Geological and Geophysical Factors: Evaluation of Minority Report by Archambeau and Price" (Evernden, 1992). This report examines and reviews various field relationships, and geochemical and isotopic lines of evidence germane to the ground-water upwelling hypothesis.

Geochemical and isotopic data were collected to evaluate the total carbonate system. The bulk of this work centered on deep vein carbonates in the unsaturated and SZs from drill holes USW G-1, USW G-2, USW G-3/GU-3, and USW G-4. Sr and Nd isotopic compositions of veins and whole-rock leachates were used to continue investigating the origins of the deep carbonate. Studies conducted during the reporting period focused on the extent carbonate chemistries represent local equilibrium with host volcanics, what extent represents exotic components transported by ground-water solutions, and what were the origins of fluids from which carbonate was deposited. In addition, samples from a variety of Paleozoic carbonate rocks in the Yucca Mountain vicinity were analyzed for Sr isotopic compositions. Resulting analyses have been added to the data base to assess their possible contributions as source areas which have supplied some of the eolian components to Yucca Mountain soils.

Several technical papers summarizing some of these results were published or prepared during the reporting period. A report entitled "Strontium Isotope Geochemistry of Calcite Fracture Fillings in Deep Core, Yucca Mountain, NV - A Progress Report" (Peterman et al., 1992) was published in the 1992 IHLRWM Conference Proceedings. A report entitled "Isotopic Studies of Fracture Coatings at Yucca Mountain, Nevada, USA" (Marshall et al., 1992) was published in the Proceedings of the 7th International Symposium on Water-Rock Interaction. A draft manuscript entitled "Isotopic Studies of Cavity Filling and Fracture Coating Minerals as an Aid to Understanding Paleohydrology, Yucca Mountain, Nevada, USA" (Marshall et al.) was prepared for submission to the Organization for Economic Co-operative and Development/Nuclear Energy Agency meeting in France.

Twenty-four samples previously analyzed for Sr isotopes were analyzed for U, Th, and Pb contents as well as Pb isotopic compositions. Results were summarized in a report entitled "Pb Isotopic Composition of Carbonate Rock and Eolian Dust from the Vicinity of Yucca Mountain, Nevada" (Zartman and Kwak) for presentation at the 1993 IHLRWM Conference.

Uranium-disequilibrium series dating was attempted on very thick, well-developed pedogenic calcrete samples that were collected from the southern end of Yucca Mountain off Stagecoach Road (Solitario Canyon/Windy Wash). Initial results were complicated by open-system behavior of decay products and unusual, but reproducible, residue compositions. Additional experiments have been designed to further test whether these deposits can be dated. Personnel completed data documentation requirements in support of the Trench 14 closure package. A report entitled "Origin of Carbonate Deposits in the Yucca Mountain

Area: Results of Strontium-isotope Analyses at Trench 14 and Busted Butte" (Marshall et al.), received final revisions and will be published in a Water Resources Investigations Report (CASY volume).

Forecast: In FY 1993, regional paleoflood evaluations (SCP 8.3.1.5.2.1.1) will focus on geomorphic analysis of possible paleoflood features in the vicinity of Yucca Mountain using map data, digital landscape models, and aerial/satellite images. Results of geomorphic analysis will be combined with field-reconnaissance data to select paleoflood deposits for detailed study. A preliminary summary report on paleoflood studies will be prepared and will describe a comparison of modern and ancient geomorphic features as they relate to paleoflooding. An evaluation of several paleodischarge sites around Yucca Mountain will continue (SCP 8.3.1.5.2.1.3). This evaluation will identify potential discharge sites, attempt to determine whether they were active in the recent geologic past, and ascertain if they were discharge points for perched, local, or regional systems. The initial round of hydrologic, geochemical, and biologic data collection from wet and dry playas and springs, over a broad geographic area, will be completed. Data collection at the two analog-recharge sites will be completed (SCP 8.3.1.5.2.1.4). Historical data from the sites will be analyzed using a precipitation-runoff model. An interpretive report describing the hydrologic balance and net infiltration for the basins will be prepared. The arid-zone infiltration site will be fully instrumented to determine the development of soil geochemistry under different climatic conditions.

2.2.4.8 Study 8.3.1.5.2.2 - Characterization of the future regional hydrology due to climate changes

Study Plan 8.3.1.5.2.2 was revised in response to YMPO review comments and returned to YMPO for a verification review on April 30, 1992.

Activity 8.3.1.5.2.2.1 - Analysis of future surface-water hydrology due to climate changes. Surface-water flow models are being evaluated. The models currently under evaluation include PRMS, HSPF, A634P, and DR3M. These models are available with documentation and are fully supported by the USGS. When complete, the evaluation will define how applicable each model is for use in the arid environment of Yucca Mountain, and how effective it is in terms of predicting (modeling) large-magnitude (flash flood) runoff conditions common to the area.

Activity 8.3.1.5.2.2.2 - Analysis of future unsaturated zone hydrology due to climate changes. A change request for the SCPB was submitted to the YMPO CCB. This change proposes the elimination of this activity because the scope of work will be performed in Activity 8.3.1.2.2.9.5 (Site Unsaturated-Zone Integration and Synthesis).

Activity 8.3.1.5.2.2.3 - Evaluation of possible future changes of the climate and regional geologic framework on the regional saturated zone hydrology. A complete structural analysis of the regional study area was conducted in an attempt to evaluate the effects of stress regimes on ground-water fracture flow. A report entitled "Hydrogeologic Characterization of Structural Discontinuities of Death Valley Region, Nevada and California" (Faunt) describing results of this study is in review. Map products from the study include mapped faults and orientations, structural zones, regional principal stresses, and potential regional flow paths. Flow paths hypotheses are undergoing continual testing with regional geology and within the three-dimensional hydrogeologic framework model.

Regional studies into the mechanism of recharge and discharge continued including both remote sensing and GIS analysis. Regional mapping of vegetation using Landsat TM data was conducted. The products of this work include vegetation distribution and density maps that will be used for three-dimensional ET studies in present, past, and future ground-water flow modeling. Methods are presently being developed that will utilize both comparative and quantitative data in recharge and discharge estimation. Work was completed on the Amargosa vegetation study that will be used as a training set and analog to regional vegetation studies.

Regional Geoscience Information System (GSIS) data base draft reports describing the conversion of geology, surface hydrology, and fault maps into digital format were completed and are in peer review. These draft reports are: "Digital Geologic Maps of the Mariposa, Kingman, Trona, and Death Valley Sheets, California" (Faunt et al.) ; "Digital Hydrographic and Land Use-Land Cover Maps of the Death Valley Region, Nevada-California" (D'Agnes, et al.) ; and "Digital Fault Trace Compilation of the Death Valley Region, Nevada and California" (Faunt et al.). A hydrogeology map report entitled "Hydrogeology of the Death Valley Region, Nevada-California" (Faunt et al.) has been developed and is in review. This surface model (map) will be "digitally linked" to regional cross sections so that construction of the solid model can proceed.

Forecast: This study will be suspended during FY 1993. The future surface-hydrology activity (8.3.1.5.2.2.1) will be suspended until a sufficient base of field data has been accumulated to support precipitation-runoff modeling of basins or subbasins in the vicinity of Yucca Mountain. The future saturated-zone activity (8.3.1.5.2.2.3) will be suspended while the regional three-dimensional ground-water flow model is developed (SCP 8.3.1.2.1.4.4).

2.2.5 Erosion (SCP Section 8.3.1.6)

Work on Study Plan 8.3.1.6.1.1 has been deferred until the NRC has responded to the topical report on erosion.

Technical chapters for the DOE topical report on erosion were completed. Time and effort for this activity were transferred from work that had been planned for 8.3.1.17.4.6. YMP staff gave an oral presentation to the NRC on the technical basis for DOE's conclusions on erosion rates and processes at Yucca Mountain to the NRC in May 1992 and wrote the technical chapters for the DOE topical report in August and September 1992. Minor revisions or responses to comments are anticipated in early FY 1993. A report entitled "Erosion Rates of Yucca Mountain: Technical Assessment and Qualification of Data," (Distel, 1992) was completed. This report documents the technical assessment team's findings and the recommendation that the erosion data be qualified. A paper entitled "Qualification of Existing Data for the Yucca Mountain Site Characterization Project," (Bjerstedt, et al.) was submitted for presentation at the 1993 IHLRWM Conference.

An abstract entitled "Photogrammetric Analysis of Modern Hillslope Erosion at Yucca Mountain, Nevada" (Coe et al., 1992) was published and a manuscript entitled "Volumetric Analysis of Debris Eroded off a Hillslope near Yucca Mountain, Nevada during a Convective Rainstorm" (Coe et al.) was submitted for USGS review with eventual plans to submit to the journal Water Resources Research. These studies documented the processes, results, and implications of modern hillslope erosion at Yucca Mountain through the use of analytical photogrammetric techniques. Volumetric studies were used to determine the amount of available hillslope colluvium eroded from Jake Ridge (about 6 km east of Yucca Mountain) by debris flows during an intense summer rainstorm in 1984 that spanned two days. The report also considers the frequency of these storm events at Yucca Mountain.

A follow up study related to the long-term erosion rate work of Harrington and Whitney (1991) is nearing completion. This study uses photogrammetric methods to calculate the volume of material eroded from relict colluvial boulder deposits on Yucca Mountain. These volumes, used in combination with dates derived from rock varnish on the surface of the deposits, will be used to calculate long-term volumetric erosion rates for the mountain.

Forecast: No Study Plan development or future data gathering activities specifically to assess erosion are presently planned. Response to NRC comments on the erosion topical report is expected in 1993.

2.2.6 Postclosure tectonics (SCP Section 8.3.1.8)

2.2.6.1 Study 8.3.1.8.1.1 - Probability of magmatic disruption of the repository

NRC completed a detailed technical review (Phase II) on July 10, 1992, where 13 comments and one question were offered. A one-day video conference was held with the NRC on August 25, 1992 to discuss their comments, which are now being addressed.

PROGRESS REPORT #7

Activity 8.3.1.8.1.1.1 - Location and timing of volcanic events. No progress during the reporting period; this is an out-year activity.

Activity 8.3.1.8.1.1.2 - Evaluation of the structural controls of basaltic volcanic events. Revised tables of E1 (recurrence rate) and E2 (disruption ratio) were completed. They included new calculations by the State of Nevada for E1 and E2 and new calculations by M. Sheridan (University of Buffalo) for E2.

Activity 8.3.1.8.1.1.3 - Presence of magma bodies in the vicinity of the site. No progress during the reporting period due to lack of funding.

Activity 8.3.1.8.1.1.4 - Probability calculations and assessment. A paper entitled "Recurrence Models of Volcanic Events: Application to Volcanic Risk Assessment" (Crowe et al., 1992a) was presented at the 1992 IHLRWM Conference and published in the conference proceedings. The paper presented a probability model for volcanic risk assessment for the Yucca Mountain site. Using a simple Poisson model, the recurrence rate of volcanic events was calculated for a range of time-distribution models. Bounds for these rates were estimated from the record of volcanism at active basaltic volcanic fields in and around the Great Basin.

A paper entitled "Recent Progress in Volcanism Studies: Site Characterization Activities for the Yucca Mountain Project" (Crowe et al., 1992b) was presented at the Waste Management '92 symposium in Tucson, Arizona, and was published in the conference proceedings. The paper summarized the progress of volcanism studies for the YMP during 1991 and 1992. Geochronology, geologic mapping, and trenching studies as well as new petrology and volcanic effects are described for the Crater Flat and Paiute Ridge areas. Calculations were performed on the probability of magmatic disruption using new and previously published models. The first draft of the technical report on volcanism is in internal review.

Forecast: During FY 1993, an initial review draft of the major technical report, summarizing more than a decade of site characterization work on volcanism will be completed. Interactions with the NRC on issue resolution for volcanism studies will continue. Values of E1, the recurrence rate of volcanic events, and E2, the probability of repository disruption, will be compiled, based on the most current volcanism data. Integration of structural models of the Crater Flat area with tectonic studies of the USGS will proceed. New structural models from recent mapping performed by USGS will be incorporated in the revisions of E2. A contract to review the existing geophysical data, and its quality, will be let to an external consultant. Study Plan 8.3.1.8.1.1 will be revised in accordance with responses provided to NRC's Phase II review comments.

The major goal of this study is to put the technical report, referenced above, into formal DOE review. Field studies at Lathrop Well center will be completed by September 1993, and revised E1 and E2 tables will also be completed in the same time frame. E3 calculations will also be developed in September 1993.

2.2.6.2 Study 8.3.1.8.1.2 - Physical processes of magmatism and effects on the repository

The draft Study Plan 8.3.1.8.1.2 was completed by LANL in September 1992, and is expected to be submitted to DOE in early FY 1993.

Activity 8.3.1.8.1.2.1 - Eruptive Effects. A paper entitled "Physical Processes and Effects of Magmatism in the Yucca Mountain Region" (Valentine et al., 1992) was presented at the 1992 IHLRWM Conference in Las Vegas, Nevada, and published in the conference proceedings. This paper describes studies of possible eruptive and subsurface effects of Yucca Mountain site disruption by basaltic volcanism. The effects are studied using field characterization of analog volcanic centers and modeling of geologic processes.

Activity 8.3.1.8.1.2.2 - Subsurface effects of magmatic activity. A second phase of field work was completed at the Paiute Ridge intrusion complex, east of Yucca Flat.

Activity 8.3.1.8.1.2.3 - Magma system dynamics. A literature survey on compaction, magma segregation, mantle ascent, magma storage, and crustal ascent was completed.

Forecast: During FY 1993, the Study Plan is expected to be submitted to DOE in early FY 1993. Field work in the Fortification basalt field and the Vulcans Throne area of the Grand Canyon to determine the depth of derivation of lithic fragments in basaltic pyroclastic and lava deposits will begin. Field work will also continue for these topics in the Paiute Ridge and Crater Flat area. First calculations of E3, the probability of exceeding regulatory releases from magma ascending through a repository and erupting at the surface will be completed. These calculations will be incorporated in Study Plan 8.3.1.8.1.1, "Probability of Magmatic Disruption of the Repository." Geologic literature and physical models on the depth of development of the fragmentation surface, conduits, and intrusions below basalt centers of the Great Basin will be evaluated.

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 was sent to YMPO in August 1992 for a verification of comment resolution in August 1992.

Activities 8.3.1.8.2.1.1 through 8.3.1.8.2.1.7. There has been no progress during the reporting period in these activities; they are out-year activities.

2.2.6.4 Study 8.3.1.8.3.1 - Analysis of the effects of tectonic processes and events on average percolation flux rates over the repository

Activities 8.3.1.8.3.1.1 through 8.3.1.8.3.1.7. There has been no progress during the reporting period in these activities; they are out-year activities.

2.2.6.5 Study 8.3.1.8.3.2 - Analysis of the effects of tectonic processes and events on changes in water-table elevation

Activity 8.3.1.8.3.2.5 - Effects of faulting on water-table elevation. A report on the large hydraulic gradient under Yucca Mountain entitled "A Hydrogeologic Analysis of the Saturated-Zone Groundwater System under Yucca Mountain, Nevada" (Fridrich et al.) has been revised following USGS internal review, and will now be submitted for DOE concurrence and publication in the Journal of Hydrology.

Work supported by this activity contributed to the geologic mapping study 8.3.1.4.2.2.1. An abstract entitled "Tectonic Framework of Crater Flat Basin, Adjacent to Yucca Mountain Nevada" (Fridrich) underwent USGS and DOE review and was submitted to GSA for presentation at the annual convention in Cincinnati, Ohio, and publication in the convention proceedings.

Forecast: The USGS has proposed that one consolidated plan be developed for the current SCP investigations of the effects of tectonic processes and events on containment, the hydrologic system, and geochemical properties. YMPO is currently evaluating the proposed change.

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

Activities 8.3.1.8.3.3.1 through 8.3.1.8.3.3.3. There has been no progress during the reporting period in these activities; these are out-year activities.

2.2.6.7 Study 8.3.1.8.4.1 - Analysis of the effects of tectonic processes and events on rock geochemical properties

Activities 8.3.1.8.4.1.1 through 8.3.1.8.4.1. 4. There has been no progress during the reporting period in these activities; these are out-year activities.

2.2.6.8 Study 8.3.1.8.5.1 - Characterization of volcanic features

The NRC accepted Study Plan 8.3.1.8.5.1 on August 20, 1990. The NRC completed a detailed technical review (Phase II) on March 18, 1991, where three comments were offered. DOE sent a response to those three comments to the NRC on July 23, 1991.

Activity 8.3.1.8.5.1.1 - Volcanism drillholes. No progress during the reporting period due to lack of funding.

Activity 8.3.1.8.5.1.2 - Geochronology studies. A paper entitled "Lathrop Wells Volcanic Center: Status of Field and Geological Studies" (Crowe et al., 1992c) was presented at the 1992 IHLRWM Conference in Las Vegas, Nevada, and was published in the conference proceedings. This paper describes the status of field and geochronology studies at the Lathrop Wells volcanic center: conventional K-Ar and $^{40}Ar/^{39}Ar$ ages for the center are about 100 to 200 ka; the U-Th chronological age of Ql_4 (lava flow) is 150 ± 40 ka; the cosmogenic helium (He) age of the main cone is 25-45 ka and the age of the lavas is 65-70 ka; thermoluminescence ages range between 10 and 25 ka. Soils and geomorphic studies suggest a late Pleistocene or early Holocene age of the main cone.

An article entitled "Measuring the Age of the Lathrop Wells Volcanic Center at Yucca Mountain" (Wells et al., 1992) was published in Science on July 24, 1992. The article is a comment on the Turrin et al. (1991) article also published in Science. Alternative interpretations of $^{40}Ar/^{39}Ar$ age determinations, which incorporate the uncertainty of the measurements and the secular variation of the magnetic field, were presented.

Paleomagnetic data was evaluated for the lava flow units Ql_6, and Ql_5, and the buried lava flow (now labeled Ql_7) at the Lathrop Wells volcanic center, and a U-Th isochron was obtained for the Ql_6 lava. A large trench was constructed on the north side of the center; chemical analyses of various soils from various trenches were obtained. Calibration analyses of thermoluminescence age estimates for sample suites obtained from soils beneath lava flows in the Snake River Plains were completed.

A Detailed Technical Procedure, DP EES-13-610, "Extraction and Analysis of Noble Gases from Solid Samples," was issued.

