineral distribution of the same scale as U measurements (i.e., microns), which helps indicate the K_d; and (3) size distribution of colloidal and dissolved U in the doped ground water, which indicates the D_m values. In addition, samples of materials having uniform pore size were acquired for use in experiments to determine the relative importance of porosity and molecular diffusivity on transport rates.

Subactivity 1.5.5.1.2 - Radionuclide Distribution in Tuff Cores. Work continued on the measurement of actinides in tuff core at LLNL. The ability to measure actinides that are less mobile than U had been constrained by instrument resolution. However, a significant improvement of the depth profiling abilities of the ion microscope was obtained by careful adjustments of the hardware. In addition, efforts continued to modify the software to increase the versatility and usefulness of the data acquisition and reduction programs associated with the ion microscope. One application of this is the ability to vary the region of the wafer over which data will be integrated. This is useful for assessing the optimum scale for averaging physical properties or parameters that are used as input for transport models.

Experiments involved measuring transport rates of actinide-bearing solutions with tuff cores in a simulated, near-field environment. Most of the work performed during the reporting period was directed towards characterizing the interactive tuff-actinide-ground water systems. There was also an effort

to prepare actinide solutions containing the various species and colloids that might be expected to occur in a repository environment. Solutions of ^{238}U, ^{235}U, ^{242}Pu, ^{239}Np, ^{243}Am, and ^{99}Tc in well J-13 ground water continued to equilibriate and were monitored periodically. Small-volume ultrafiltration equipment was acquired and used to determine the sizes of particulate or colloidal actinide in the solutions. Another effort was made to identify the abundance and composition of colloidal material that occurs naturally in ground water, since their presence near the repository may affect the transport rates of actinides in a number of ways. This effort entailed (1) literature search and consultation, (2) acquisition and characterization of colloids concentrated from NTS well waters, and (3) investigation of instruments and techniques that can measure colloid sizes in well J-13 water.

A third effort has been to characterize the pore structure, fracture frequency, and fracture lining minerals in tuff cores. Again, literature search and consultation have been useful. The tuff wafer experiments pointed out the difficulties of interpreting data obtained in static transport experiments on heterogeneous media and heterogeneous solutions. Fluid flow of a sorbing species in a heterogeneous medium generates results that are even more difficult to interpret, model, or predict. During the report period, modifications to the core flow-through apparatus have continued and construction of equipment for diffusion experiments using core-size tuff samples has begun.

2.5.3 Characteristics and Configurations of the Waste Packages (SCP Section 8.3.4.3)

A review of the DWPF draft of the Waste Compliance Plan and the preliminary waste acceptance specifications was completed at LLNL. Comments were provided to the Waste Acceptance Committee for development of generic waste acceptance specifications.

2.5.4 Waste Package Production Technologies (SCP Section 8.3.4.4)

Readiness reviews for Design Activities 4.3.1.1, Waste Package Fabrication Process Development, and 4.3.1.2, Waste Package Closure Process Development, were conducted in April. Work authorization for these activities was given by the DOE in May 1989.

Accelerated thermal/mechanical processing feasibility studies and accelerated inertial welding studies were initiated in August and successfully completed in September. Samples will be analyzed at LLNL as part of other Activities.

The Phase 2 work scope (waste package closure studies) began in May 1989. This involves the setup of three weld process stations (plasma arc, friction, and electron beam) for parameter evaluation studies.

2.5.5 Waste Package Performance (SCP Section 8.3.5.9)

2.5.5.1 Activity 1.4.1.1 - Integrate Design and Materials Information (Metal Container)

Microstructural analysis of candidate alloy base metals and welds is on hold pending implementation of a revised LLNL QAPP. An internal activity plan for characterization of the container material has been prepared and a readiness review is scheduled for October 1989.

2.5.5.2 Activity 1.4.1.2 - Integrate Design and Materials Information (Alternate Barriers Investigation)

A SIP for this activity was written and approved at LLNL. In addition, an internal activity plan was written in accordance with revised QA requirements.

2.5.5.3 Activity 1.4.2.1 - Selection of the Container Material for the License Application Design

Subactivity 1.4.2.1.1 - Establishment of Selection Criteria and their Weighting Factors. The establishment of selection criteria for the container material is on hold pending implementation of a revised LLNL QAPP. Under the new QA plan, an internal activity plan has been prepared, and a readiness review was completed on August 1. Authorization from the DOE to restart this activity is pending. The formal material selection process can be initiated following establishment of selection criteria.

2.5.5.4 Activity 1.4.2.2 - Degradation Modes Affecting Candidate Copper-Base Container Materials

Subactivity 1.4.2.2.1 - Assessment of Degradation Modes in Copper-Based Materials. A degradation mode survey has been reviewed, revised, and prepared for publication. This report consists of eight bound volumes and reviews approximately 1,200 relevant publications. Each volume discusses a unique mode of degradation, such as uniform oxidation and corrosion, localized corrosion, or stress corrosion cracking. The survey includes both copper-based alloys and austenitic alloys.

Subactivities 1.4.2.2.2 through 1.4.2.2.8 - Laboratory Test Plan for Copper-Based Materials. Internal activity plans and technical implementing procedures have been written for experimental work to be conducted at LLNL. To the extent possible, experiments will be performed for each copper-based alloy to determine (1) corrosion and pitting potentials, (2) rates of uniform oxidation and corrosion, (3) plain strain fracture toughness, (4) the threshold stress intensity for stress corrosion cracking, and (5) the propagation rate of stress corrosion cracks. New experimental equipment has been received, installed, tested, and calibrated. Work is also being conducted at ANL to assess the susceptibility of each copper-based alloy to stress corrosion cracking in concentrated well J-13 water and to determine the effect of radiolysis on alloy corrosion.

2.5.5.5 Activity 1.4.2.3 - Degradation Modes Affecting Candidate Austenitic Materials

Subactivity 1.4.2.3.1 - Assessment of Degradation Modes in Austenitic Materials. A degradation mode survey was completed. This is discussed under Section 2.5.5.4.

Subactivities 1.4.2.3.2 through 1.4.2.3.9 - Laboratory Test Plan for Austenitic Materials. Internal activity plans and technical implementing procedures have been written for experimental work to be conducted at LLNL. Experiments will be performed for each austenitic alloy to determine (1) corrosion and pitting potentials, (2) rates of uniform oxidation and corrosion, (3) plain strain fracture toughness, (4) the threshold stress intensity for stress corrosion cracking, and (5) the propagation rate of stress corrosion cracks. Work is also being conducted at ANL to assess the susceptibility of each austenitic alloy to stress corrosion cracking in concentrated well J-13 water and to determine the effect of radiolysis on alloy corrosion.

2.5.5.6 Activity 1.4.2.4 - Degradation Modes Affecting the Ceramic-Metal Bimetallic/Single Metal, or Coatings and Filler Systems

The SIP for this activity was written and revised, and an internal activity plan was written in accordance with revised QA requirements.

2.5.5.7 Activities 1.4.3.1 and 1.4.3.2 - Models for Copper and Copper-Alloy Degradation and Models for Austenitic Material Degradation

J. Farmer made an oral presentation on corrosion models for performance assessment of high-level radioactive waste containers at the Structural Mechanics in Reactor Technology Conference held in Anaheim, California, on August 21. After final review and approval, this report will be published in the Journal of Nuclear Engineering Design. This paper discusses models of uniform oxidation and corrosion, localized corrosion, and stress corrosion cracking of copper-based alloys. An internal activity plan and software plan were prepared to satisfy QA requirements for this modeling activity. A formal readiness review was conducted in September.

2.5.5.8 Activity 1.4.3.3 - Models for Degradation of Ceramic-Metal Bimetallic/Single Metal, and Coatings and Filler Alternative Systems

The SIP was written and revised, and an activity plan was written in accordance with revised QA requirements.

2.5.5.9 Activity 1.4.4.1 - Estimates of the Rates and Mechanisms of Container Degradation in the Repository Environment for Anticipated and Unanticipated Processes and Events, and Calculation of Container Failure Rate as a Function of Time

Subactivity 1.4.4.1.1 - Deterministic Calculation of Rates of Container Degradation in the Repository Environment. This subactivity is in prototype analysis and planning for QA Level I work. The LLNL SQAP and the revised SIP for waste package performance assessment are currently being finalized.

The results of prototype analysis have indicated that general corrosion will not cause container failure within its assigned service lifetime. Conclusions on other corrosion modes, however, cannot be made at this time, given the present state of the data.

Consideration of the effects on waste packages from unanticipated events is expected to begin in fiscal year 1990. This is reflected in the SIP for this activity, which is currently in revision.