Activity 8.3.1.8.5.1.3 - Field geological studies. Three phases of trenching at the Lathrop Wells volcanic center were completed with a total of 35 trenches excavated. A second phase of trenching at the Black Tank cone of the Cima volcanic center was completed with 9 trenches excavated. R.V. Fisher of the University of California, Santa Barbara, examined the quarry tephra units of the Lathrop Wells volcanic center and provided information on the origin of the tephra deposits. Safety plans and standard operating procedures for operation of the truck-mounted back-hoe were revised.

Activity 8.3.1.8.5.1.4. - Geochemistry of scoria sequences. Trace-element data for 40 samples were obtained and evaluated for the Lathrop Wells volcanic center.

Activity 8.3.1.8.5.1.5 - Geochemical cycles of basaltic volcanic fields. Isotopic analysis for Pb were obtained for samples of basalt from Crater Flat.

Forecast: Completion of field work and the major phase of trenching at the Lathrop Wells volcanic center is planned. Trenching and sampling at the Sleeping Butte and Crater Flat volcanic centers will begin. Evaluation of the evolutionary cycles of volcanic fields will be expanded to volcanic fields of the Great Basin and Study Plan 8.3.1.8.5.1 will be revised to make it consistent with 8.3.1.8.1.2 and 8.3.1.8.1.1.

2.2.6.9 Study 8.3.1.8.5.2 - Characterization of igneous intrusive features

Study Plan 8.3.1.8.5.2 was completed and underwent USGS internal review. The revised Study Plan was transmitted to YMPO for DOE review in September 1992.

Activities 8.3.1.8.5.2.1 through 8.3.1.8.5.2.3. No progress during the reporting period due to lack of funding.

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. Preparations were made for data collection activities including preparation and approval of all three required technical procedures, and routine maintenance of lab and field equipment. Additionally, lab balances and secondary weight standards were calibrated, a National Institute for Standards and Testing (NIST) calibration for a newly acquired standard thermometer was ordered, and modifications were made to the temperature calibration bath to improve its performance. Plans were made to collect data in the field and temperature logging was conducted in several holes that penetrate Tertiary volcanic rocks adjacent to faults on Yucca Mountain to determine the possible thermal effects of the June 29, 1992 earthquake. Reduction of the logging data was conducted. An abstract entitled "Thermal Evidence for Ground Water Flow Paths at Yucca

Mountain, Nevada" (Dudley and Sass) was submitted for presentation at the 1993 IHLRWM Conference. The abstract addresses the application of temperature data to define ground-water flow paths.

Forecast: During FY 1993, Study Plan 8.3.1.8.5.2 will be submitted to DOE. Variations of temperature with depth will be measured in existing boreholes, and thermal conductivities will be measured on core and cuttings samples.

2.2.6.10 Study 8.3.1.8.5.3 - Investigation of folds in Miocene and younger rocks of the region

Activity 8.3.1.8.5.3.1 - Evaluation of folds in Neogene rocks of the region. No progress during the reporting period; this is an out-year activity.

Forecast: No activity is planned for FY 1993.

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

Activities 8.3.1.9.1.1.1 and 8.3.1.9.1.1.2. No progress during the reporting period; this is an out-year study.

Forecast: No activity is planned for FY 1993.

2.2.7.2 Study 8.3.1.9.2.1 - Natural resource assessment of Yucca Mountain, Nye County, Nevada

The Study Plan is ready for YMPO approval, but is on hold pending a management review to ensure that relevant SCA open items are addressed in the Study Plan.

A USGS open-file report ,"Geophysical Characterization of Mineral and Energy Resources at Yucca Mountain and Vicinity, Nevada," was published (Langenheim et al., 1991).

Forecast: Investigations in FY 1993 will include geochemical sampling and analysis for mineral potential, radiometric age dating, evaluation of pre-existing geophysical surveys for anomalies of economic significance, and assessment of hydrocarbon potential in the region

by studies of potential source rocks in the recent Amargosa wildcat wells, hydrocarbon accumulations in Railroad Valley, and a search for potential source rocks in Tertiary sediments near Yucca Mountain.

2.2.7.3 Study 8.3.1.9.2.2 - Water resource assessment of Yucca Mountain, Nevada

The NRC accepted the Study Plan on May 4, 1992. They expressed one concern in their Phase I review letter, concerning how ground water was being regarded as a potential resource, and they requested specific references that were cited in the Study Plan. The former concern was responded to by DOE in a letter dated June 29, 1992, and the latter in a letter dated September 16, 1992.

Activity 8.3.1.9.2.2.1 - Projected trends in local and regional ground-water development, and estimated withdrawal rates in Southern Nevada, proximal to Yucca Mountain. No progress during the reporting period; this is an out-year study.

2.2.7.4 Study 8.3.1.9.3.1 - Evaluation of data needed to support an assessment of the likelihood of future inadvertent human intrusion at Yucca Mountain as a result of exploration and/or extraction of natural resources

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

Forecast: No activity is planned for FY 1993.

2.2.7.5 Study 8.3.1.9.3.2 - An evaluation of the potential effects of exploration for, or extraction of, natural resources on the hydrologic characteristics at Yucca Mountain

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

Forecast: No activity is planned for FY 1993.

2.2.8 Meteorology (SCP Section 8.3.1.12)

2.2.8.1 Study 8.3.1.12.1.1 - Characterization of the regional meteorological conditions

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

Forecast: No activity is planned for FY 1993.

2.2.8.2 Study 8.3.1.12.1.2 - Plan for synthesis of Yucca Mountain Site Characterization Project meteorological monitoring

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

Forecast: No activity is planned for FY 1993.

2.2.8.3 Study 8.3.1.12.2.1 - Meteorological data collection at the Yucca Mountain site

Revision 0 of Study Plan 8.3.1.12.2.1 was accepted by the NRC on November 12, 1991. YMPO review comments on Revision 1 were sent to the principal investigator on June 17, 1992.

Activity 8.3.1.12.2.1.1 - Site meteorological monitoring program. Meteorological monitoring continued at the five original sites with no significant equipment problems. The monitoring is focused on acquiring atmospheric dispersion information, that is, measurements of airflow and diffusion, but includes other meteorological monitoring for general environmental characterization that could be used for other purposes. Past data were processed in preparation for an upcoming five-year report. Three new stations began operations as of July 1, 1992. These stations were added to provide a finer resolution of airflow and general meteorological characteristics in the area near the ESF work with focus on the nighttime drainage wind patterns. The new stations are as follows: site 6 is "WT-6," at the WT-6 wellpad in upper Yucca Wash; site 7 is "Sever Wash," between Alice Hill and Fran Ridge in the eastern outflow of Midway Valley; site 8 is called "Knothead Gap," and is southeast of the C-well wellpad in the southern end of Midway Valley. The new stations were instrumented similarly to the previous four "remote" stations, with the addition and/or change of four measurements. The basic height for humidity and temperature was established as 2-m above ground level (m-agl) to comply with current monitoring guidance. Delta-temperature 10 m-agl, solar radiation, and vertical wind speed measurements were added as likely atmospheric stability indicators for future dispersion modeling work.

A limited amount of meteorological data from two calendar quarters were reported to the State of Nevada to fulfill monitoring conditions associated with Air Quality Permit No. 2693. Particulate matter data are also reported in the State reports. The air quality data are collected under environmental programs not included in the SCP. This activity is included for continuity, although outside the scope of the SCP.

Activity 8.3.1.12.2.1.2 - Data summary for input to dose assessments. No progress during the reporting period; this is an out-year activity.

Forecast: The data collection program is planned to continue throughout FY 1993. The Study Plan revision is scheduled to be completed by October 1992. Revision 0 of this Study Plan was approved by DOE on March 20, 1991. It was sent to the NRC on May 16, 1991, and was accepted on November 12, 1991, with no comments. A CAR from YMPO QA audit YMP-92-004 occurred in March 1991, with respect to variances in Study Plan format and level-of-detail requirements from administrative procedure 1.10Q (YMPO's preparation, review, approval and revision procedure for Study Plans). On March 30, 1991, YMPO directed Science Applications International Corporation (SAIC) to undertake a revision to the Study Plan to address the CAR. This revision is in preparation by SAIC. The required data will continue to be reported to the State of Nevada to maintain the air quality permit. A fourth new site (site 9), which is similar to the three new ones, is planned for the Gate-510 location along the southern border of the NTS near the community of Amargosa Valley. Work is also under way to upgrade the first five sites to the additional measurement capability of the four new sites.

2.2.8.4 Study 8.3.1.12.3 - Studies to provide data on the location of population centers relative to wind patterns in the general region of the site

This investigation on the SCP was written with no distinct studies or activities. Instead of a study plan, a Scientific Investigation Implementation Package (SIIP), which is the planning document used for investigations, was written to control work performed for this investigation. This is the first report of work on this investigation.

The SIIP entitled "Scientific Investigation Implementation Package for Characterizing Wind Patterns Relative to Population Centers" received final YMPO approval on April 1, 1992. The work in the SIIP is divided into four tasks, which can be grouped into two major efforts. Tasks 1 through 3 are planned to identify population centers and to characterize regional and local wind flow patterns relative to the centers using data from sources outside this investigation. Task 4 is planned to characterize nocturnal down-valley winds, which could be the most important wind pattern for this investigation. This task includes a special study with participation from the National Oceanic and Atmospheric Administration (NOAA) Atmospheric Turbulence and Diffusion Division (ATDD) from Oak Ridge, Tennessee.

A planning meeting for work in Task 4 was held in Las Vegas, Nevada, on September 1, 1992. It was attended by NOAA/ATDD and NOAA Weather Service office (WSNSO). WSNSO may participate in the field work in Task 4.

Forecast: During FY 1993, existing regional and local data will be compiled, and preliminary analysis will begin. Planning for the primary special field measurements will be completed and the measurements are planned for October 1993. There are no interim reports in this work.

2.2.8.5 Study 8.3.1.12.4.1 - Characterize the potential extreme weather phenomena and their recurrence intervals

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

Forecast: No activity is planned for FY 1993

2.2.9 Offsite installations and operations (SCP Section 8.3.1.13)

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

2.2.10 Surface characteristics (SCP Section 8.3.1.14)

The DOE responded on August 31, 1992, to NRC concerns about the level-of-detail in the Study Plan expressed in their Phase I review of the Study Plan. DOE also responded on August 21, 1992 to ten comments on this Study Plan from the State of Nevada.

2.2.10.1 Study 8.3.1.14.2.1 - Exploration program

This study began in October 1991 and was essentially competed in March 1992. The purpose of this reconnaissance study was to identify the locations for a series of soil test pits to be excavated.

2.2.10.2 Study 8.3.1.14.2.2 - Laboratory tests and material property measurements

All of the north ramp ESF test pits, 33, were excavated and the in-place testing was completed in May 1992. Removal of the typical 0.3-0.6 m (1-2 ft) of topsoil to the widespread caliche-cemented gravelly material is expected to provide an excellent foundation for the anticipated north ramp surface facility structures. Data from density and caliper logs and check shot data will be used to determine dynamic moduli for the rock and alluvium. Drill hole UE-25NRG#1 was completed in June 1992, and pit wall mapping of the test pits was completed. The core was received in July 1992 by the USBR laboratory in Denver, and testing of core is under way to provide data needed by RSN to complete design work and verification for pad construction. Geophysical logging of UE-25NRG#1 is scheduled for completion in November 1992. The work to clear a pavement adjacent to UE-25NRG#1 was finished, and detail line surveys were run to provide the fracture information requested for ESF design.

Laboratory investigations under this activity tested a range of soil and rock properties. This was a major effort in May-June 1992 with soil gradations, and relative and/or Proctor densities determined for seven representative locations.

Soil and rock properties (engineering data) were reviewed as acquired and submitted for use in the design process for surface facilities. Logs and laboratory test data for representative soil materials were submitted to YMPO's TDB in September 1992.

The draft reports for field testing of physical properties of the rock, for engineering geophysical evaluation, for laboratory investigation of physical and mechanical properties of samples, and for field measurements of mechanical properties of materials in the North Ramp site area were submitted to the ESF designers in June 1992. The check shot equipment was tested at the site in September 1992.

U.S. Bureau of Reclamation (USBR) participants met in September 1992 with USGS representatives and discussed adjustments to the north ramp and south ramp geotechnical drilling plans in response to DOE requests.

2.2.10.3 Study 8.3.1.14.2.3 - Field tests and characterization measurements

No progress during the reporting period due to lack of funding.

Forecast: In FY 1993, field activities, which include geologic mapping, core drilling, test pit excavation, and field soil and geophysical testing will be conducted along the proposed south ramp. Maps will be submitted at a scale of 1:500.

Laboratory tests on soils will consist of gradations (approximately 100) to assess engineering properties. For UE-25NRG#1 core, triaxial and direct shear testing (approximately 15) to determine mechanical properties such as friction angle and cohesion, one-dimensional consolidation, relative densities and/or Proctor densities (approximately 50) and compaction methods are to be done. Laboratory tests of rock samples will consist typically of uniaxial and triaxial shear and direct shear testing (approximately 30), direct tension testing, and dynamic tests including sonic velocities (approximately 50). A variety of indirect tests such as point load, Brazilian, and Schmidt Hammer type, as appropriate, will be performed to determine tensile strengths and uniaxial compressive strengths.

Depending on the final location of the south portal, exploration will consist of an extensive test pitting program. Approximately 30 test pits will be excavated, logged, and sampled. Approximately 100 soil samples will be collected for testing. Typical field soil testing will consist of determining densities (approximately 24 tests) and determining soil conditions; densities provide an indication of bearing capacity and settlement potential.

Standard penetration testing will be done if fine-grained materials are encountered to assess bearing capacity of the material. Dynamic tests include p- and s- wave velocity determination utilizing the portal drill holes. Field exploration in rock will consist of vertical (approximately two holes) and angle-holes (approximately four), and geotechnical geophysical testing. Typical in situ rock conditions will be determined using dynamic tests including p- and s-wave velocity determination. Discontinuities will be evaluated, especially in relation to stability of cutslopes and underground excavations.

2.2.11 Thermal and mechanical rock properties (SCP Section 8.3.1.15)

2.2.11.1 Study 8.3.1.15.1.1 - Laboratory thermal properties

The Study Plan, which had been approved by YMPO and sent to the NRC in January 1991, is being revised to incorporate changes to the ESF design. The NRC had informed DOE that they were deferring their acceptance review until ESF-related Study Plans were updated to the new ESF configuration. The revisions will be submitted to YMPO by November 1992.

Activity 8.3.1.15.1.1.1 - Density and porosity characterization. Review comments on the paper entitled "An Experimental Comparison of Laboratory Techniques in Determining Bulk Properties of Tuffaceous Rocks" (Boyd et al.) are being resolved.

Activity 8.3.1.15.1.1.2 - Volumetric heat capacity characterization. No progress during this reporting period; this activity was not funded in 1992.

Activity 8.3.1.15.1.1.3 - Thermal conductivity characterization. The C-Matic low temperature (LT) instrument is being prepared for the scoping study on the effects of saturation on thermal conductivity. The LT is used to measure thermal conductivity at temperatures from 20 to 100 °C. The system was overhauled because of erratic output from the heat flux transducers. Internal thermocouples were calibrated and installed in the instrument and modifications were made that simplify the procedure for calibrating the permanent thermocouples and digital voltmeter. The system, including the permanent thermocouples, reference thermocouples, electronic ice reference, and the data acquisition unit, was calibrated using approved calibration standards. Calibration and verification runs using the moisture containment cell are in process. The moisture containment cell is used to maintain sample saturation during thermal conductivity measurements. The guard differential is being adjusted to account for the interface resistance using the moisture containment cell. Heat-sink compound has not been used between the interfaces of the moisture containment cell and the samples because it may be absorbed into the rock pores after it is applied between testing cycles. A suitable medium is being sought to reduce the interface resistance.

PROGRESS REPORT #7

Calibration of the Thermal Conductivity Analyzer (TCA) using approved calibration standards was completed. Problems in verifying the calibration at 110 °C were caused by variances in sample-plate interfaces caused by inadequate application of heat-sink compound. The data acquisition software has been approved, as the successful calibration of the TCA using reference materials of known values satisfies the software verification requirements. The TCA will be used for thermal conductivity measurements made at or above 110 °C.

Calibration of the comparative instrument, which will be used in the scoping study to examine the effects of a fracture on thermal conductivity, has been completed. Several procedures were modified including "Saturation Effects on Thermal Conductivity," "Calibration of Temperature Sensors Used for Thermal Properties Testing," and "Calibration of Mechanical and Electrical Measuring Equipment Used for Thermal Properties Testing." A draft of the procedure "Calibration of Lawson Board Systems" has been written. This procedure uses an electronic ice reference to calibrate the Lawson thermocouple board and Lawson A/D board used in the TCA.

A QA audit was completed at Holometrix, Inc. The audit focused on documentation to confirm that test prerequisites are met for the scoping study on the effects of saturation on thermal conductivity. No major QA findings were reported and the audit has been closed out. SNL has contracted Holometrix, Inc. to perform thermal conductivity, heat capacity, and thermal expansion testing.

Forecast: A report "An Experimental Comparison of Laboratory Techniques in Determining Bulk Properties of Tuffaceous Rocks" (Boyd et al.) will be published during FY 1993.

The scoping study on the effects of saturation on thermal conductivity will begin after the C-Matic LT instrument is calibrated with the moisture containment cell, the data acquisition software is verified and approved, and the relevant procedures/revisions are issued. Three samples of welded devitrified tuff and three samples of nonwelded zeolitic tuff will be used for this study. The thermal conductivity of each sample will be measured at nominal temperatures of 30, 50, and 70 °C, at five different saturation states (fully saturated, oven-dry, air-dry, and two other intermediate states). The estimated completion date is February 15, 1993. The data and analysis report for this scoping study is estimated to be complete by August 1, 1993.

The scoping study on the effects of confining pressure and fractures will be completed. Two samples of welded devitrified tuff will be measured at a nominal temperature of 30 °C. Each sample will be then be cut in half perpendicular to the sample axis, the cut surfaces will be roughened, and the halves will be rejoined. The thermal conductivity will be remeasured at 30 °C as a function of stress applied normal to the artificial fractures. Confining pressures

of 0, 2.5, 5, 7.5 and 10 MPa will be used. The estimated completion date is March 15, 1993. The data and analysis report for this scoping study is estimated to be completed by September 1, 1993.

2.2.11.2 Study 8.3.1.15.1.2 - Laboratory thermal expansion testing

The Study Plan, which had been approved by YMPO and sent to the NRC in October 1990, is being revised to incorporate changes to the ESF design. The NRC had informed DOE that they were deferring their acceptance review until ESF-related Study Plans were updated to the new ESF configuration. The revisions will be submitted to the YMPO by November 1992.

Activity 8.3.1.15.1.2.1 - Thermal expansion characterization. A report entitled "Linear Thermal Expansion Data for Tuffs From the Unsaturated Zone at Yucca Mountain, Nevada" (Schwartz and Chocas, 1992) was published in July 1992.

Efforts focused on stabilizing the drift in the linear variable differential transformer (LVDT) of the dilatometer during long runs in which the temperature is held constant and the sample is allowed to dehydrate. The drift was attributed to changes in the LVDT temperature as driven by room temperature. Variations in the signal conditioner temperature were determined to have a minimal effect, if any, on the LVDT drift. The LVDT chamber was insulated and a heating element with a power supply/controller unit was integrated into the dilatometer apparatus to control the temperature of the LVDT chamber. A power supply/controller was also incorporated into the saturation test apparatus (STA) to regulate the water temperature. A series of verification runs of the dilatometer with the STA installed were completed. The temperature of the LVDT chamber has been controlled at 30 °C during these runs and the drift ($\Delta\mu$) during the isothermal segment of the run has been minimal ($<1\mu$). Also, the signal conditioner was replaced and calibration factors for this unit were established. Glitches in the data acquisition code that were identified during the verification runs were corrected. The calibration runs used a 10.16-cm (4-in.) borosilicate glass reference sample and the sample was heated and cooled at a rate of ≤ 1 °C/min. Water was drained from the STA when the sample reached about 100 °C (on heatup) and the sample then was allowed to soak at 125 °C for 10 hours. Afterwards, the sample was heated to 325 °C and then allowed to cool to ambient. The maximum difference between the expected expansion and the measured expansion was -6.82 percent. A series of calibration and verification runs using the same parameters with a 2.54-cm (1-in.) borosilicate glass sample will be conducted after a sample holder to accommodate the shorter sample length is fabricated.

PROGRESS REPORT #7

The draft procedure, "Measurement of Thermal Expansion of Geologic Samples Using a Push Rod Dilatometer," is being revised and a draft procedure, "Effects of Sample Size on Thermal Expansion," has been written and is being reviewed.

Forecast: The scoping study on the effect of sample size on thermal expansion will be initiated after the accuracy and reproducibility of the test data are established, data acquisition software is verified and approved, and relevant procedures are issued. The linear thermal expansion of five samples of each of four different lithologies of two different sample sizes will be measured during this study. The samples will be heated at a controlled rate of ≤1 °C/min, and the atmosphere surrounding the sample during testing will be controlled to minimize sample dehydration at temperatures below the nominal boiling temperature of 100 °C. When this temperature is reached, temperature will be held constant and the sample allowed to dehydrate until the length stabilizes. The heating will continue until the maximum temperature planned for the experiment is reached, then the sample will be cooled at a controlled rate of ≤1 °C/min. Estimated completion date for testing is May 15, 1993. A preliminary draft of the data and analysis report for this scoping study will be completed by September 30, 1993.

The scoping study on the effects of sample saturation on thermal expansion will begin after completion of the scoping study on the sample size effects. Three initial saturation states will be examined (fully saturated, air-dry, and oven-dry). For these tests, the preconditioned samples will be heated to 100 °C, allowed to dehydrate, heated to 125 °C, then allowed to cool. The estimated date for initiation of these tests is September 15, 1993. The data and analysis reports will not be completed during FY 1993.

2.2.11.3 Study 8.3.1.15.1.3 - Laboratory determination of mechanical properties of intact rock

The Study Plan, which had been approved by YMPO and sent to the NRC in June 1991, is being revised to incorporate changes to the ESF design. The NRC had informed DOE that they were deferring their acceptance review until ESF-related Study Plans were updated to the new ESF configuration.

Activity 8.3.1.15.1.3.1 - Compressive mechanical properties of intact rock at baseline experiment conditions. Samples are not yet available for this testing effort; however, the prototype experiments have been completed and the technical procedures necessary for future testing at baseline conditions are being drafted in anticipation of sample availability in the next one to three years.

Testing of several rock types has been conducted at eight government and private rock mechanics laboratories in support of the American Society for Testing and Materials

(ASTM)/Institute for Standards Research (ISR)/ Steering Committee for the Interlaboratory Testing Program for Rock Properties. An SNL staff member is serving on the committee and has provided test data from contractors for the Phase I testing. The results have been analyzed and a report has been written summarizing the results. The report also suggests measures of precision for published rock-property standard ASTM test methods. The results, conclusions, and recommendations of the committee were presented during a meeting at the NAS in Washington, D.C. on July 21, 1992.

Activity 8.3.1.15.1.3.2 - Effects of variable environmental conditions on mechanical properties. New England Research, Inc. (NER) is conducting a study involving experiments on samples of welded Topopah Spring Member tuff at low strain-rate and creep (constant stress) conditions in order to investigate the time-dependent behavior of the intact rock. The series of experiments run at a nominal axial strain rate of 10^{-9} s^{-1} (inverse seconds; one over seconds) has been completed. The preparations for the series of constant stress (creep) experiments are complete and the first experiment has been initiated.

The data have been collected and reduced for the completed series of six experiments on saturated samples tested at room temperature and pressure and a nominal axial strain rate of 10^{-9} s^{-1}. This information has been reported in a document entitled "Unconfined Compression Experiments on Topopah Spring Member Tuff at 22 °C and a Strain Rate of 10^{-9} s^{-1}: Data Report" (Martin et al.). The data will be analyzed and the results published in an analysis report at a later date.

The first of six creep experiments is being performed. For each experiment, a sample is saturated and tested at a pore pressure of 4.5 MPa, a confining pressure of 5 MPa, and a constant differential (or creep) stress of 80 MPa. An experiment will have two phases: the first will be performed at room temperature for a week and, during the second phase, the sample will be tested at 250 °C for two months. With the appropriate calibrations and aluminum system calibration checks, the tests will each take approximately four months to complete and the series should be completed in 1994.

A report entitled "Anisotropy of Topopah Spring Member Welded Tuff" (Martin et al., 1992) was approved and published in July 1992. "The Influence of Strain Rate and Sample Inhomogeneity on the Moduli and Strength of Topopah Spring Member Tuff" (Price et al.) was presented at the 1992 AGU Spring meeting on May 11-16, 1992, in Montreal, Canada. The abstract was published in April 1992 in the Transactions of the AGU. "Modulus Dispersion and Attenuation in Tuff, Sandstone, and Granite" (Haupt et al.) was presented at the 33rd U.S. Symposium on Rock Mechanics, on June 8-10, 1992, in Santa Fe, New Mexico. A paper summarizing the presentation was published in the conference proceedings.

A paper entitled "Characterization of Porosity in Support of Mechanical Property Analysis" (Price et al.) has been submitted for presentation at the 1993 IHLRWM Conference.

A paper entitled "The Influence of Strain Rate and Sample Inhomogeneity on the Moduli and Strength of Topopah Spring Member Tuff" (Price et al.) has been submitted for consideration to be presented at the 34rd U.S. Symposium on Rock Mechanics. The conference will be held on June 27-30, 1993, in Madison, Wisconsin, and the paper will be published in the conference proceedings.

Two additional reports entitled "Experimental Comparison of Laboratory Techniques in Determining Bulk Properties of Tuffaceous Rocks" (Boyd et al.) and "The Effect of Frequency on Young's Modulus and Seismic Wave Attenuation in Tuff" (Martin et al.) have been written and are in internal review.

Forecast: Minor support will be given to the ASTM/ISR Steering Committee for the Interlaboratory Testing Program for Rock Properties. A few experiments will be performed at NER and an SNL staff member will continue to serve on the committee.

NER will be continuing a study involving experiments on samples of welded Topopah Spring Member tuff to investigate the time-dependent behavior of the intact rock. The results from a series of experiments run at a nominal axial strain rate of 10^{-9} s^{-1} will be interpreted and published. The first of six creep experiments at a constant differential (or creep) stress of 80 MPa is being performed. This experiment will be completed and at least three more will be initiated during the next year. In addition, several conference papers and other reports summarizing results from several aspects of this study will be drafted.

2.2.11.4 Study 8.3.1.15.1.4 - Laboratory determination of the mechanical properties of fractures

Study Plan 8.3.1.15.1.4 completed YMPO's screening review and comments were returned to SNL in May 1992.

Activity 8.3.1.15.1.4.1 - Mechanical properties of fractures at baseline experiment conditions. Samples are not yet available for this testing effort; however, studies are proceeding to define the baseline-condition test technique and the approach for future characterization of fracture topography.

Several SNL staff members comprise the Fracture Properties Working Group which met seven times during the last six months to discuss testing plans and progress. The discussions centered on the need to revise the Study Plan and planning for an investigation of the physical significance of some empirically derived fracture models.

Detailed characterization and analysis of fracture surfaces will aid in the interpretation of mechanical properties (e.g., normal stiffness, shear stiffness, and frictional shear strength)

and transport properties (e.g., fluid and solute transport). To accomplish this, a laser profilometer has been designed, built, and tested. During this six-month period, the existing profilometer system (profiler and software) has been adapted to profile circular samples, as used in rotary friction (axial compression-torsion) experiments on thin-walled cylinders with a fracture oriented perpendicular to the cylinder axis. Previous to this improvement, only linear profiles could be taken.

In an initial study to determine the variability of the roughness of natural fracture surfaces, the topographies of seventeen natural fractures from various rock types (including tuff from Yucca Mountain) were profiled. These data are being analyzed to quantify the roughness of each surface, its scaling (size-dependent) properties, and the degree of mismatch between the two opposing surfaces. A simple mathematical model of rough fractures has been developed based on these data. Using this simple model, a computer code is being developed for simulation of the frictional shear strength of rock fractures. Simulations using this code will allow some physical insight into empirically derived relationships commonly used in engineering geology for design of structures in rock. The data and analyses are being included in a report being drafted for submittal to a technical journal.

A study addressing what variables are important for inclusion into the constitutive description of fractures is continuing. Experiments will be performed on artificial (relatively smooth) and natural (rough) fractures. The analysis is continuing on a series of experiments on artificial fractures in samples of welded Topopah Spring Member tuff. These experiments were designed to study the effect of water in rate-stepping experiments. A creep experiment on a sample with an artificially produced fracture oriented approximately 35 degrees to the sample axis is continuing. The test will be completed in the next few months and the resulting data analyzed.

<u>Activity 8.3.1.15.1.4.2 - Effects of variable environmental conditions on mechanical properties of fractures.</u> Amonton's law ($\tau = \mu\sigma$, where τ is the shear stress parallel to the fracture, σ is the normal stress across the fracture, and μ is called the coefficient of friction) is the most common relationship used to describe the mechanical properties of relatively smooth (or artificial) fractures. A study is continuing that begins to address whether other variables (e.g., time of stationary contact, velocity of sliding, degree of saturation, temperature, and history) are important for inclusion into the constitutive description, or whether the simple formulation of Amonton's law is sufficient for most modeling efforts. The preliminary results indicate that these other variables produce second-order effects and may be required.

The frictional behavior of artificially produced (i.e., relatively "smooth") fractures was investigated using a range of stress paths. Following shear deformation, the subsequent behavior is highly dependent on whether the fracture remains primed (i.e., normal stress is not relieved).

PROGRESS REPORT #7

One of the major reasons for performing the majority of characterization experiments on artificially produced surfaces is that each natural fracture surface has a unique topography and individual relationship between the two surfaces. One way of studying a natural fracture in a detailed, statistical way is to create a mold of each surface and then cast multiple replicas of the original surfaces for testing. This has been done for a few natural fractures in tuff using potting rubber and gypsum cement for the mold and cast, respectively. The replicas will be tested multiple times at a single set of conditions and various sets of environmental conditions to compare with the results obtained in the artificially produced fractures in tuff.

The time-dependent mechanical properties of fractures are being investigated to address long-term stability issues within the potential repository. Experiments have been completed on artificial fractures in samples of welded Topopah Spring Member tuff to study the effect of water in rate-stepping experiments. Fracture samples were tested at room dry and saturated conditions, with rates varying form 10^{-1} to 10^{2} μm/s. A sample under constant normal stress is sheared at a constant velocity until the shear stress reaches steady state. At that time, the shearing velocity is changed by an order of magnitude. The response of the sample, in terms of the shear stress required to continue sliding at the induced velocity, is recorded and analyzed. Preliminary analysis of the data has indicated that there is very little, if any, difference in the shear behavior at these two saturation conditions.

In an additional study of time-dependent properties, a sample (right-circular cylinder, diameter of approximately 54 mm, and a length-to-diameter ratio of 3:1) with an artificially produced fracture oriented approximately 35 degrees to the sample axis is being tested under creep (constant shear stress) conditions. The confining pressure and the initial axial stress difference were both set at 10 MPa, which gives a ratio of shear-to-normal stress on the surface of about 0.36. The value for fully established sliding would be in the range of 0.6-0.7. The sample is at room temperature and vented to the atmosphere. The axial stress difference will be increased every week or so until time-dependent sliding is observed.

A presentation entitled "Shear Response of a Rock Joint Under Different Boundary Conditions: An Experimental Study" (Wibowo et al., 1992) was made at the Fractured and Jointed Rock Masses Conference on June 3-5, 1992, in Lake Tahoe, California. A paper summarizing the presentation was published in the conference proceedings. A report entitled "Effect of Boundary Conditions on the Strength and Deformability of Replicas of Natural Fractures in Welded Tuff" (Wibowo et al.) has been written and is in SNL review.

Forecast: Study Plan 8.3.1.15.1.4, "Laboratory Determination of the Mechanical Properties of Fractures" is being revised in response to YMP review comments. The plan will be returned to the YMPO in the next few months.

The characterization and analysis of fracture surfaces will continue. The initial study to determine the variability of the roughness of natural fracture surfaces is being reported in

an article to be submitted to an appropriate journal in the next few months. Three reports will be in the review process during the FY 1993. These reports detail the data, results, and analysis of a study entitled "Effect of Boundary Conditions on the Strength and Deformability of Replicas of Natural Fractures in Welded Tuff."

2.2.11.5 Study 8.3.1.15.1.5 - Excavation investigations

The Study Plan, which had been approved by YMPO and sent to the NRC in February 1989, is being revised to incorporate changes to the ESF design. The NRC had informed DOE that they were deferring their acceptance review until ESF-related Study Plans were updated to the new ESF configuration.

SNL hosted a meeting of the Rock Mechanics Review Panel on June 11-12, 1992. The Rock Mechanics Review Panel consists of six independent, objective, and highly qualified experts in rock mechanics who provide advice and technical recommendations to SNL's rock mechanics investigators. SNL's current plans for the testing in the ESF were presented to the panel and the discussions with the panel that followed helped advance the design of the ESF experiments. These design enhancements, which should result in better test measurements when the experiments are fielded, will be incorporated into revisions of the applicable Study Plans.

A technical exchange was held with staff from the Canadian Underground Research Laboratory. Fielding of a large mining test was discussed along with instrumentation problems and in situ stress measurement techniques. SNL staff benefitted greatly from the interchange. A letter report on the interchange was forwarded to DOE.

Activities 8.3.1.15.1.5.1 through 8.3.1.15.1.5.3. No progress during the reporting period; these are out-year activities.

Forecast: During FY 1993, Study Plan 8.3.1.15.1.5, "Excavation Investigations," will be revised to reflect the change in the ESF configuration from shaft access to ramp access, and to reflect the change in mining method from drill-and-blast to mechanical mining using a TBM. It is anticipated that the revised Study Plan will be submitted to YMPO before the end of FY 1993. Additionally, SNL will provide support to the LANL Test Coordination Office in developing test planning packages (TPPs) for the SNL ESF tests. This will be a minimal effort to define critical design information for the TPPs and the ESFDR Appendix B for Title II design. No activity is planned for Activities 8.3.1.15.1.1.1, 8.3.1.15.1.5.2, or 8.3.1.15.1.3.

2.2.11.6 Study 8.3.1.15.1.6 - In situ thermomechanical properties

The Study Plan for this study is being scoped by SNL.

A report on the thermal effects on instrumentation was finished. The report will support the ESF thermomechanical experiments. The report lists the instruments that will be required in the experiments, along with their required accuracy, range, and temperature capabilities. This list is matched with off-the-shelf instrumentation, where possible, and notes where this is not possible. New technologies, such as fiber optics, and advanced materials, such as graphite composites, that hold promise for use in developing those instruments that cannot be obtained as off-the-shelf items are discussed. The performance of geologic test instruments in other thermomechanical experiments is reviewed.

Written material detailing the basis for SNL's estimates of the cost of the in situ thermomechanical properties experiments was provided to the Independent Cost Estimation (ICE) Team. Detailed discussions were held with the members of the team to allow an independent estimate of the cost of the experiments to be made.

SNL provided support to the writing of a heater test duration decision paper. This paper examines alternative means of providing the information needed from the planned in situ coupled hydrothermal tests.

Activities 8.3.1.15.1.6.1 through 8.3.1.15.1.6.5. There has been no progress during the reporting period; these are out-year activities.

Forecast: During FY 1993, the writing of Study Plan 8.3.1.15.1.6 will begin. Additionally, efforts at test consolidation between the SNL ESF thermal-mechanical tests and the LLNL thermal-hydrologic tests will be supported.

2.2.11.7 Study 8.3.1.15.1.7 - In situ mechanical properties

The work to be performed under this activity is described in Study Plan 8.3.1.15.1.7. Written material detailing the basis for SNL's estimates of cost of the in situ mechanical properties experiments, as documented in the PACS system, was provided to the ICE Team. Detailed discussions were held with the members of the team to allow an independent estimate of the cost of the experiments to be made. Clarification was provided to the ICE Team to explain differences between SNL's PACS estimates and the ICE Team's estimates for this activity.

Activities 8.3.1.15.1.7.1 and 8.3.1.15.1.7. 2. No progress during the reporting period; these are out-year activities.

Forecast: During FY 1993, the writing of Study Plan 8.3.1.15.1.7 will begin. Also, SNL will provide support to the LANL Test Coordination Office in developing TPPs for the SNL ESF tests. This will be a minimal effort to define critical design information for the TPPs and the ESFDR Appendix B for Title II design. No activity is planned for Activities 8.3.1.15.1.7.1 or 8.3.1.15.1.17.2.

2.2.11.8 Study 8.3.1.15.1.8 - In situ design verification

YMPO reviewer comments on Study Plan 8.3.1.15.1.8 were reviewed and proposed resolutions to each of the comments were developed. Additionally, to be consistent with the new ESF configuration, substantial portions of this Study Plan were rewritten and incorporated into the proposed resolutions. The comment resolution meeting is planned for January 12, 1992.

Activities 8.3.1.15.1.8.1 through 8.3.1.15.1.8. 4. No progress during the reporting period; these are out-year activities.