Subactivity 1.4.4.1.2 - Probabilistic Calculation of Rates of Container Degradation and Distribution of Time to Initiation of Release of Radionuclides from the Waste Packages. This activity is currently in the planning stages. The LLNL SQAP and the revised SIP for waste package performance assessment are currently being finalized.

2.5.5.10 Activity 1.4.5.1 - Determination of Whether the Substantially Complete Containment Requirement is Satisfied

This activity is in prototype analysis and in planning for QA Level I work. The LLNL SQAP and the revised SIP for waste package performance assessment are currently being finalized.

Prototype application using the deterministic performance assessment code, PANDORA-1.0, has exercised two elements that will enter into a conclusion on substantially complete containment, namely time of container breach and rate of release of radionuclides. No conclusion can be made at this time, however, given the present state of the data.

2.6 PERFORMANCE ASSESSMENT

Performance assessment is the process of evaluating components, subsystems, or system behavior relative to radiological health and safety or the containment and isolation of radioactive wastes. The objectives of these assessments are to demonstrate compliance with the numerical criteria associated with 10 CFR Part 60, to support the development of the repository system, and to guide testing during site characterization. Status of the performance assessment program is provided in this section.

2.6.1 Waste Retrievability (SCP Section 8.3.5.2)

MVS continued work on a report evaluating emplacement drift cooling. A review of the assumptions used in the MVS report was made, and concerns about its relevance to the repository are being examined.

2.6.2 Public Radiological Exposures - Normal Conditions (SCP Section 8.3.5.3)

No significant progress was made during the reporting period.

2.6.3 Worker Radiological Safety - Normal Conditions (SCP Section 8.3.5.4)

As part of Activity 2.2.2.3 (Advanced Conceptual Design Assessment of the Worker Radiological Safety - Normal Operations), a study is underway on various radiation source characteristics on shielding requirements. This study provides dose rate information that can be used to estimate required shield thicknesses. Gamma and neutron source strengths are determined for various waste types and source geometries representative of conditions at the repository.

2.6.4 Accidental Radiological Releases (SCP Section 8.3.5.5)

2.6.4.1 Performance Assessment Activities 2.3.1.1 and 2.3.2.1 - Refinement of Site Data Parameters

No significant progress was made in these performance assessment activities during the reporting period.

2.6.4.2 Performance Assessment Activity 2.3.1.2 - Determination of Credible Accident Sequences and their Respective Frequencies

No significant progress was made in this performance assessment activity during the reporting period.

2.6.4.3 Performance Assessment Activity 2.3.1.3 - Development of Candidate Design-Basis Accidents

No significant progress was made in this performance assessment activity during the reporting period.

2.6.4.4 Performance Assessment Activity 2.3.2.2 - Consequence Analyses of Credible Accidents

A study is currently being conducted on the bases for and uncertainties associated with the use of source terms, calculations involving release and transport mechanisms, and calculations of off-site doses under accident conditions. The various uncertainties will be statistically combined to determine accident doses at various confidence levels. The results of this

task will provide a means for assessing the conservatism in safety assessments.

2.6.4.5 Performance Assessment Activity 2.3.2.3 - Sensitivity and Importance Analyses of Credible Accidents

A study has been initiated to identify repository items important to safety for the proposed Yucca Mountain repository. The study will assess radiological accident scenarios associated with the failures of repository items during the preclosure periods of waste emplacement, caretaking, and decommissioning.

2.6.4.6 Performance Assessment Activity 2.3.2.4 - Documentation of Results of Safety Analyses and Comparison to Applicable "Limiting" Values

A study is currently being conducted to investigate criticality safety for intact and consolidated fuel configurations proposed for the repository. Accident scenarios will be developed and the effective neutron multiplication factor calculated. For study cases where the factor exceeds the required limit of 0.95 K_{eff}, options such as container reconfiguration, neutron absorbers, filler materials, etc., will be evaluated.

The report on preclosure criticality safety analyses for the Yucca Mountain repository prepared by BNI was completed and is in review at SNL. Criticality analysis parameters include water immersion, fuel burnup allowances, waste container designs, and geometry control. Preliminary results indicate that further criticality analyses are necessary to develop waste package designs.

2.6.5 Ground-Water Travel Time (SCP Section 8.3.5.12)

A report prepared by LBL on the processes, mechanisms, and parameters governing partially saturated flow in soil and rock medium was completed and is in review at SNL.

A report on the conceptual, experimental, and computational approaches to support performance assessment of hydrogeology and chemical transport at Yucca Mountain was also completed and is in review at SNL.

Project staff continued to participate in the identification, specification, and scheduling of hydrologic analyses for ESF Title II design.

Interactions with the Technical Integration Group - Working Group 3 continued. These interactions consisted of several presentations that were used as a basis for defining test problems required to address specific technical concerns related to ground-water flow in the unsaturated zone.

Numerical experiments demonstrating the dependent nature of the infiltration flux on prior assumptions in a one-dimensional, steady-state model were completed.

2.6.5.1 Activity 1.6.2.1 - Model Development

Modifications of the one- and two-dimensional hydrologic modeling codes have been completed to increase efficiency and capability. Modifications made to the one-dimensional, steady-state, variably saturated flow code, LLUVIA, greatly increased the speed of execution. Comparisons of a boundary integral equation code for two-dimensional, steady-state, variably saturated flow with the NORIA flow code indicate at least an order of magnitude improvement in computational time in the solution of liquid phase boundary value flow problems.

A report was completed describing LLUVIA, the one-dimensional, steady-state program for flow through partially saturated porous media (Hopkins and Eaton, approved).

A code was installed to correlate parameters in multivariate stochastic simulations. Test of the sensitivity of ground-water travel time to assumptions about correlation structure have been initiated.

2.6.5.2 Activity 1.6.2.2 - Verification and Validation

Subactivity 1.6.2.2.1 - Verification of Codes. An abstract on predicting flow through low-permeability, partially-saturated, highly fractured rock (Eaton et al., approved) was presented at the 28th International Geological Congress held in Washington, D.C., on July 13, 1989.

SNL staff performed more flow calculations using the two-phase flow code TOUGH. The COVE3A benchmarking problem with 10 grid blocks was run and the problem with 20 grid blocks was initiated.

Subactivity 1.6.2.2.2 - Validation of Models. A paper on Miller scaling of finger properties in sandy soils (Glass, 1989a) was completed. The paper will be presented at the U.S. Department of Agriculture International Workshop on Indirect Methods for Estimating the Hydraulic Properties on Unsaturated Soils, October 11-13, 1989, in Riverside, California.

A paper on the analysis of wetting front instability using modified invasion percolation theory (Glass and Yarrington, 1989) was completed and will be presented at the AGU Fall Meeting, December 4-8, 1989, in San Francisco, California.

A paper on the laboratory research program for development and validation of conceptual models for flow and transport through unsaturated porous media (Glass, 1989b) was completed and will be presented at the GEOVAL-90 Symposium, May 14-17, 1990, in Stockholm, Sweden.

Development of experimental procedures for scoping experimentation into unsaturated flow and transport mechanism identification and understanding is in progress.

2.6.5.3 Activity 1.6.3.1 - Analysis of Unsaturated Flow System

No progress was made in this activity during the reporting period.

2.6.5.4 Activity 1.6.4.1 - Calculation of Pre-Waste-Emplacement Ground-Water Travel Time

No progress was made in this activity during the reporting period.

2.6.5.5 Activity 1.6.5.1 - Ground-water Travel Time after Repository Construction and Waste Emplacement

No progress was made in this activity during the reporting period.

2.6.5.6 Activity 1.6.5.2 - Definition of the Disturbed Zone

LBL staff continued refinement of the semianalytical solution for fluid and heat flow around a waste package in a partially saturated medium. Current analysis indicates that for most cases of practical interest, the region with immobile water may have a near zero thickness, which indicates there will be a sharp boiling front with a saturation discontinuity. Additional analysis of the region of immobile liquid is being performed.

Convergence of the shooting algorithm was attained after a moderate amount of trial-and-error for a case with a non-zero irreducible water saturation. This advance appeared to overcome the last major lack of realism in the restrictions that need to be imposed to obtain a similarity solution.

A paper prepared by LBL on thermohydraulic conditions near high-level nuclear wastes emplaced in partially saturated, fractured tuff (Pruess et al., approved) was submitted for publication in Water Resources Research Journal.

2.6.6 Total System Performance (SCP Section 8.3.5.13)

2.6.6.1 Performance Assessment Activity 1.1.2.1 - Preliminary Identification of Potentially Significant Release Scenario Classes

No progress was made in this performance assessment activity during the reporting period.