Forecast: SNL will support the LANL Test Coordination Office in developing TPPs for the SNL ESF tests. This will be a minimal effort to define critical design information for the TPPs and the ESFDR Appendix B for Title II design. The revision of Study Plan 8.3.1.15.1.8, incorporating the change in configuration and construction method of the ESF, will be completed. No activity is planned for Activities 8.3.1.15.1.8.1, 8.3.1.15.1.8.2, 8.3.1.15.1.8.3, or 8.3.1.15.1.8.4.

2.2.11.9 Study 8.3.1.15.2.1 - Characterization of the site ambient stress conditions

The Study Plan, which had been approved by YMPO and sent to the NRC in February 1989, is being revised to incorporate changes to the ESF design. The NRC had informed DOE that they were deferring their acceptance review until ESF-related Study Plans were updated to the new ESF configuration.

Forecast: No activity is planned for FY 1993.

2.2.11.10 Study 8.3.1.15.2.2 - Characterization of the site ambient thermal conditions

The Study Plan is in internal SNL review and will be submitted to YMPO early in FY 1993.

Forecast: Existing and new temperature logs will be compiled, evaluated, and processed for inclusion in the YMP TDB.

2.2.12 Preclosure hydrology (SCP Section 8.3.1.16)

2.2.12.1 Study 8.3.1.16.1.1 - Characterization of flood potential of the Yucca Mountain site

DOE responded to two concerns expressed in NRC's Phase I review in a letter to the NRC dated September 3, 1992.

Activity 8.3.1.16.1.1.1 - Site flood and debris hazards studies. Isolated thunderstorms during the period April 1, 1992, to September 30, 1992, caused flooding and debris transport in areas of central and northern Nevada. Damage to private and public property was severe in some cases, but no injuries or deaths were reported. Data were collected and documented for further evaluation and interpretation of the mechanisms that caused debris transport to occur. Data were also collected on minor runoff which occurred along Cano Springs Wash, NTS, and along the Amargosa River at Eagle Mountain, Tecopa, and Westside Road in southern Death Valley.

Analysis and evaluation of FY 1991 flood data were completed. Interpretation of the results will take place during a multiyear analysis phase during which the FY 1991 floods will be compared and contrasted with those that occurred during the period 1983-92.

An interpretive report on the 1984 debris flows at Jake's point near Yucca Mountain is being prepared. An aerial reconnaissance of the mouth of Fortymile Wash was conducted to determine a method for deriving the flow paths of recent floods. It was determined that detailed maps could be prepared to accurately delineate the locations and paths of floodwaters that may have recently flowed through a distributary stream network which extends from Fortymile Wash Canyon to the Amargosa River.

Forecast: This study, beyond monitoring of emplaced instrumentation, will be placed on hold during FY 1993, pending a decision as to whether or not more data needs to be collected.

2.2.12.2 Study 8.3.1.16.2.1 - Location of adequate water supply for construction, operation, closure, and decommissioning of a mined geologic disposal system at Yucca Mountain, Nevada

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

Forecast: No activity is planned for FY 1993.

2.2.12.3 Study 8.3.1.16.3.1 - Determination of the preclosure hydrologic conditions of the unsaturated zone at Yucca Mountain, Nevada

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

Forecast: No activity is planned for FY 1993.

2.2.13 Preclosure tectonics (SCP Section 8.3.1.17)

2.2.13.1 Study 8.3.1.17.1.1 - Potential for ash fall at the site

Activities 8.3.1.17.1.1.1 through 8.3.1.17.1.1.3. No progress during the reporting period due to lack of funding.

Forecast: No activity is planned for FY 1993.

2.2.13.2 Study 8.3.1.17.2.1 - Faulting potential at the repository

Activities 8.3.1.17.2.1.1 and 8.3.1.17.2.1.2. No progress during the reporting period; these are out-year activities.

Forecast: No activity is planned for FY 1993.

2.2.13.3 Study 8.3.1.17.3.1 - Relevant earthquake sources

The NRC accepted the Study Plan in a Phase I review letter dated May 18, 1992.

No progress during the reporting period due to lack of funding.

Forecast: Work this year will focus on developing the methodology to be used for a seismic hazard evaluation of Yucca Mountain and to prepare documentation of DOE's proposed approach for the NRC.

2.2.13.4 Study 8.3.1.17.3.2 - Underground nuclear explosion sources

Activities 8.3.1.17.3.2.1 and 8.3.1.17.3.2.2. No progress during the reporting period; this is an out-year activity.

Forecast: No activity is planned for FY 1993.

2.2.13.5 Study 8.3.1.17.3.3 - Ground motion from regional earthquakes and underground nuclear explosions

The Study Plan has completed YMPO review, and resolution of comments is underway.

Activity 8.3.1.17.3.3.1 - Select or develop empirical models for earthquake ground motions. Work elements include: (1) selection and (or) development of empirical ground-motion models that are appropriate for estimating earthquake ground motions at the site, and (2) collecting and synthesizing ground-motion data from the Great Basin and other regions that are tectonically analogous and which may be useful in selecting the most appropriate model.

Activity 8.3.1.17.3.3.2 - Select or develop empirical models for ground motion from underground nuclear explosions. Data-collection efforts for this activity were halted because of reductions in funding.

A report entitled "A Statistical Analysis of Ground Motion Resulting from Underground Nuclear Explosions in the Yucca Mountain Region" (Rutherford) was submitted for internal SNL review. This report explains the results of a modeling effort designed to predict ground motion in the region and to provide details of the statistical analysis performed to construct the model. Predictions based on this model are provided that can be compared to the predictions of ground motion from other seismic sources to determine the appropriate design for the proposed repository.

Forecast: Empirical ground-motion models will be used to predict ground motion at the potential repository site as a function of earthquake magnitude and distance between the earthquake source and the site.

Finite-difference synthetic seismograms will be used to investigate the causes for observed differences between downhole and uphole UNE waveforms recorded at Yucca Mountain. The computer code used for seismic transmission studies will be adapted to allow for an input waveform. Modeling will include propagation of the known downhole waveforms up to the surface through estimated structures based on geologic information and well logs. Prior to modeling, available geologic information will be carefully reviewed, and characteristic waveforms inspected in order to form reasonable starting models. Modeling results will be documented in a report. Evaluation of old data sets as candidates for a qualification process will be completed.

2.2.13.6 Study 8.3.1.17.3.4 - Effects of local site geology on surface and subsurface motions

The NRC accepted the Study Plan in a Phase I review letter dated June 8, 1992. A response to a minor concern in this letter was being prepared for transmittal to the NRC.

Forecast: During FY 1993, work will continue in the following areas: (1) determination from ground-motion records, systematic effects of the local site geology on surface and subsurface motions, (2) identification of any significant site-wide bias in ground-motion levels, as compared with average levels for the Southern Great Basin, (3) recording of ground-motion at several stations or in one or more boreholes in order to calibrate theoretical models and determine motion averages of surface facilities location, and (4) estimation of spectral amplification functions and amplification factors for peak ground-motion parameters.

2.2.13.7 Study 8.3.1.17.3.5 - Ground motion at the site from controlling seismic events

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

Forecast: No activity is planned for FY 1993.

2.2.13.8 Study 8.3.1.17.3.6 - Probabilistic seismic hazards analyses

Activities 8.3.1.17.3.6.1 and 8.3.1.17.3.6.2. No progress during the reporting period; these are out-year activities.

Forecast: Development of a Study Plan is scheduled during FY 1993.

2.2.13.9 Study 8.3.1.17.4.1 - Historical and current seismicity

The NRC accepted Study Plan 8.3.1.17.4.1 on May 14, 1991.

Activity 8.3.1.17.4.1.1 - Compile historical earthquake record. No progress during the reporting period. Work is scheduled to begin in 1993.

Activity 8.3.1.17.4.1.2 - Monitor current seismicity. Continuous monitoring of the SGBSN enabled successful recordings of a large number of seismic events during the reporting period. Lab and field testing continued and six new stations and one node were added to the seismic network. A 1991 earthquake catalog entitled "Seismicity and Focal Mechanisms for the Southern Great Basin of Nevada and California, in 1991" (Harmsen) went through USGS review and was submitted for DOE approval.

Personnel worked very hard at short notice to deploy portable seismographs to record aftershocks of the Little Skull Mountain earthquake during the period of June 29 - July 14, 1992. Personnel were on duty 24 hours a day to keep the data collection system operational and perform routine processing of incoming data. During this period, a backlog of more than 160 data tapes was accumulated due to the high rate of incoming data from monitoring of aftershocks in the vicinity of Little Skull Mountain and throughout the network.

Considerable work has effected a relatively smooth transition of the SGBSN from management by the USGS Branch of Geologic Risk Assessment (BGRA) to the UNRSL. Cooperation between BGRA and UNRSL continued, data and preliminary results were exchanged on a regular basis and seismological recording equipment was transported to Reno, Nevada. UNRSL staff conducted numerous tasks to prepare for reception of the SGBSN.

An informational "white paper" titled "The Little Skull Mountain Earthquake of June 29, 1992" was prepared by USGS/UNRSL staff at the request of the YMPO Project Manager. The letter report contained basic information on the earthquake, including parameters measured by SGBSN instrumentation and effects of the earthquake on the immediate area. This report was sent to YMPO on August 5, 1992. DOE supplied a copy to the NRC by letter dated August 31, 1992.

Forecast: Monitoring of the SBGSN will continue during FY 1993. Work will begin in compiling a record of historical seismic events.

2.2.13.10 Study 8.3.1.17.4.2 - Location and recency of faulting near the prospective surface facilities

The NRC accepted Study Plan 8.3.1.17.4.2 on November 24, 1989. The NRC completed a detailed technical review (Phase II) on March 16, 1990, where 16 comments were offered.

Activity 8.3.1.17.4.2.1 - Identify appropriate trench locations in Midway Valley. Twenty-eight soil test pits were excavated for soil-stratigraphic studies in Midway Valley. Soil profiles are being described in these pits to provide correlations and temporal control of Quaternary stratigraphic units mapped in Midway Valley with units exposed in trenches. Soil descriptions are complete for approximately one half of the soil pits. Soils data were compared with age assignments estimated on the basis of surface mapping criteria. Refinement of the 1:6,000-scale Quaternary surficial map of Midway Valley continued based on soil descriptions and field checks. The report "Preliminary Mapping of Surficial Geology of Midway Valley, Yucca Mountain Project, Nye County, Nevada" (Wesling et al., 1992) was published.

Activity 8.3.1.17.4.2.2 - Conduct exploratory trenching in Midway Valley. Three trenches were excavated in June 1992 as part of continued work in Midway Valley. Trenches MWV-T5 and MWV-T6 were excavated at the site of prospective surface facilities. MWV-T5 exposes a more than 315-m-long section of Quaternary alluvium and colluvium from Exile Hill east into Midway Valley. A down-to-the-east step of brecciated bedrock at the western-most end of the trench was examined. Fractures with strikes approximately coincident with the trend of the step were also examined with particular attention to evidence of vertical or horizontal displacement of the colluvium. Similar fractures also were studied in trench MWV-T6 and in three soil test pits (NRSF-TP7, 8 & 32). Trench MWV-T4 (old USGS trench 17) was cleaned and deepened to assess the paleoseismic history of the western branch of the Paintbrush Canyon fault within southern Midway Valley. Trench mapping activities focused on surface faulting events, total vertical dip-slip displacement, and the amount of lateral displacement of Pleistocene colluvial deposits. Trench mapping and soil pit descriptions are continuing.

A draft report entitled "Geologic Interpretation of Trench A/BR-3 for Site Characterization Study 8.3.1.17.4.2, Midway Valley Area, Yucca Mountain Site, Nevada" (Swan et. al.) was completed in April 1992, and will probably be released as an Interim Data Report by SNL. In cooperation with Study 8.3.1.5.1.4.2, carbonate was obtained from selected trenches and soil test pits for uranium-series age estimates. Five geophysical lines (gravity and electromagnetic) were established across Midway Valley in cooperation with Study 8.3.1.4.2.1. The purpose of the geophysical lines is to assess the location of faults beneath the Quaternary cover of the valley. The preliminary results of trench mapping, surficial geologic mapping, soil pit descriptions and gravity and magnetic geophysical data

from the lines in Midway Valley were presented to the NRC during a site visit on September 18-19, 1992. The field trip was attended by approximately 50 people, including observers from the NWTRB, the State of Nevada, and surrounding Nevada counties.

Forecast: The report and map showing surficial geology in Midway Valley will be completed. Prepare and submit preliminary data report (with trench logs) on the exploratory trenches through the potential surface facilities locality. One or two new trenches may be necessary to further examine the features identified in Trench 6 and at the western-most end of T5. One new trench may be located above the Midway Valley fault as identified by 1992 geophysical surveys. This study will be completed in FY 1993.

2.2.13.11 Study 8.3.1.17.4.3 - Quaternary faulting within 100 km of Yucca Mountain, including the Walker Lane

YMPO comments on Study Plan 8.3.1.17.4.3 were addressed and the Study Plan was returned to YMPO for verification of comment resolution and approval on September 22, 1992.

Activity 8.3.1.17.4.3.1 - Conduct and evaluate deep geophysical surveys in an east-west transect crossing the Furnace Creek fault zone, Yucca Mountain, and the Walker Lane. No progress during the reporting period; this is an out-year activity.

Activity 8.3.1.17.4.3.2 - Evaluate Quaternary faults within 100 km of Yucca Mountain. Staff conducted field reconnaissance of the Furnace Creek fault zone, Bare Mountain fault, Beatty scarp, and Ash Meadows fault zone. After the June 29, 1992, earthquake near Little Skull Mountain, a search for evidence of possible surface-fault rupture was conducted. Initial compilation of data on known and suspected Quaternary faults was completed and a computerized reference data base established. A draft open-file report entitled "Preliminary Assessment of Quaternary Faults within 100 km of Yucca Mountain" (Piety et.al.) was completed in September 1992. The report outlines the small amount of data on age, amount of displacement, recurrence, and slip rate for most of the faults within the area of study.

Activity 8.3.1.17.4.3.3 - Evaluate the Cedar Mountain earthquake of 1932 and its bearing on wrench tectonics of the Walker Lane within 100 km of the site. This study was not funded in 1992. It is a planned activity scheduled to begin in FY 1994.

Activity 8.3.1.17.4.3.4 - Evaluate the Bare Mountain fault zone. This activity was not funded in 1992. Work is scheduled to begin in FY 1993.

Activity 8.3.1.17.4.3.5 - Evaluate structural domains and characterize the Yucca Mountain region with respect to regional patterns of faults and fractures. No progress during the reporting period; this is an out-year activity.

Forecast: Data collection under Activity 8.3.1.17.4.3.4 is scheduled to begin in FY 1993.

2.2.13.12 Study 8.3.1.17.4.4 - Quaternary faulting proximal to the site within northeast-trending fault zones

Study Plan 8.3.1.17.4.4 was submitted to YMPO on August 3, 1992. YMPO review comments were returned to the principal investigator on September 25, 1992. Documentation is being prepared by USGS to change the SCPB to transfer activity 3 to Study Plan 8.3.1.17.4.6 work scope.

Activity 8.3.1.17.4.4.1 - Evaluate the Rock Valley fault system. A preliminary study of the fault zones was begun by compilation and desk analysis of base maps, published maps and reports, aerial photography and satellite images. Work included creation of a reference data base of all published data relevant to Study 8.3.1.17.4.4 and analysis of 1:40,000 air photos and 1:250,000 Side-Looking Airborne Radar (SLAR) mosaics of the fault zones in preparation for field work. Reconnaissance field work was undertaken from August 26, 1992, to September 3, 1992, to evaluate the suitability of previous mapping for seismic hazards evaluation, to appraise the style and history of strike-slip faults exposed in bedrock and consolidated alluvium, and to assess possible sites for trenching. An interim report entitled "A Reconnaissance Study of Strike-Slip Faulting near Yucca Mountain, Nevada" (O'Leary) was prepared. The report summarizes the results of field examinations of the Rock Valley, Mine Mountain, and Cane Spring fault zones.

Activity 8.3.1.17.4.4.2 - Evaluate the Mine Mountain fault system. No progress during the reporting period; this is an out-year activity.

Activity 8.3.1.17.4.4.3 - Evaluate the Stagecoach Road fault zone. The Stagecoach Road fault evaluation has been transferred to Study Plan 8.3.1.17.4.6 (Quaternary faulting in the Site Area) because geologic mapping has demonstrated that the Stagecoach Road fault is an extension of the Paintbrush Canyon fault. Documentation to change the SCPB, to provide for transfer of this scope of work, is being prepared by the USGS.

Activity 8.3.1.17.4.4.4 - Evaluate the Cane Spring fault system. No progress during the reporting period; this is an out-year activity.

Forecast: Work planned for FY 1993 includes completion of Study Plan comment resolution, field mapping along the Rock Valley fault system with emphasis on fault slip indicators, and preparation of a preliminary report. Due to the Little Skull Mountain earthquake, additional field work will be conducted on the Mine Mountain fault system.

2.2.13.13 Study 8.3.1.17.4.5 - Detachment faults at or proximal to Yucca Mountain

Study Plan 8.3.1.17.4.5 received DOE approval and was sent to NRC on August 12, 1992.

Activity 8.3.1.17.4.5.1 - Evaluate the significance of the Miocene-Paleozoic contact in the Calico Hills area to detachment faulting within the site area. Two weeks of reconnaissance field work were conducted in the second half of FY 1992. Several detachment faults along the California - Nevada border and in the Bare Mountain area were examined. Field work was conducted in CH area and a preliminary geologic map of the area was completed. A draft report entitled "Geology and Hydrothermal Alteration at the Calico Hills, Nevada" (Simonds and Scott) was prepared and is anticipated to be ready for USGS review early in FY 1993.

Activity 8.3.1.17.4.5.2 - Evaluate postulated detachment faults in the Beatty-Bare Mountain area. In addition to library research and consultations with geologists who have worked in the Beatty - Bare Mountain areas, a reconnaissance field trip to Bare Mountain was conducted to evaluate published and unpublished geologic mapping in the area of a proposed detachment fault. A scientific notebook plan was prepared so that investigators can begin a thermobarometry study of lower plate rocks as soon as the Study Plan receives NRC approval. The scientific notebook plan was submitted for USGS review.

Activities 8.3.1.17.4.5.3 through 8.3.1.17.4.5.5. No progress during the reporting period; these are out-year activities.

Forecast: During FY 1993 geologic maps will be completed for CH and Bare Mountain areas known or hypothesized to expose detachment faults. The origin of distinctive breccia masses proximal to Yucca Mountain, which appear to have formed as a consequence of tectonic activity and may have formed in conjunction with detachment faulting, will be evaluated. Work under Activity 8.3.1.17.4.5.5 will begin. Isotopic dates of geologic materials that overlap detachment faults will be determined. Studies of minerals believed to have formed during faulting will be studied to determine at what depth below the land surface detachment faulting was active in the past.

2.2.13.14 Study 8.3.1.17.4.6 - Quaternary faulting within the site area

The NRC accepted Study Plan 8.3.1.17.4.6 on October 3, 1991.

Documentation is being prepared by USGS to change the SCPB to transfer the scope of work pertaining to study of the Stagecoach Road Fault from Activity 8.3.1.17.4.4.3 to Study Plan 8.3.1.17.4.6.

Activity 8.3.1.17.4.6.1 - Evaluate Quaternary geology and potential Quaternary faults at Yucca Mountain. Detailed fault zone mapping was obtained from previous workers for the Solitario Canyon, Fatigue Wash, Windy Wash, Sever Wash, Pagany Wash, Paintbrush Canyon, and Stagecoach Road faults. Field mapping, including fault locations and fault attributes, was compiled from aerial photos and plotted on overlays for the twelve, 1:12,000 scale orthophoto quadrangles that cover Yucca Mountain. A structure map of southern Yucca Mountain was prepared from unpublished geologic mapping. Data from previous workers will be combined with new mapping to prepare a comprehensive map showing all Quaternary faults in the vicinity of Yucca Mountain.

An open file report entitled "Photogeologic and Kinematic Analysis of Lineaments at Yucca Mountain, Nevada: Implications for Strike-Slip Faulting and Oroclinal Bending" (O'Neill, et. al.) received USGS approval. A revised version of the manuscript was prepared for submittal to an outside journal. Staff also contributed to the Electric Power Research Institute (EPRI) probabilistic seismic hazard study of future faulting within the proposed repository block.

Activity 8.3.1.17.4.6.2 - Evaluate age and recurrence of movement on suspected and known Quaternary faults. Excavation of four new trenches, re-excavation of two existing trenches, and cleaning of four natural exposures on the Solitario Canyon, Fatigue Wash, Paintbrush Canyon, and Stagecoach Road faults were completed. Preliminary investigations of the Busted Butte exposures of the Paintbrush Canyon fault focused on net vertical displacement since 700 ka, and determining the number of faulting events that affected the upper part of the exposed section. Logging has commenced on the Solitario Canyon fault trenches, and all of the other trenches have been examined and cleared by safety inspectors for mapping activities.

Along the Bow Ridge fault, trench 14C was cleaned and trench 14D was extended and modified as part of the Midway Valley activities (8.3.1.17.4.2). Trench 14C and a new section of trench 14D were logged. The surficial deposits in these trenches were correlated with the Quaternary stratigraphy developed as part of the Midway Valley activities.

Samples of pedogenic carbonate were collected from both buried and relict soils, and fault zones, in the Busted Butte exposures and trenches 14C and 14D. These samples will be processed for both U-series dating and stable isotopic analyses.

Recently exposed relationships between buried soils and fault-related fractures and veins have been examined and sampled for geochronological work at several sites. Critical cross-cutting relationships in gully walls of the sand ramps on the west side of Busted Butte are particularly important to bracketing the latest movement along the Paintbrush Canyon fault in this area, and to placing constraints on earthquake recurrence intervals and rates of displacement. In addition, similar relationships exposed in Trenches 14C and 14D on the west side of Exile Hill have been sampled and should provide geochronological constraints on Bow Ridge fault activity. Although some zones have high opal contents, initial scoping work indicates the presence of other soil horizons consisting of relatively pure carbonate which will hopefully provide accurate and unambiguous ages.

Forecast: A draft map of Quaternary faults in the vicinity of Yucca Mountain is anticipated by early FY 1993. It is expected that a probabilistic seismic hazard study of future faulting within the proposed repository block will be published by the end of calendar year 1992 by EPRI.

2.2.13.15 Study 8.3.1.17.4.7 - Subsurface geometry and concealed extensions of Quaternary faults at Yucca Mountain

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

Forecast: No activity is planned for FY 1993.

2.2.13.16 Study 8.3.1.17.4.8 - Stress field within and proximal to the site area

Activities 8.3.1.17.4.8.1 through 8.3.1.17.4.8.4. No progress during the reporting period; these are out-year activities.

Forecast: No activity is planned for FY 1993.

2.2.13.17 Study 8.3.1.17.4.9 - Tectonic geomorphology of the Yucca Mountain region

Activities 8.3.1.17.4.9.1 through 8.3.1.17.4.9.3. No progress during the reporting period; these are out-year activities.

Forecast: During FY 1993, the Study Plan will be written, reviewed internally by USGS, and submitted to YMPO.

2.2.13.18 Study 8.3.1.17.4.10 - Geodetic leveling

Activities 8.3.1.17.4.10.1 through 8.3.1.17.4.10.3. No progress during the reporting period; these are out-year activities.

Forecast: During FY 1993, a survey of about 92 km from Bare Mountain across Yucca Mountain and Rock Valley will be completed by first-order, class-one levels. This datum will be compared with that obtained in 1980. A Global Positioning Satellite (GPS) survey will also be conducted to measure the amount of horizontal movement since the original network was laid out in 1983.

2.2.13.19 Study 8.3.1.17.4.11 - Characterization of regional lateral crustal movement

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

Forecast: No activity is planned for FY 1993.

2.2.13.20 Study 8.3.1.17.4.12 - Tectonic models and synthesis

A draft version of the Study Plan was prepared, informally reviewed within USGS, and further revised.

Activity 8.3.1.17.4.12.1 - Evaluate tectonic processes and tectonic stability at the site. A request to procure enhanced Landsat thematic mapper and SPOT imagery for the Yucca Mountain region was prepared and submitted. The order is currently being processed at the Jet Propulsion Laboratory and is anticipated for delivery in early FY 1993. These enhanced images will assist in the tectonic, surficial geologic, hydrologic, and paleoclimatic interpretations of the Yucca Mountain region.

Surface deformation caused by the Landers earthquake (magnitude 7.5) of June 28, 1992, was examined in the field to determine whether similar features, indicative of paleoearthquakes, might be recognizable near Yucca Mountain. A draft report entitled "Tectonic Modeling in the Yucca Mountain Region" (Hamilton) summarizes the authors' observations to date and compares the geology of the Landers region with Yucca Mountain.

A report entitled "Tectonic Characterization of a Potential High-Level Repository at Yucca Mountain, Nevada" (Whitney and O'Leary) underwent USGS and YMPO review and was submitted to the American Society of Civil Engineers (ASCE). The report will be published in a proceedings volume of ASCE entitled Dynamic Analysis and Design Considerations for High-Level Nuclear Waste.

Activities 8.3.1.17.4.12.2 and 8.3.1.17.4.12.3. No progress during the reporting period; these are out-year activities.

Forecast: During FY 1993, complete internal USGS reviews and submit Study Plan for YMPO review. A scoping study will be initiated on the behavior of major Quaternary faults in the region of tectonic interest by using a boundary-element modeling approach.

2.3 REPOSITORY OVERVIEW

2.3.1 Geomechanical analyses (SCP Section 8.3.2.1.4.1)

The objective of this work is to develop evaluate, document, verify, and validate material models, analysis methods, and computer codes for use in preclosure performance analyses of a repository.

An important component of this work involves developing constitutive models capable of analyzing the responses of jointed rock masses. SNL's current continuum-jointed rock constitutive models represent state-of-the-art analysis capabilities. In this reporting period, there were ongoing efforts to improve both the capabilities and efficiency of the models. The two-dimensional orthogonal joint set model was reformulated to run faster and the results were verified against the results from the original formulation.

SNL continued its work in code documentation. The manual for the JAC3D finite-element code "JAC3D: A Three-Dimensional Finite-Element Computer Program for the Non-Linear Quasi-Static Response of Solids with the Conjugate Gradient Method" (Biffle) is essentially complete. In support of ESF activities, SNL has worked to obtain QA certification for the pertinent computer codes so that quality-affecting work can be performed. In this reporting period, a number of the codes used for thermal-mechanical analyses have received QA certification. These codes include FASTQ (finite-element mesh generation), BLOT (display and plotting of finite-element results), COYOTE II (finite-element thermal analyses), and JAC2D (finite-element solid mechanics analyses). This effort will continue as the codes are updated and specific modifications for application to jointed rock are made.

In addition to the work on the continuum joint models, scoping studies performed to determine boundary element and discrete element techniques would benefit the analysis effort. If modeling a large block of the repository or surrounding rock were necessary to ensure that

the boundary effects were properly accounted for, boundary-element technology coupled with finite elements could make analysis procedures economically feasible. The local nonlinearities could be handled with the finite elements, while the boundary elements would take care of the far-field effects. This finite element-boundary element work has been a joint effort between SNL and Geologic, Inc., a company specializing in boundary-element technology. To date, SNL has been able to couple finite elements and boundary elements in a single code and perform a number of successful test problems. There are some test problems that have not been successful, indicating more work is needed.

There has also been some effort to assess the applicability of discrete element technology to the classes of problems of interest at Yucca Mountain. The ability to perform detailed modeling of jointed rock structures is important when answers to questions regarding local effects, such as drift stability when subjected to seismic loading, are needed. Some effort was spent in formulating a discrete-element method that is well-suited to the types of static and dynamic loads that are expected at Yucca Mountain. This effort is viewed as essential in making discrete-element analysis economically feasible for addressing the relevant problems.

In order to have high-quality data for evaluating numerical analysis methods and joint models, an experimental study was initiated in which a stack of polycarbonate plates with a centrally located hole was axially loaded to induce sliding between the plates. Sliding displacements are measured using Moiré grid techniques. As of September 1992, the experimental and data reduction techniques had been developed and refined to a point that experiments could be performed with high confidence. After these initial series of tests are performed, more complicated joint patterns and rock, or rock simulate materials, will be used. These tests are very important for developing and validating SNL's analysis methods.

As part of the effort to assess and recommend rock mass properties for analyses to support the ESF, ACD and site characterization, SNL performed work to analyze the spacing and orientation of fractures for thermal-mechanical units down through CH. Using this information, rock quality designations for each unit were developed. Once the rock quality designations were assigned and by using intact rock properties and well-known empirical methods, it was then possible to estimate the rock mass mechanical properties such as elastic moduli and strength. These estimates of properties will be very useful for subsequent design analyses.

To better understand the properties of rock joints, SNL and the University of Colorado conducted an experimental study on the effects of nonstandard loading conditions on the frictional properties of joints. In these studies, the normal stiffness with which the rock specimens were loaded was varied. By varying the loading stiffness, the effect of joint dilation could be studied.

Forecast: During FY 1993, SNL will develop the user and theory manual for JAC2D, one of the principal thermomechanical analysis codes. Continuum joint models in two and three dimensions will be developed, documented, and verified. This work will include defining the appropriate test problems that will be needed to meet software QA requirements. FY 1993 efforts will work on the robustness of the two-dimensional models and will review, assess, and modify the three-dimensional work performed to date. This work, along with code documentation work, will allow JAC2D and a continuum joint model to be entered into SNL's QA system. Deliverables include reports and conference papers. Discrete joint and discrete block modeling capabilities will be developed for use in validation analyses along with the continuum joint models. Deliverables also include reports detailing development efforts. A coupled boundary-element/finite-element computer code will be developed for analyzing three-dimensional thermomechanical problems associated with designing a nuclear waste repository. This coupling will allow the finite elements in JAC to be used to focus on the near-field effects with the far-field boundaries accounted for properly by use of boundary elements.

SNL will conduct thermal and structural analyses which will provide verification for software, benchmark analyses (code comparisons), and validation analyses. This work will include validation analyses of laboratory experiments and will also include benchmark analyses using different codes of hypothetical (but realistic) repository structures.

2.3.2 Seismic analyses (SCP Section 8.3.2.1.4.2)

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

Forecast: No activity is planned for FY 1993.

2.3.3 Ventilation analyses (SCP Section 8.3.2.1.4.3)

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

Forecast: No activity is planned for FY 1993.

2.3.4 Safety analyses (SCP Section 8.3.2.1.4.4)

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

Forecast: No activity is planned for FY 1993.

2.4 REPOSITORY DESIGN

2.4.1 Configuration of underground facilities (postclosure) (SCP Section 8.3.2.2)

2.4.1.1 Design Activity 1.11.1.1 - Compile a comprehensive list of all the information required from site characterization to resolve this issue

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

Forecast: No activity is planned for FY 1993.

2.4.1.2 Design Activity 1.11.1.2 - Determine adequacy of existing site data

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

Forecast: No activity is planned for FY 1993.

2.4.1.3 Design Activity 1.11.1.3 - Document reference three-dimensional thermal/mechanical stratigraphy of Yucca Mountain

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

Forecast: No activity is planned for FY 1993.

2.4.1.4 Design Activity 1.11.1.4 - Preparation of reference properties for the Reference Information Base

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

Forecast: No activity is planned for FY 1993.

2.4.1.5 Design Activity 1.11.2.1 - Compile waste package information needed for repository design

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

Forecast: No activity is planned for FY 1993.

2.4.1.6 Design Activity 1.11.3.1 - Area needed determination

SNL and other participants' staffs have been involved in an effort sponsored by YMP and the M&O to develop a coherent strategy and plan for resolving the issue of repository thermal loading. SNL will continue to support several working groups.

Forecast: Two- and three-dimensional thermal analyses will be run to evaluate thermal loading scenarios. Included in the analyses will be evaluations of waste emplacement options (drifts versus borehole), general repository layouts, and waste stream projections. Output from these analyses will be required by the repository designers as the YMP begins ACD. Deliverables include reports and briefings to repository designers.

2.4.1.7 Design Activity 1.11.3.2 - Usable area and flexibility evaluation

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

Forecast: No activity is planned for FY 1993.

2.4.1.8 Design Activity 1.11.3.3 - Vertical and horizontal emplacement orientation decision

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

Forecast: No activity is planned for FY 1993.

2.4.1.9 Design Activity 1.11.3.4 - Drainage and moisture control plan

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

Forecast: No activity is planned for FY 1993.

2.4.1.10 Design Activity 1.11.3.5 - Criteria for contingency plan

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

Forecast: No activity is planned for FY 1993.

2.4.1.11 Design Activity 1.11.4.1 - Chemical changes resulting from the use of construction materials

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

Forecast: No activity is planned for FY 1993.

2.4.1.12 Design Activity 1.11.4.2 - Material inventory criteria

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

Forecast: No activity is planned for FY 1993.

2.4.1.13 Design Activity 1.11.4.3 - Water management criteria

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

Forecast: No activity is planned for FY 1993.

2.4.1.14 Design Activity 1.11.5.1 - Excavation methods criteria

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

Forecast: During FY 1993, development of design constraints to limit the extent and magnitude of excavation-induced changes in rock mass permeability will be initiated. Realistic criteria for establishing the suitability of proposed construction methods (e.g., blasting techniques, TBMs, etc.) will be developed based on PA requirements. For example, such criteria include not changing the extent of the disturbed zone or unnecessarily complicating seal evaluations or emplacement.

2.4.1.15 Design Activity 1.11.5.2 - Long-term subsidence control strategy

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

Forecast: During FY 1993, the development of a long-term subsidence control strategy will be initiated. This work will be tailored to help clarify YMP's position regarding

the potential for surface subsidence and the impact of postclosure ground movement on waste containment and isolation. Included in the evaluation will be an assessment of current SCP goals as well as backfill requirements.

2.4.1.16 Design Activity 1.11.6.1 - Thermal loading for underground facility

A report entitled "Equivalent Energy Density Concept: A Preliminary Reexamination of a Technique for Equating Thermal Loads" (Ryder, 1992) has been published. The report documents the results of a study that addresses the thermal design problem of bounding-induced thermomechanical responses over expected ranges of waste stream characteristics (age and burnup). Generic scaling results based on 5,000 mega-Watt day per metric ton of uranium (MWd/MTU) burnup bins are presented in addition to results for the extreme yearly average characteristics of an oldest-fuel-first receipt schedule.

Initial design analyses to address a range of thermal loading for both in-drift and in-borehole emplacement schemes have been completed and will be consolidated with the M&O waste-stream studies. SNL and the M&O will review these results and will designate several cases for further study.

Forecast: During FY 1993, two- and three-dimensional thermal analyses will be run (as stated in Design Activity 1.11.3.1 forecast) to evaluate thermal loading scenarios. Included in the analyses will be evaluations of waste emplacement options (drifts vs. borehole), general repository layouts, and waste stream projections. Outputs from these analyses will be required by the repository designers as the YMP begins ACD.

2.4.1.17 Design Activity 1.11.6.2 - Borehole spacing strategy

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

Forecast: No activity is planned for FY 1993.

2.4.1.18 Design Activity 1.11.6.3 - Sensitivity studies

An extended summary of the results of a far-field thermal study (abstract) was submitted by Eric Ryder, SNL, for presentation at the 1993 IHLRWM Conference. The title of the paper will be "Comparison of Predicted Far-Field Temperatures for Discrete and Smeared Heat Sources." The study focuses on an evaluation of a range of design-basis areal

power densities (APDs) given a consistent set of modeling assumptions. Captured in the three-dimensional model are an accounting for variations in yearly average waste characteristics and the use of a detailed repository geometry.

Forecast: No activity is planned for FY 1993.

2.4.1.19 Design Activity 1.11.6.4 - Strategy for containment enhancement

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

Forecast: During FY 1993, SNL will develop a strategy to enhance containment for ACD. This task will examine and document alternative approaches that can be used to enhance postclosure performance. Included in the analyses will be examinations of the impacts of tailored waste streams, altered edge geometries, waste emplacement orientations, and panel aspect ratios.

2.4.1.20 Design Activity 1.11.6.5 - Reference calculations

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

Forecast: No activity is planned for FY 1993.

2.4.1.21 Design Activity 1.11.7.1 - Reference postclosure repository design

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

Forecast: No activity is planned for FY 1993.

2.4.1.22 Design Activity 1.11.7.2 - Documentation of compliance

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

Forecast: No activity is planned for FY 1993.

2.4.2 Repository design criteria for radiological safety (SCP 8.3.2.3)

2.4.2.1 Design Activity 2.7.1.1 - Design evaluation for compliance with radiological safety design safety design criteria and performance goals

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

Forecast: No activity is planned for FY 1993.