2.6.6.2 Performance Assessment Activity 1.1.3.1 - Development of Mathematical Models of the Scenario Classes

Subactivity 1.1.3.1.1 - Development of Models for Releases Along the Water Pathways. The TOSPAC computer program was used to model some possible 1,000-year flooding events at Yucca Mountain. The results indicate that the Paintbrush tuff can absorb the excess water and there is little effect at repository depth. SNL staff presented some results of TOSPAC calculations to the Performance Assessment Technical Integration Group (TIG). These

calculations were made as part of the performance assessment calculational exercises being sponsored by the TIG. It is hoped that other groups will model the same problems so that results can be compared.

Numerical experiments demonstrating the dependent nature of the infiltration flux on prior assumptions in a one-dimensional, steady-state model were completed as part of a larger performance assessment exercise.

Subactivity 1.1.3.1.2 - Development of a Model for Gas-Phase Releases. Investigations of the development of realistic boundary conditions for full-scale simulation of gas movement at Yucca Mountain continued.

A detailed case distinction of matrix-matrix, fracture-matrix, and fracture-fracture flow for both liquid and gaseous phases was developed and programmed into the TOUGH computer code.

Subactivity 1.1.3.1.3 - Development of a Model of Releases through Basaltic Volcanism. SNL staff compiled the elements of a model of volcanic events at the Yucca Mountain site. Some elements included in the model are (1) a detailed repository plan, including orientation of the repository and the placement, orientation, size, and content of the waste containers; (2) orientations of possible magmatic dikes; (3) existence and orientation of possible magma chambers; and (4) time distribution of past volcanic events in the region surrounding Yucca Mountain.

2.6.6.3 Performance Assessment Activity 1.1.4.1 - The Screening of Potentially Significant Scenario Classes against the Criterion of Relative Consequences

No progress was made in this performance assessment activity during the reporting period.

2.6.6.4 Performance Assessment Activity 1.1.4.2 - The Provision of Simplified, Computationally Efficient Models of the Final Scenario Classes Representing the Significant Processes and Events

Subactivity 1.1.4.2.1 - Preliminary Development of Simplified, Computationally Efficient Scenario-Class Models. SNL staff completed the process of merging four separate programs into TOSPAC Version 1.1: (1) INDATA (for interactive entry of input data), (2) STEADY (for modeling steady-state ground-water flow), (3) DYNAMICS (for modeling transient ground-water flow), and (4) TRANS (for contaminant transport in the groundwater). A fifth program, OUTPLOT (for computer-graphics output), still needs to be incorporated into this version of TOSPAC. Work on a TOSPAC RS/1 interface also continues. This interface will simplify the use of TOSPAC on systems with the RS/1 data-analysis software.

2.6.6.5 Performance Assessment Activity 1.1.5.1 - Calculation of an Empirical Complementary Cumulative Distribution Function

No progress was made in this performance assessment activity during the reporting period.

2.6.7 Individual Protection (SCP Section 8.3.5.14)

2.6.7.1 Activity 1.2.1.1 - Calculation of Doses Through the Ground-Water Pathway

No progress was made in this activity during the reporting period.

2.6.7.2 Activity 1.2.2.1 - Calculation of Transport of Gaseous Carbon-14 Dioxide Through the Overburden

A preliminary sensitivity analysis of gaseous carbon-14 release was performed based on an analytic solution of the advection-dispersion equation in one dimension. The results indicate the possibility of very rapid carbon-14 transport to the ground surface, but more realistic models and data are needed.

2.6.8 Ground-Water Protection (SCP Section 8.3.5.15)

No significant progress was made during the reporting period.

2.6.9 Performance Confirmation (SCP Section 8.3.5.16)

No significant progress was made during the reporting period.

2.6.10 NRC Siting Criteria (SCP Section 8.3.5.17)

No significant progress was made during the reporting period.

3.0 REFERENCES

All technical reports and research products published by participating organizations on the Yucca Mountain Project are available through the Office of Scientific and Technical Information (OSTI) at Oak Ridge, TN. OSTI is the national center for dissemination of non-classified scientific and technical information sponsored by DOE.

References cited in Section 3.0 are available through OSTI, the open literature, or through proceedings volumes for symposia and technical conferences. "DOE-approved" references in the text of the TSR represent reports or abstracts that have received DOE approval, but, 1) have not yet been published, 2) have proceedings volumes still in preparation, or 3) for which no publication was ever intended. These are not cited in Section 3.0. Many abstracts are not captured on databases maintained by OSTI and are generally not cited in Section 3.0. Exceptions occur where a proceedings volume is available through the professional societies sponsoring specific conferences or symposia.