2.4.3 Nonradiological health and safety (SCP Section 8.3.2.4)

2.4.3.1 Design Activity 8.3.2.4.1.1 - Design activity to verify access and drift usability

A series of calculations have been completed that examine the temperature and stress changes at all exploratory access and drift locations planned for construction during site characterization. Results were obtained using a three-dimensional, semi-analytic model assuming a conceptual layout that has been proposed for development using TBMs. Initial design-basis APDs of 57 and 80 kW/acre (141 and 198 kW/ha) were examined, and the models run to 10,000 years following emplacement. The results of this study are being documented in a report ["Drift Design Methodology and Preliminary Application for the Yucca Mountain Site Characterization Project (Hardy et al., 1991)].

A series of two-dimensional thermal analyses were run in support of the M&O's systems study on the thermal management of the potential repository. The analyses examined the near-field thermal effects of two emplacement options, two waste package concepts, two drift shapes and sizes, and five design-basis APDs [20, 57, 80, 100, and 114 kW/acre (49, 124, 198, 247 and 282 kW/ha)]. Thermal profiles generated in this study are currently being analyzed structurally using the compliant joint model ["Two-Dimensional Continuum Model for Jointed Media with Orthogonal Sets of Joints," (Chen, 1986)] and rock-quality designations of one, three, and five (Hardy and Bauer, 1991).

Forecast: During FY 1993, thermal and mechanical analyses will be conducted to assess the impacts of various thermal loading scenarios on the ESF accesses and drifts. These analyses will be conducted as part of SNL's implementation of the drift design methodology in support of the ESF design. Thermal and mechanical analyses will be done to assess the impacts of various thermal loading scenarios on waste containment and isolation. Included in the analyses will be evaluations of drift, borehole, and access stability. Specific analyses to be conducted during FY 1993 will depend on the needs of the ESF or repository design team.

2.4.3.2 Design Activity 8.3.2.4.1.2 - Design activity to verify air quality and ventilation

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

Forecast: No activity is planned for FY 1993.

2.4.4 Preclosure design and technical feasibility (SCP Section 8.3.2.5)

Several integration processes took place during the reporting period. Working with LLNL and LANL, SNL developed a plan to consolidate thermal tests in the ESF. Working with LLNL and the M&O, SNL began revising the thermal-design goals for the repository. Working with the M&O, SNL transferred design information from its previous work and identified issues to be resolved by the new design contractors during ACD.

As part of the integration efforts, SNL completed a set of initial design analyses to address the range of thermal loading that would be appropriate for both in-drift and in-borehole emplacement schemes. The results of these and other studies were transmitted to the M&O for use in current design studies.

Forecast: During FY 1993, management support will be provided to assemble thermal, mechanical, hydrologic, and other data to support the design of the repository and to evaluate repository subsystem design options.

2.4.4.1 Design Activity 4.4.3.1 - Operations plan to accompany the advanced conceptual design

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

Forecast: No activity is planned for FY 1993.

2.4.4.2 Design Activity 4.4.3.2 - Operations plan to accompany the license application design

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

Forecast: No activity is planned for FY 1993.

2.4.4.3 Design Activity 4.4.4.1 - Repository design requirements (RDR) for license application design

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

Forecast: No activity is planned for FY 1993.

2.5 SEALS SYSTEM DESIGN

2.5.1 Shaft and borehole seals characteristics (SCP Section 8.3.3.2)

2.5.1.1 Study 1.12.2.1 - Seal material properties development

Activities 1.12.2.1.1 and 1.12.2.1.2. No progress during the reporting period; these are out-year activities.

Forecast: During FY 1993, a plan for laboratory testing to be performed in support of the sealing program will be written, reviewed at SNL, and submitted to the YMP. Study Plan 8.3.3.2.2.1 will address materials properties as emplaced and as altered in anticipated geologic environments. Both cementitious and earthen materials will be addressed and important properties of the materials will be determined.

Evaluations of backfill performance will be documented. Evaluations will address the areas of hydrologic, structural, mechanical, thermal, and geochemical behavior, as well as integration with relevant information concerning the site and waste package. The primary focus of the document will be crushed rock, i.e., rockfill created by the TBM. The rockfill, as modified by the extraction, handling, and placement will also be considered. From the evaluations, a strategy for backfilling the repository will be developed, including how and when to backfill the repository.

Due to funding constraints, the number of numerical analyses to be performed in this summary account has been reduced. The analyses to be performed here will support laboratory and field testing efforts. Some of the analyses will provide direction in the testing program. For example, geochemical analyses would be performed to predict end products which should be analyzed for during the experimental program. Other calculations will be performed to determine how seals will respond during the field test.

2.5.1.2 Design Activity 1.12.2.2 - A degradation model for cementitious materials emplaced in a tuffaceous environment

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

Forecast: No activity is planned for FY 1993.

2.5.1.3 Study 1.12.2.3 - In situ testing of seal components

The final version of the report "Initial Field Testing Definition of Subsurface Sealing and Backfilling Tests in Unsaturated Tuff" (Fernandez et al.) was submitted to YMPO for review at the end of FY 1992. This report discusses the field testing program, and technical rationale for it for YMPO to consider in adopting a sealing strategy for site characterization boreholes and underground access ways. Two papers corresponding to this field testing effort were presented at the IHLRWM Conference in April 1992. The first paper was entitled "Proposed Sealing Field Tests for a Potential High-Level Radioactive Waste Repository" (Fernandez et al., 1992). The second paper was entitled "Supporting Hydration Calculations for Small- to Large-Scale Seal Tests in Unsaturated Tuff" (Case et al., 1992).

To support the field test planning effort, the program SHAFT.SEAL was completed, including review of the applicable SNL procedures associated with software development and use and generation of verification problems to evaluate the effectiveness and correctness of the software code. A draft user's manual was also prepared.

Forecast: Comment resolution on the Fernandez report will take place, otherwise no activity is planned for FY 1993.

2.5.1.4 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. The development of a strategy to seal exploratory boreholes continued at a low level of effort during this period. The primary activities completed were: portions of Chapter 3 dealing with the work strength and the in situ conditions; a draft of Chapter 4, Design Evaluations of Borehole Seals, including considerations when emplacing cementitious seals, corrosion of casing, and grout bulb effectiveness; and a draft of Chapter 5, Feasibility in Emplacing Borehole Seals.

Analyses were performed on the seismic evaluation of sealing components. This work involves (1) definition of the equivalent static and dynamic loads, (2) evaluation of dynamic

amplification as a function of frequency, (3) Universal Distinct Element Code (UDEC) analyses of rigid sealing components, and (4) pseudostatic analysis to establish critical angle of incidence and peak loads.

The results of the analysis were reported in "Seismic Considerations for Sealing a Repository in Unsaturated Fractured Tuff" (Fernandez et al.) which was presented at the Symposium on Dynamic Analysis and Design Considerations for High-Level Nuclear Waste Repositories. The symposium was held August 19-20, 1992, in San Francisco, California. The report concludes by recommending several strategies that can potentially enhance the performance of the sealing components.

A review of technologies to seal underground openings continued. This review included case histories prepared for a number of mining and civil operations, the preparation of the available technologies report, and the initiation of the review of Defense Nuclear Agency (DNA) sealing activities.

Design Subactivity 1.12.4.1.2 - Perform trade-off studies to support advanced design development. The primary area of effort involved performing numerical analysis to support the backfilling strategy development. Hydrologic, gaseous, geochemical, and in situ temperature and stress analyses were performed.

The hydrologic analyses are intended to determine the lateral extent of water flow in a drift from a discrete, water-producing zone. All water flow scenarios involved water entering a drift through a saturated fault zone. The drift was assumed to be backfilled with a variety of backfill materials. Additionally, the drift was inclined. Other variables in the analysis included the hydraulic conductivity of the fractured, bulk rock, the fault zone hydraulic conductivities, two steady-state water flow boundary conditions, and two transient water flow boundary conditions. To enhance the understanding of the water flow in the backfill, simple analytical solutions were performed.

The objective of the gaseous flow analyses is to determine the lateral migration of gaseous flow through backfill. The effort focused on development of an analytical solution evaluating the effectiveness in limiting gas flow along drifts of backfill (or seals) occupying the entire drift cross section. The analytical solution indicates that if seals can be constructed such that their gas permeability is on the same order as the gas permeability of the host rock, they can be very effective in limiting the flow of gas along the drifts. These preliminary results are independent of the driving pressure gradient and assume that the driving pressure gradient for gas flow is parallel to the axis of the drifts.

The geochemistry analyses evaluations considered alterations of the mineralogy of the Topopah Spring tuff and CH tuff. Several areas were investigated, including the effects of

temperature, water composition, and moisture content, through the use of numerical analysis. Other areas investigated included the thermal and chemical stability of clays and the optimum clay ratio.

Finally, preliminary temperature and stress change histories were developed assuming various loading conditions. For example, 20 kW/acre (49 kW/ha) 30-year-old waste, 20 kW/acre 60-year-old waste, 57 kW/acre (141 kW/ha) 30-year-old waste, and 80 kW/acre (198 kW/ha) 30-year-old waste.

Forecast: The primary effort for FY 1993 will include a strategy to seal exploratory boreholes and a review of available technologies to seal underground openings including a review of the DNA activities. Two SNL reports summarizing the work will be submitted to YMPO. An SNL report on the available technologies to seal underground openings will be completed during FY 1993. It will include discussions of backfilling, grouting, and bulkhead installation technologies. Specifically, a historical perspective on each of these technologies will be presented. Material usage, emplacement methods, and specific issues to each technology will also be addressed. This effort also includes responding to peer review comments and publishing the report.

2.5.1.5 Design Activity 1.12.4.2 - Development of the license application design for sealing

Activities 1.12.4.2.1 through 1.12.4.2.3. No progress during the reporting period; these are out-year activities..

Forecast: No activity is planned for FY 1993.

2.6 WASTE PACKAGE DESIGN

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. The status of the waste package program is provided in this section.

2.6.1 Post emplacement near-field environment (SCP Section 8.3.4.2)

The Preliminary Near Field Environment Report was sent to YMPO for review on April 27, 1992. Following YMPO review and comment resolution, LLNL will prepare a submission to the Reference Information Base (RIB).

2.6.1.1 Design Activity 1.10.1.1 - Consideration of 10 CFR Part 60.135 (a) factors

Conceptual design began for a large-block (3-5 m sides) laboratory test of coupled thermal-hydrological-mechanical-geochemical-corrosion phenomena. A proposal for this test was submitted to YMPO.

LLNL comments on the PNL report entitled "Incentives for Selection of Spent Fuel for Delivery to the Federal Radioactive Waste Management System - A Preliminary Analysis" were discussed and clarified with staff at the Battelle Washington office. This draft report is currently under revision at PNL in preparation for a peer review. A draft paper entitled "Systems Implications of Repository Thermal Loading, Phase I Analysis Methodology" (Gottlieb) was reviewed by LLNL staff.

LLNL is supporting the M&O by conducting repository-heat-driven hydrothermal calculations and by providing technical assistance to support drafting the report "Systems Implications of Repository Thermal Loading, Phase I Analysis Methodology." LLNL staff provided input to and reviewed the Phase I draft of the thermal loading study being prepared by M&O-Vienna and attended a meeting of the report authors in Las Vegas, Nevada on August 19, 1992.

Forecast: During FY 1993, consideration will be given to redrafting Study Plan 8.3.4.2.4.1 (originally prepared in 1988) to more accurately reflect current plans for work in this task. As part of Activity 1.10.4.1.7, runs using EQ3/6 geochemical modeling code to consider precipitation and dissolution effects on pore and fracture properties will continue.

2.6.1.2 Study 1.10.4.1 - Characterize chemical and mineralogical changes in the post-emplacement environment

The review comments for Study Plan 8.3.4.2.4.1, "Characterization of the Chemical and Mineralogical Changes in the Post-Emplacement Environment" were fully incorporated in the text of the Study Plan. Although a draft of the revised Study Plan is near completion, consideration is being given to preparing a revised version that more accurately reflects the current plans for the work in this task, because the draft Study Plan currently under review was prepared originally in 1988.

LLNL staff attended the joint meeting of the Geochemistry and Hydrology Integration Team in Denver, Colorado, June 9-11, 1992. The meeting focused on detecting and characterizing fast pathways for fluid transport at Yucca Mountain and on integrating geochemistry and hydrology. Of particular interest was the influence of man-made materials (e.g., cement, grout) on the hydrological and geochemical properties of the environment in the

repository, and how excavation could modify the site properties. Reports from working groups and recommendations are being compiled and will be distributed later this year.

Activity 1.10.4.1.1 - Rock-water interactions at elevated temperatures. LLNL staff participated in the Oklo Working Group meeting in Brussels, Belgium, and meetings in Paris, France, with Agence Nationale pour la Gestion des Dechets Radioactifs (ANDRA) representatives, April 4-11, 1992. These meetings were called for to explore possible sites for analog studies that may be useful for radionuclide and code validation activities.

A paper entitled "Water-Rock Interactions in New Zealand Hydrothermal Systems: Comparison of Some Simulated and Observed Geochemical Processes" (Glassley and Christenson, 1992) was presented at the 1992 IHLRWM Conference held in Las Vegas, Nevada.

Activity 1.10.4.1.2 - Effect of grout, concrete, and other repository materials on water composition. The SCPB Revision 8, necessary to incorporate Man-Made Materials activities into the Waste Package Environment Testing area and create a Study Plan, completed technical review and was approved by YMPO.

Activity 1.10.4.1.3 - Composition of vadose water from the waste package environment. No progress during the reporting period; this is an out-year activity.

Activity 1.10.4.1.4 - Dissolution of phases in the waste package environment. The paper entitled "Free Energy Dependence of Albite Dissolution Kinetics at 80 °C, pH 8.8" (Burch et al.,) was approved by YMPO on June 29, 1992, and submitted to Chemical Geology, July 1992.

Activity 1.10.4.1.5 - Effects of radiation on water chemistry. No progress during the reporting period; this is an out-year activity.

Activity 1.10.4.1.6 - Effects of container and borehole liner corrosion products on water chemistry. No progress during the reporting period; this is an out-year activity.

Activity 1.10.4.1.7 - Numerical analysis and modeling of rock-water interaction. Attempts to model the coupling of fluid-rock interaction with hydrological properties continued, with emphasis on identifying specific regimes within which particular equilibrium conditions could be recognized. These early calculations suggest that chemical equilibrium will be approached in regions near the waste package. Initial runs with EQ3/6 to consider precipitation and dissolution effects on pore and fracture properties were started.

PROGRESS REPORT #7

The paper entitled "Modeling Fluid-Rock Interaction at Yucca Mountain, Nevada: A Progress Report" (Viani and Bruton, 1992a) was approved by YMPO on July 30, 1992, and was published in September 1992.

The paper entitled "Modeling Ion Exchange in Clinoptilolite Using EQ3/6 Geochemical Modeling Code" (Viani and Bruton, 1992b) was approved by YMPO on May 8, 1992, and was presented at the 7th International Symposium, Water Rock Interaction Conference held at Park City, Utah, July 13-18, 1992.

2.6.1.3 Study 1.10.4.2 - Hydrologic Properties of waste package environment

Work continues at LLNL to resolve YMPO comments on Study Plan 8.3.4.2.4.2, "Hydrologic Properties of the Waste Package Environment."

Activity 1.10.4.2.1 - Single-phase fluid system properties. Most of the LLNL hydrology work in this period was in the two-phase fluid system properties activity.

Activity 1.10.4.2.2 - Two-phase fluid system properties. The feasibility study of using a resonant cavity to measure relative humidity in laboratory rock samples continued. Calibration was completed of the prototype resonant cavity at 85 °C and a range of relative humidity levels from 50 percent to almost 100 percent. Work was completed to redesign the resonant cavity. Work has been temporarily discontinued due to problems with the network analyzer.

The determination of the characteristic curves of the eight disc-type Topopah Spring Tuff samples from U3hg-1 hole, at a depth of 400 m (1,312 ft) continue to be studied. The discs are 2.54 cm in diameter and about 0.6 cm thick. Imbibition studies have been done on this rock before. The characteristic curve information will be added to the results of the previous imbibition study for the estimation of relative permeability of this rock. Although the sample is from Area 3, far from Yucca Mountain, the relative permeability and other hydrologic properties of this rock can be used for model validation. The porosities of these samples have been determined. During the test, the discs were saturated with water and put into a constant-humidity chamber which was set at a constant temperature and various relative humidity levels. Measurements have been completed at 50, 60, 70, 80, 90, and 98 percent relative humidity levels at 20 °C. The samples are in the draining phase at a relative humidity of 75 percent.

A suite of fracture-matrix flow calculations was conducted to compare primary retardation mechanisms affecting radionuclide transport in fractures. Transport of radionuclides can occur under locally fracture-dominated or matrix-dominated flow conditions. The type of flow has a major impact on the relative amount of hydrological and geochemical interaction between the infiltration pulse and the mineralogy of the fractures and

matrix. In general, three primary categories of retardation have been identified which retard aqueous species transport in fracture-matrix systems, two of them involving physical retardation of the wetting front and one involving chemical retardation.

Radionuclide transport under matrix-dominated flow conditions is retarded by the chemical sorption properties of the matrix. Transport under fracture-dominated flow conditions, on the other hand, is retarded by chemsorption onto fracture surfaces which, because of geochemical alteration from previous episodic events (or from repository-heat-generated condensate drainage), could be considerably different from the matrix. Additional retarding mechanisms for fracture-dominated transport are liquid advection and diffusion, resulting in transport of the species from the fracture into the matrix.

Radionuclides moving through fractures will be advected into the matrix by matrix imbibition. The concentration of radionuclides in the fracture is not reduced by matrix imbibition, but the movement of the advective liquid front down the fracture is retarded. This type of retardation could be termed "physical-advective retardation" as opposed to "chemical retardation".

Molecular diffusion from the fracture to the matrix is an important retarding process only when it is comparable to or stronger than the imbibition flux. Diffusion into the matrix dominates if the matrix imbibition diffusivity constant, D_m, is much smaller than the apparent molecular diffusivity constant of the solute. Because of the small storativity of the fracture, molecular diffusion from fracture to matrix may be an important retarding mechanism for fracture-dominated transport, even though it is a relatively slow process. Diffusion, unlike advection, retards transport by reducing the solute concentration in the fracture stream. This type of retardation could be termed "physical-diffusive retardation."

"Back-diffusion" occurs when a clean pulse of water flowing down a fracture is contaminated by radionuclides diffusing out of the matrix. This process occurs if the apparent molecular diffusivity constant of the solute is comparable to or larger than the matrix imbibition diffusivity constant, D_m. On the other hand, if D_m is large relative to the apparent molecular diffusivity constant, advection by imbibition from fracture to matrix will dominate molecular diffusion from matrix to fracture, limiting the entrainment of radionuclides in the fracture pulse.

An important release and transport scenario pertains to the situation in which the emplacement drift is backfilled with a high k_m (matrix permeability) material. For high-k_m backfill, flow conditions in the emplacement drift (surrounding the waste package) are matrix-dominated, which will attenuate any potential fracture-dominated pulse of water reaching the emplacement drift. Consequently, any release and transport of radionuclides is controlled by molecular diffusion, resulting in a slowly expanding plume of radionuclides through the backfill and into the surrounding Welded Topopah Spring (TSw2) host rock. Radionuclides

will diffuse from the contaminated matrix into any flowing fractures each time a liquid fracture pulse passes through the contaminated plume domain. Depending on the relative magnitude of D_m and the molecular diffusivity constant, the mass of entrained radionuclides may be quite limited.

Scoping calculations of in situ heater tests were conducted in support of the decisional analysis for the proposed Yucca Mountain Test Facility (YMTF) at Busted Butte. A major objective of this study is to look at the trade-offs between test duration (and heating rate) and the primary hydrological, geochemical and geomechanical objectives of in situ heater tests. Because of the range of considered testing options, calculations were designed to address in situ heater tests which range from an 18-month duration (with a 12-month full-power heating stage) to a 5-7 year duration (with a 3-5 year full-power heating stage). During the latter stage of the test the heating rate will be ramped down to observe cool-down and re-wetting behavior. Work also began on investigating the impact of heater test size by considering three cases: (1) six 5.5-kW heaters in two parallel heater drifts with 8.23-m center-to-center drift spacing; (2) twenty-one 5.5-kW heaters in three parallel heater drifts with 12.8-m center-to-center drift spacing; (3) sixty-five 5.5-kW heaters in five heater drifts with 14.26-m center-to-center drift spacing.

Hydrologic and thermal properties and hydrostratigraphy used to model the reference case of previous modeling studies of repository-heat-driven hydrothermal flow were applied. Because of the presumed similarity in hydrostratigraphy between Busted Butte and the repository block at Yucca Mountain, these preliminary calculations are considered to be equally applicable to potential prototype tests at Busted Butte and to the ESF tests at Yucca Mountain.

The in situ heater tests are represented with two kinds of models. The drift-scale model is a two-dimensional cross-sectional model which explicitly represents the details of the heaters and heater drifts in the plane orthogonal to the drift axes. A 21-heater configuration is composed of three parallel 4.6 x 4.6-m heater drifts, with 12.8-m center-to-center drift spacing. Each drift contains seven 1.5 x 1.5 x 4.57-m drift-emplaced heaters with 5.49-m center-to-center spacing between heaters. The heated length of each drift is 38.4 m. Because it is two-dimensional, the drift-scale model effectively assumes that the heater drifts are infinitely long, effectively neglecting the heat loss which occurs due to heat flow parallel to the drift axes.

Also represented is the 21-heater test configuration as a disk-shaped "homogenized" heat source with a diameter of 21.665 m and a height of 1.5 m, yielding the same bulk-heated volume as the actual configuration. The radial "test-scale" model smears temperature effects between the heater drifts at very early time, but is representative after the dry-out zones have coalesced and has the advantage of accurately accounting for the overall heat balance. Comparisons between the drift-scale and test-scale models show outstanding agreement in

rock temperature at the center of the heater array for the first four years of full-power heating for twenty-one 5.5-kW heaters. The dry-out performance also agrees well between the two kinds of models.

Because of the limited time frame available for testing, all heater testing must be conducted at accelerated heating rates relative to actual repository thermal conditions. Therefore, the major challenge is to determine how much the heating rate can be accelerated without distorting the critical coupling between hydrothermal flow, geochemistry and geomechanics. For sizing the temporal and spatial extent of the heater tests, the following criteria were considered: (1) the velocity of the dry-out front; (2) the spatial extent and duration of the hydrothermal perching of condensate; (3) the peak rock temperatures; (4) the time rate of change of temperature; and (5) the volume of the dry-out zone.

The first and second criteria primarily relate to hydrothermal-geochemical coupling at the re-fluxing front which may result in the geochemical alteration of fracture and matrix properties. If the dry-out front is driven too quickly, there will be inadequate time for geochemical effects to occur. The third and fourth criteria relate to the potential for geomechanical and geochemical effects to significantly alter the thermo-hydrological properties in a way that is not representative of repository thermal loading conditions. The fifth criterion relates to the scale of the dry-out zone relative to the scale of the heterogeneity of the fracture properties (particularly the fracture spacing). If the dry-out zone is small relative to the scale of heterogeneity, dry-out and condensate drainage may be completely dominated by the local heterogeneity. Moreover, the validation of models which incorporate bulk-averages of matrix and fracture properties require tests where bulk averages are statistically meaningful. To hydrothermally perch condensate, it is necessary to coalesce the boiling zones, thereby precluding condensate from being easily shed off the sides of the individual boiling zones surrounding each heater.

Heating rates from 2.25 to 22 kW per heater were considered. With respect to the second criterion, it was determined that adequate coalescence of the dry-out zones occurs when dry-out extends approximately 14 m vertically. For 5.5-kW heaters, 14 m of vertical dry-out is achieved in four years with a peak rock temperature of 214 °C. For 6.3, 8.25, 12.38, and 22-kW heaters, 14 m of vertical dry-out is achieved in 3.4. 2.5, 1.7 and 1.1 years, respectively, with peak rock temperatures of 230, 264, 335, and 485 °C, respectively. Therefore, to achieve coalescence between heater drifts during an 18 month test, it is necessary to drive peak rock temperatures to nearly 500 °C. Moreover, the velocity of the dry-out front associated with the 22-kW accelerated-rate test is on the order of 10 m/yr which is much greater than the dry-out front velocities typical of repository conditions ($\leq$ 1.0 m/yr).

The impact of test size was investigated by considering the following three cases: (1) six 5.5-kW heaters in two parallel heater drifts with 8.23-m center-to-center drift spacing; (2) twenty-one 5.5-kW heaters in three parallel heater drifts with 12.8-m center-to center-drift

spacing; (3) sixty-five 55.5-kW heaters in five heater drifts with 14.26-m center-to center-drift spacing. At the center of the heater array, the rock temperatures at the end of four years of full-power heating are 147, 214, and 231 °C for the 6, 21, and 65 heater arrays, respectively, while the vertical thickness of the dry-out zone is 5.6 m, 14.3 m, and 16.6 m for these three arrays. Effectively, the center of the 21-heater array performs as though the test were infinite in areal extent during the first four years of full-power heating.

Also investigated was the ability to discriminate between conduction-dominated heatflow and heatflow which is significantly influenced by far-field convection (called convection-influenced heatflow). Two general conditions are required for convection-influenced heatflow: (1) thermal loading conditions which are sufficiently high to drive UZ-scale buoyancy flow and (2) sufficiently large bulk permeability, k_b, of the fractured rock mass. Because far-field convection occurs on the UZ-scale, fracture pathways which give rise to the large k_b must be contiguous throughout the UZ. In addition to the reference case of 2.8×10^{-13} m^2 (3.3 100-μm fractures per meter), also considered was 8.3×10^{-11} m^2 (1-1000-μm fractures per meter), and 1.9×10^{-18} m^2 (no fractures).

When heat conduction dominates heat flow, vapor flow is driven both vertically upwards and downwards from the boiling zone. Local boiling pressure gradients (which drive water vapor away from the boiling zone) tend to be more dominant than the buoyancy-driven pressure gradients which drive UZ-scale convection cells. Because the boiling pressure gradients are symmetric about the heated zone, roughly equal quantities of water vapor are driven above and below the dry-out zone, resulting in a vertically symmetric distribution of condensate generation. Superimposed on this vertically symmetric distribution of condensate generation is the effect of condensate shedding off the sides of the boiling zone. Because of the relatively small size of the heater tests, it was found that condensate shedding quickly results in a greater proportion of the condensate lying below the boiling zone for the reference case, causing an apparent asymmetry in condensate distribution. However, because heat flow is conduction-dominated, the temperature distribution is vertically symmetric about the heater horizon.

When far-field heat convection significantly influences far-field heat flow, the UZ-scale buoyancy-driven pressure gradients dominate the local boiling pressure gradients. Therefore, although local boiling pressure gradients below the dry-out zone tend to drive vapor downwards, UZ-scale convection cells dominate vapor flow, resulting in water vapor being driven upwards. Consequently, in the high-k_b case, all of the water vapor is driven upwards where it condenses above the dry-out zone. Therefore, for convection-influenced heatflow, the expectation would be to see nearly all of the condensation occurring above the dry-out zone. This asymmetry in condensate distribution results in a much larger vertical upward component of latent heat convection in the high-k_b case, manifested by a very pronounced vertical asymmetry in the temperature distribution and reduced temperatures near the heaters. The upper heat-pipe (or condensate) zone is more than twice the vertical extent

of the reference case. The uppermost extent of boiling temperatures is significantly higher in the high-k_b case, and the lowermost extent is considerably less. The resultant vertical upward shift in the upper boiling temperature front is 2.5 m after one year, 5.5 m after two years, and 9.0 m after four years of full-power heating in the twenty-one 5.5-kW heater array. Therefore, the vertical temperature distribution is a very clear discriminator as to whether far-field convection significantly affects heat flow.

A linear ramp-down to zero power in the one year period following four years of full power heater testing has also been modeled for both the reference and high-k_b cases for the twenty-one 5.5-kW heater array. Although the heaters were turned off after five years, boiling conditions at the center of the heater array persisted until 6.54 years for the reference case. The cooling effect of far-field convection resulted in boiling conditions persisting only until 5.8 years for the high-k_b case. Re-wetting of the heater horizon back to ambient saturation takes much longer than cooling to sub-boiling temperatures. For the reference case, it takes 533 years for the center of the heater array to re-wet back to one-half ambient saturation (34 percent). Although the high-k_b case dried out 13 percent less rock, it takes 16.5 percent longer (621 years) to re-wet back to one-half ambient saturation. The longer re-wetting time is due to the enhanced vertical movement of gas carrying away moisture from the condensate zone above the dry-out zone. Hence, "breathing" of the UZ is facilitated by a large k_b. Both cases require nearly 5,000 years to re-wet back to ambient saturation.

Repository thermal calculations using heat conduction models have been conducted by three groups (LLNL-Hydrology, LLNL-Engineering and SNL). The LLNL-Engineering and SNL groups have assumed that the thermal conductivity (K_{th}) for TSw2 can be applied to the entire UZ. However, K_{th} (both wet and dry values) for TSw2, are twice as large as the wet K_{th} value for the nonwelded Paintbrush Tuff (PTn) and CHnv units and the welded CHnz, and nearly four times larger than the dry K_{th} value of the CHnz. Therefore, assuming the TSw2 K_{th} can be applied to the entire UZ substantially under-represents the insulating effect of the lower K_{th} values of the far-field units. LLNL-Hydrology calculations (assuming that the TSw2 K_{th} values apply to the entire UZ) found that the duration of boiling decreases by 50 percent relative to the case with the RIB Version 4 K_{th} distribution. For 30-year-old fuel and an APD of 114 kW/acre (282 kW/ha), the duration of boiling decreases from 6,500 to 3,200 years. The three most similar calculations [114, 102 and 100 kW/acre (282, 252, and 247 kW/ha)] by the three groups agreed within about 10 percent for both peak temperature and boiling duration when the temperature rise was scaled to the heat load. For long-term boiling performance, the depth of the repository appears to be optimally located with the highest K_{th} being in the near-field (providing for limiting peak temperatures), and the lowest K_{th} being in the far-field (insulating the repository, thereby extending the duration of boiling).

Several suites of scoping calculations were conducted that systematically examined the sensitivity of the hydrothermal performance of the UZ to four drivers: thermal conductivity

(K_{th}), bulk permeability (k_b), recharge flux, and the treatment of hydrothermal flow in the SZ. APDs of 20-114 kW/acre (49-282 kW/ha) were used with 30- and 60-year-old fuel.

In past calculations, the thermal conductivity values were used from the RIB version 3. In the latest calculations, a suite of cases was run using RIB version 4 values of K_{th}. Because version 4 values are generally lower, all of the version 4 cases have longer boiling periods. For example, the calculated duration of the boiling period (t_{bp}) for 30-year old fuel with an APD of 57 kW/acre (141 kW/ha) increases from 1,800 to 2,100 years. For 30-year-old fuel and an APD of 114 kW/acre (282 kW/ha), t_{bp} increases from 5,000 to 6,500 years and for 60-year-old fuel and an APD of 114 kW/acre, t_{bp} increased from 10,000 to 13,000 years. While the duration of boiling increases, the peak temperatures for the version 4 cases do not increase. Although K_{th} for many of the units (the nonwelded units in particular) are smaller in version 4, the dry K_{th} of the TSw2 (the repository horizon), is significantly greater than in version 3. Therefore, the relative changes in K_{th} (version 4 vs. version 3) tend to reduce the far-field heat loss outside of the boiling zone (thereby prolonging the duration of boiling), but allowing for greater heat dissipation within the dry-out zone (thereby reducing the peak temperatures in the near-field).

The sensitivity of hydrothermal performance was examined at a range in bulk permeability from $1.9 \times 10^{-18} m^2$ (no fractures) to $2.8 \times 10^{-13} m^2$ (3-100-μm fractures per meter). When no fractures are present, there is no significant boiling because the small matrix permeability results in very large gas-phase pressure gradients, resulting in an elevated boiling point. Therefore, matrix-only flow is associated with completely conduction-dominated flow with no boiling effects, resulting in somewhat higher peak temperatures than the case with fracture flow and significant boiling effects. In contrast, if buoyancy does not significantly affect the mass flow of vapor, the duration of boiling is insensitive to the presence or absence of fractures. When buoyancy dominates vapor flow, both peak temperatures and the duration of boiling conditions are somewhat reduced. For $k_b = 2.8 \times 10^{-13} m^2$, the local boiling pressure gradients dominate far-field buoyancy, resulting in conduction-dominated heat flow for both 57 and 114 kW/acre (141 and 282 kW/ha) of 30-year-old fuel using RIB version 4 values of K_{th}.

The sensitivity of hydrothermal performance was examined at a range of net recharge flux from 0 mm/yr (resulting in an initial repository saturation of 68 percent) to 0.132 mm/yr (95 percent initial saturation) using the RIB version 4 values of K_{th}. In spite of the much wetter initial saturation distribution in the high net recharge case, the duration of boiling is the same as the zero net recharge case. The high net recharge case is associated with lower peak repository temperatures due to the higher initial heat capacity of the partially saturated rock.

In all of the calculations to date, the water table has been treated as being at a fixed depth and at a constant temperature. This assumption causes the SZ to act both as a heat sink

and a reservoir of liquid for re-wetting the dry-out zone. The impact of this assumption was examined by including the upper 1000 m of the SZ in the model. Heat conduction as well as convection, including buoyancy flow, are modeled in the SZ. For all of the cases considered [20-114 kW/acre (49-282 kW/ha), 30- and 60-year-old fuel], the treatment of the water table and SZ has very little impact on peak repository temperatures. Beyond 1,000 years (after temperatures have peaked), the SZ begins to heat up, thereby becoming less of a heat sink. Consequently, the duration of boiling substantially increases, particularly for higher thermal loading conditions. For 30-year-old fuel and an APD of 57 kW/acre (141 kW/ha), t_{bp} increases from 2,100 to 3,500 years. For 30-year-old fuel and an APD of 114 kW/acre (282 kW/ha), t_{bp} increases from 6,500 years to 11,500 years.

Calculations for low thermal loads which do not result in boiling are also affected by the treatment of the SZ. For 30-year-old fuel and an APD of 20 kW/acre (49 kW/ha), hydrothermal flow in the SZ extends the duration of time the repository is above 50 °C from 2,200 to 3,600 years and extends the duration of time the repository is above 40 °C from 5,060 to 14,150 years.

The impact of low thermal loads (resulting in sub-boiling conditions) on repository-heat-drive re-fluxing was examined. Even for sub-boiling conditions, repository-heat-driven re-fluxing will be significant for tens of thousands of years. Under ambient conditions, the geothermal gradient drives ambient re-fluxing even if the net flow of moisture is zero. Depending on what is assumed for naturally-occurring net recharge flux, repository-heat-driven condensate drainage (and the ambient re-fluxing) will probably be the dominant sources of liquid flux in the UZ.

For 30-year-old fuel and an APD of 36 kW/acre (89 kW/ha) (the same waste package spacing as the reference SCP case of 57 kW/acre (141 kW/ha) with 10-year old fuel), the average temperature at the center of the repository peaks at 90 °C. Although boiling temperatures never occur, repository-heat-driven re-fluxing results in as much as 1 mm/yr of liquid flux at the repository horizon (90 times the ambient re-fluxing). For 30-year-old fuel and an APD of 20 kW/acre (49 kW/ha), repository-heat-driven re-fluxing is at least five times larger than ambient re-fluxing. Therefore, boiling conditions are not required to generate significant vapor-phase and liquid-phase flux due to repository heating. Because sub-boiling conditions will also not mitigate the occurrence of episodic meteoric sources of deep nonequilibrium fracture flow, hydrologic assessments of low thermal loading conditions must account for the superposition of naturally occurring episodic fracture flow and repository-heat-driven re-fluxing for essentially all the time of regulatory concern.

Work began to examine the impact of repository-heat-driven hydrothermal flow on the hydrology and geochemistry of the SZ. It was found that there is a significant temperature rise in the upper SZ even for the lowest thermal loads. For 30-year-old fuel and an APD of 20 kW/acre (49 kW/ha), the upper SZ peaks at 46.9 °C (16.5 °C above ambient) at 6,900

years and remains above 40 °C for 26,350 years. Therefore, there is the potential for repository-heat-driven hydrothermal-geochemical alteration of the upper SZ even for low thermal loads. Work will soon begin to conduct preliminary scoping calculations of the potential of such alteration. For 30-year-old fuel and 114 kW/acre (282 kW/ha), the upper SZ peaks at 90 °C at 830 years, remains above 90 °C for 670 years, and remains above 70 °C for 12,400 years.

Several enhancements were made to EXTOOL including a new capability that maps the duration of time for which certain threshold conditions are exceeded. Data are examined between successive snapshots at a location to determine if a specified threshold is exceeded, and the time of threshold crossing is calculated. When the value at that location drops below the threshold, the second crossing time is calculated. For instance, if one is interested in the duration of fracture flow conditions which are generated by condensate drainage during repository-heat-driven boiling and dry-out, the duration of fracture flow conditions throughout the UZ can be contoured to indicate the potential for hydrothermal-geochemical alteration of fracture pathways.