Copies of Yucca Mountain Project reports and other documents published by DOE and the participating organizations that are available through OSTI can be ordered from:

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

Further information on the availability of Project-sponsored reports can be found in the Yucca Mountain Project Bibliography Updates which are published every six months.

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ACRONYM LIST

ACD	advanced conceptual design
ACNW	Advisory Committee for Nuclear Waste
AECL	Atomic Energy Commission, Limited
AGU	American Geophysical Union
ANL	Argonne National Laboratory
ANS	American Nuclear Society
AP	administrative procedure
ARS	Agricultural Research Service
ASTM	American Society for Testing and Materials
ATM	approved testing material
BFD	Basis for Design
BLM	U.S. Bureau of Land Management
BNI	Bechtel National, Inc.
CCB	Change Control Board
DAS	Data Acquisition System
DOE	U.S. Department of Energy
DOE/HQ	U.S. Department of Energy/Headquarters
DOE/NV	U.S. Department of Energy/Nevada Operations Office
DOP	department operating procedure
DRI	Desert Research Institute
DWPF	Defense Waste Process Facility
EBS	Engineered Barrier System
EBSFT	Engineered Barrier Systems Field Tests
EIS	Environmental Impact Statement
EP	experiment procedure
EPA	U.S. Environmental Protection Agency
ES	exploratory shaft
ESF	Exploratory Shaft Facility
ESHPIP	Environmental Safety and Health Program Implementation Plan
GIS	Geographic Information System
GPR	ground-penetrating radar
GSA	Geological Society of America
GTUF	G-Tunnel Underground Facility
H&N	Holmes & Narver, Inc.
ICP-AES	inductively-coupled plasma (spectrometer)-auger electron spectroscope
IDS	Integrated Data System
IGT	Institute of Gas Technology
I/S	illite/smectite
LANL	Los Alamos National Laboratory
LBL	Lawrence Berkley Laboratory
LLNL	Lawrence Livermore National Laboratory
LRC	Local Records Center
MCC	Materials Characterization Center
MMDS	Martin Marietta Data Systems
MPBH	multipurpose borehole
MPBX	multiple-point borehole extensometer
MSS	multi-spectral scanner
MVS	Mine Ventilation Services

NAFBR	Nellis Air Force Base Range
NDEP	Nevada Division of Environmental Protection
NEA/CEC	Nuclear Energy Agency/Commission of European Communities
NIST	National Institute of Standards and Technology
NPS	National Park Service
NRC	U.S. Nuclear Regulatory Commission
NTS	Nevada Test Site
NWPO	Nevada Nuclear Waste Project Office
NWTRB	Nuclear Waste Technical Review Board
OCRWM	Office of Civilian Radioactive Waste Management
PA/TIG	Performance Assessment/Technical Integration Group
PBQ&D	Parsons, Brinckerhoff, Quade, and Douglas
PEBSFT	Prototype Engineered Barrier System Field Test
PNL	Pacific Northwest Laboratories
PSAR	Preliminary Safety Analysis Report
PWR	pressurized-water reactor
QA	quality assurance
QAP	Project Quality Assurance Plan (NNWSI/88-9, Rev. 2)
QAPD	Quality Assurance Program Description
QAPP	Quality Assurance Program Plan
QAR	Quality Assurance Requirements
RIB	Reference Information Base
ROWR	Right-of-Way Reservation
SAIC	Science Applications International Corporation
SANDARS	Sandia Data Acquisition and Reduction System
SBIP	Surface-Based Investigations Plan
SCP	Site Characterization Plan
SCP/CD	Site Characterization Plan/Consultation Draft
SDRD	Subsystem Design Requirements Document
SIP	Scientific Investigation Plan
SKB	Swedish Nuclear Fuel Supply Company
SMF	Sample Management Facility
SNL	Sandia National Laboratories
SPWLA	Society of Professional Well Log Analysts
SQAP	Software Quality Assurance Plan
SSSA	Soil Science Society of America
TAR	Technical Assessment Review
TBM	tunnel boring machine
TGA	thermogravimetric analysis
TL	thermoluminescence
TSR	Technical Status Report
TSRD	Test Support Requirements Document
UNE	underground nuclear explosion
USBR	U.S. Bureau of Reclamation
USFWS	U.S. Fish and Wildlife Service
USGS	United States Geological Survey
VOG	Validation Oversight Group
VSP	vertical seismic profiling
WSO	Weather Service Office
WVDP	West Valley Demonstration Project