Minor modifications were made to the output routine in V-TOUGH and was ported to the code to the Open Computing Facility (OCF) IBM workstations as well as to the National Energy Research and Supercomputing Center (NERSC) Crays which are now running UNICOS. Minor changes were also made to V-TOUGH to make it compatible with the most recent FORTRAN compiler on the IBMs. These changes resulted in version 5.4 of V-TOUGH. Several cases were benchmarked on the NERSC Crays, and it was found that the turn-around time was unsatisfactory for LLNL applications. Presently, it has been decided to emphasize running on the OCF IBMs.

An Individual Software Plan (ISP) has been completed to qualify the V-TOUGH code for quality affecting activities. The ISP was modified to reflect recent changes in the SQAP. The ISP has been signed by the LLNL Software QA manager and is now being processed by the LLNL QA manager.

A Flow and Transport Workshop was held in Las Vegas, Nevada on May 5-6, 1992. Presentations were given entitled "The Impact of Repository-Heat-Generated Hydrothermal Flow on Repository Performance" (Buscheck) and "The Impact of Physical and Chemical Retardation on Radionuclide Transport in Fractures" (Nitao).

UNR staff members visited LLNL on April 23, 1992, and July 16, 1992, to discuss possible collaboration efforts on modeling. M&O staff visited LLNL on June 24, 1992, to discuss hydrothermal-geomechanical coupling issues. YMPO and M&O staff visited LLNL on July 27, 1992, to discuss YMTF issues with the LLNL staff.

PROGRESS REPORT #7

The following papers were presented at the 1992 IHLRWM Conference: "Characterizing the Altered Zone at Yucca Mountain: The Beginning of a Testing Strategy" (Chesnut, 1992); "The Impact of Thermal Loading on Repository Performance at Yucca Mountain" (Buscheck and Nitao, 1992); and "The Implications of Episodic Nonequilibrium Fracture-Matrix Flow on Site Suitability and Total System Performance"(Nitao, 1992).

Activity 1.10.4.2.3 - Numerical analysis of flow and transport in laboratory systems.

Liquid and gas velocity fields were extracted from the long-term hydrothermal calculations of the repository to calculate Damkohler numbers that indicate whether the assumption of local geochemical equilibrium is valid.

Work has begun on the development of the prototype version of the NUFT code, focusing on the three-dimensional gridblock generator. This version will handle aqueous species transport. Heatflow has been added and runs have been set up to run the NUFT code for imbibition calculations.

LLNL staff attended an INTRAVAL meeting at the HRF of the NTS on April 7, 1992, to discuss the Yucca Mountain model test case of the transect between neutron boreholes USW N-54 and USW N-55. Plans are to develop several alternative conceptual models of the hydrologic system in the vicinity of the transect, including the welded Tiva Canyon (TCw) unit, the various subunits of the nonwelded vitric PTn, and the upper welded Topopah Spring (TSw) unit. The related numerical modeling study will include various combinations of nonequilibrium fracture-matrix models and equivalent continuum models in order to analyze the impact of episodic nonequilibrium flow and steady-state matrix-dominated flow. The impact of the geothermal gradient and vapor movement will be investigated with nonisothermal models. Because the critical dimensionality of the system does not coincide with the transect between USW N-54 and USW N-55, the site-specific models will be augmented with an analysis of the mechanisms affecting the moisture balance in the vicinity of the transect.

LLNL staff attended the INTRAVAL meeting at LBL on August 24, 1992, to discuss the model validation test case using data from neutron boreholes USW N-54 and USW N-55.

Forecast: During FY 1993, a revised Study Plan will be prepared.

2.6.1.4 Study 1.10.4.3 - Mechanical attributes of the waste package environment

A final draft was prepared for Study Plan 8.3.4.2.4.3, "Characterization of the Geomechanical Attributes of the Waste Package Environment" with all comments being

resolved. The SCPB Section 8.3.4.2.4.3 was revised in Revision 8 to remain consistent with the structure of this Study Plan. This draft was submitted to YMPO.

Activity 1.10.4.3.1 - Waste package environment stress field analysis. Input was prepared for the thermal loading studies and for the proposed large block facility study. LLNL staff attended the Workshop on Fractured Rock Masses in Lake Tahoe, California, on June 3-5, 1992, and the Rock Mechanics Symposium in Santa Fe, New Mexico, on June 8-11, 1992.

Forecast: During FY 1993, Study Plan 8.3.4.2.4.3 will be issued.

2.6.1.5 Study 1.10.4.4 - Engineered barrier system field tests

Activity 1.10.4.4.1 - Repository horizon near-field hydrologic properties. The first draft of Study Plan 8.3.4.2.4.4 "Engineered Barrier System Field Tests" has been completed. The internal review process will soon be started.

LLNL chaired the Probabilistic Risk Assessment in Waste Processing session at the 1992 IHLRWM Conference held in Las Vegas.

LLNL staff attended the Sample Overview Committee (SOC) meetings on May 1, June 3, and July 7, 1992, in Las Vegas, Nevada and on September 10, 1992, at the NTS, the ESFTC design review meetings in Las Vegas, Nevada on May 12 and June 1, 1992, and participated in the ESFTC meeting in Las Vegas, Nevada on August 18, 1992.

LLNL staff met with an M&O group to kickoff the heater test duration decision analysis on June 19, 1992, and attended a meeting on thermal testing in Las Vegas, Nevada with the M&O group leader on June 24, 1992. Calculations were conducted at LLNL for several heater tests scenarios. These calculations were incorporated in the M&O group report in early July 1992. LLNL staff participated in the Heater Test Duration task force meetings in Las Vegas, Nevada on July 6, 10, and 13, 1992.

Activity 1.10.4.4.2 - Repository horizon rock-water interaction. No progress during the reporting period; this is an out-year activity.

Activity 1.10.4.4.3 - Numerical analysis of fluid flow and transport in repository horizon near-field environment. No progress during the reporting period due to lack of funding.

Forecast: A new Study Plan, 8.3.4.2.4.5 "Characterization of the Effects of Man-Made Materials on the Chemical & Mineral Changes in the Post-Emplacement Environment"

was created in Revision 8 of the SCPB. It will be written to address the portions of the SCP Issues 1.4 and 1.5 that pertain to the impacts of man-made materials on the local water chemistry. At the time LLNL is authorized to proceed with each of the Study Plans, the workscope will be assessed and a forecast for completion of these activities will be projected.

2.6.2 Characteristics and behavior of the waste form (SCP Section 8.3.5.10)

2.6.2.1 Activity 1.5.1.1 - Integrate waste form data and waste package design data

Subactivity 1.5.1.1.1 - Integrate spent fuel information. Review comments for the Waste Form Characterization Report have been received and are being addressed.

PNL received approval for their program-specific SQAP. Their QA Plan was revised to incorporate this new information.

A combined meeting was held on September 17-18, 1992, in Winnipeg, Canada, with LLNL, PNL and the AECL staff to discuss progress on the spent fuel dissolution task (SA-2 US/Canada collaboration agreement). AECL and LLNL representatives gave brief overview presentations of the spent fuel activities at this meeting.

A report entitled "Spent Fuel Acquisition Plan" has been reviewed by LLNL and comments are being incorporated into the final draft. In this report, recommendations are made for fuels to be acquired for characterization as testing materials. The five fuel types suggested for the testing program are: (1) high burnup fuel (>60 MWd/kgM) with strong rim effect; (2) low fission-gas release (<10%), high burnup fuel; (3) low fission-gas release (<10%), low burnup fuel; (4) burnable poison fuel (5 to 8 wt% Gd_2O_3) with relatively high burnup; and (5) high-fission gas release BWR fuel. The report has been delayed as there has been some difficulty defining what constitutes a high burnup fuel. The data suggest that burnup has little effect on the oxidation processes of spent fuel, but this has not been confirmed for a high-burnup fuel (>60 MWd/kgM).

It might be thought that one only needs to obtain a fuel of this burnup level and then test it. However, when fuels are allowed to achieve higher burnups, microstructure reorientation (rim effect) can occur. This restructuring may effect oxidation kinetics. However, it may not be possible to identify any fuels that would have sufficient restructuring to allow systematic evaluation of this effect. Also, a review of the current literature data has not shown that there is a correlation between burnup and the amount of restructuring that may occur. This is contrary to the assumption that higher burnup will equate to more restructuring.

Subactivities 1.5.1.1.2 and 1.5.1.1.3. No progress during the reporting period; these are out-year activities.

Forecast: During FY 1993, LLNL will complete the review process of the preliminary waste form characterization report.

2.6.2.2 Activity 1.5.2.1 - Characterization of the spent fuel waste form

Subactivity 1.5.2.1.1.1 - Dissolution and leaching of spent fuel. A series of UO_2 dissolution measurements on UO_2 pellets at room-temperature and 20 percent oxygen (O_2) experiments were completed. The dissolution rates were much higher than the first series reported last fall. An explanation for this difference is being sought. The only planned difference was the higher dissolved O_2 levels of the recently finished runs, which was the reason for the repeated runs. The O_2 content is not likely to be a significant factor here. The buffer compositions were the same as before and have no measurable impurities. One cell from the last series was disassembled so that the surface of the pellet could be examined with X-ray Photoelectron Spectroscopy (XPS) to look for impurities or other anomalies that might explain the higher dissolution rates. No unexpected chemical species were seen; however, the cell interior and filters contained dark powder that presumably spalled from the UO_2 dissolution test sample. This spall would increase the surface area above the nominal area value used in evaluating the intrinsic dissolution rate. The origin of this irregularity is being pursued. The increase in surface area would account for the high dissolution rate.

To further investigate the uncertainties in surface area changes during the tests, four UO_2 pellets were analyzed by using Electron Spectroscopy for Chemical Analysis (ESCA) and Scanning Electron Microscopy (SEM). These pellets included one from the last series of runs showing high dissolution rates of U, one from the low dissolution-rate runs last fall, and two unused pellets from batches that were hydrogen-reduced at different times. The latest series had buffers saturated with 20 percent O_2 in Ar. The similar runs last fall lost some O_2 via permeation through the plastic tubing during the tests. Although there were differences in the surface chemistry, all pellets showed U at a higher oxidation state than UO_2. The SEM analyses showed that the two pellets used in the dissolution runs experienced significant grain-boundary and pore etching via dissolution of UO_2. The buffer solutions before and after leaching, as well as the high-purity water used in their preparation, were analyzed via Inductively Coupled Plasma (ICP) MS. This highly sensitive technique for aqueous solutions can detect impurities in the part-per-trillion range. No unexpected chemical species were found. Dissolved O_2 concentration in the buffers is a possible cause of the high dissolution rates, although the reason for such a large effect is unclear. Experiments using single-crystal UO_2 and stainless steel systems with integral O monitors were performed. These experiments eliminate the surface area and O_2 concentration uncertainties.

Because of the surface area uncertainties, a follow-up series of uranium-dissolution experiments using single-crystal UO_2 were completed at room temperature in buffer solutions saturated with 20 percent O_2 in Ar. These experiments minimized the surface area uncertainties that were seen in the last series. The results showed good agreement and compared well with spent fuel dissolution data obtained by PNL and with the UO_2 powder experiments performed at both LLNL and PNL.

At PNL, flow-through testing of spent fuel specimens at reduced O_2 fugacities is in progress according to the approved test matrix. The inconsistent spent fuel test results reported by PNL were caused by loose-end fittings on the flow-through columns. This apparently resulted from reuse of columns that had been used in previous tests. The end fittings were not sufficiently tightened in the hot cell after new spent-fuel specimens were installed. Use of new columns that allow pretightening of the end fittings outside the hot cell should eliminate the problem. New spent-fuel specimens will be installed in new columns, and testing at reduced O_2 fugacities will be restarted.

Tests with partially oxidized (U_4O_9 lattice that is smaller than the UO_2 lattice) spent fuel fragments 1 mm in size are in progress. Results obtained to date (total of 21 days of testing) indicate little difference between the oxidized fragments and similar fragments of unoxidized fuel. The U and the ^{137}Cs dissolution rates from the oxidized specimens were less than a factor of two greater than from the unoxidized specimen). These results are similar to those obtained earlier when partially oxidized (U_4O_9 lattice) spent-fuel grains approximately 15 μm in size were found to dissolve at about the same rate as unoxidized grains of the same fuel. The fuel in both sets of tests was the same (ATM-105, a BWR fuel with 31 MWd/kgM burnup and 0.6-percent fission gas release). The partially oxidized fuel had been oxidized in air at 175 °C for about two years resulting in specimens with stoichiometries of $UO_{2.38}$ and U_4O_9 crystal lattice structures. Both oxidized and unoxidized specimens of fragments (~1 mm) and grains (~15 μm) were prepared using identical procedures, and identical methods were used to determine the surface areas of the oxidized and unoxidized specimens. Test conditions were the same for all four specimens (2×10^{-3} M carbonate/bicarbonate, pH = 9, atmospheric O_2 fugacity, 50 °C).

The absence of a substantial difference in dissolution rates between these oxidized and unoxidized specimens under the given conditions is an important preliminary result for the spent fuel characterization activities. Results obtained with the fuel grain specimens show that prior oxidation by air had little effect on the chemical dissolution rate per unit surface area. Results obtained with fragment (~1 mm) specimens show that the oxidation did not crack open the grain boundaries wide enough to make them more accessible to water as was thought possible, i.e., oxidation did not increase the effective surface area of the fuel. Thus, these preliminary results indicate that air oxidation to a U_4O_9 lattice structure would not increase the potential rate of release of radionuclides from a waste package should the spent fuel ever be contacted by water.

To show that these favorable results are generally applicable to spent fuel for the lifetime of a Yucca Mountain repository, two additional pieces of information are required: (1) additional tests must be performed to determine whether the reported results can be shown to be generally applicable to other fuels and other water chemistry test conditions that are relevant to the Yucca Mountain potential repository site; (2) further testing must be performed to determine whether air oxidation of spent fuel can progress past the U_4O_9 stage under expected Yucca Mountain conditions (the next oxidation phase beyond U_4O_9 is expected to be U_3O_8 which will have a significant volume increase).

The paper "Dissolution Rates of As-Received and Partially Oxidized Spent Fuel" (Gray et al., 1992) was presented at the 1992 IHLRWM Conference held in Las Vegas, Nevada.

An Argonne National Laboratory (ANL) paper entitled "Uranium Release and Secondary Phase Formation During Unsaturated Testing of UO_2 at 90°C" (Wronkiewicz et al.), (previously entitled "Leaching Patterns and Secondary Phase Formation During Unsaturated Leaching of UO_2 at 90°C") was approved by YMPO on May 8, 1992, and was submitted to the Journal of Nuclear Materials. A collaborative PNL/LLNL paper entitled "Parametric Study of LWR Spent Fuel Dissolution Kinetics" (Gray et al., 1992) was approved by YMPO on June 3, 1992, and was submitted to the Journal of Nuclear Materials. It was also published as an LLNL report in June 1992.

Subactivity 1.5.2.1.2 - Oxidation of spent fuel. An interim examination of the spent fuel in the dry baths at PNL was conducted. There were no unusual results. There was no indication of excessive weight gain indicating formation of the next phase change above U_4O_9. The next interim examination is scheduled in August 1992. Weight gain data had indicated that moisture level has no effect on the oxidation rate. This was confirmed by ceramographically examining two samples oxidized to O_2/M~2.4 at -55 and +80 °C dewpoints. No difference in appearance was found. X-ray diffraction analyses are being conducted on the samples.

As part of the oxidation investigations, issues were being considered that might have been overlooked and which would affect the data interpretation. There is a possibility that higher oxides might have been forming on the surface of the fuel grains, and the new phase might be falling off the grains in powder form. Since only individual spent fuel grains from each dry bath crucible are examined, any powders falling off the grains into the bottom of the crucibles would be missed and the data interpretation would be incorrect. The entire contents of one of the crucibles containing fragments with O_2/M-2.4 was examined. No powder was observed in the crucible, putting this concern to rest.

A series of short-term oxidation scoping experiments on Gd-doped unirradiated UO_2 and spent fuel were performed to determine the parameters for next year's dry bath tests.

The Gd-bearing fuel oxidized to U_4O_9 similar to spent fuel oxidation (not to U_3O_7 like unirradiated UO_2). The rate of oxidation decreased with increasing Gd content. The amount of Gd used in these experiments ranged from the amount of fission products in current spent fuel to the higher values expected from future high-burnup fuels that use burnable poisons. These scoping experiments support the earlier evidence that suggests fission products may be responsible for the stabilization of the UO_2 matrix against oxidation.

Very short-term, one day or less, Thermogravimetric Apparatus (TGA) ramp tests are being conducted to approximately determine the temperature and time domains for which the phase of oxidation beyond U_4O_9 will occur. This scoping work will be used to complete test plans for O_2 drybath and future TGA oxidation activities during FY 1993.

For high-burnup spent fuels, spatial variation may occur in oxidation and dissolution response across the diameter of a pellet. A marker to identify the original diametrical position of a fragment within a pellet is conjectured to be the distribution of "epsilon" particles (aggregation of fission product metals). An empirical relationship to relate "epsilon" distribution and fragment spatial position is being investigated, but efforts to date have not been successful. Such a relationship would be useful in spent fuel characterization of test matrix samples.

The paper "Oxidation of Spent Fuel in Air at 175°C to 195°C" (Einziger et al., 1992), (previously entitled "Ceramographic Determination of Spent Fuel Oxidation Rate") was presented at the 1992 IHLRWM Conference held in Las Vegas, Nevada.

Subactivities 1.5.2.1.3 through 1.5.2.1.6 . No progress during the reporting period due to lack of funding.

Forecast: The oven dry-bath oxidation testing of spent fuel at PNL will continue and will provide oxidized spent fuel samples for spent fuel dissolution activities. TGA oxidation testing at PNL will be planned and initiated to characterize the U_4O_9 to U_3O_8 oxidation phase transformation. The spent fuel (PNL) and UO_2 (LLNL) dissolution activities will continue; an oxidized spent fuel dissolution test matrix will be initiated and a repository nominal water chemistry dissolution test matrix will be planned and initiated. Available spent fuel waste form information will be incorporated into the Waste Form Characteristics Report for design and Performance Assessment use.

2.6.2.3 Activity 1.5.2.2 - Characterization of the glass waste form

Subactivity 1.5.2.2.1 - Leach testing of glass. This activity has received limited funding in FY 1992. These funds are being used to maintain the N2 and N3 tests at ANL. The N2 tests (SRL actinide-doped glass) continue, with no sampling occurring during this

reporting period. These tests have been in progress for 340 weeks. The N3 tests (ATM-10, a West Valley actinide-doped glass) continue and have been in progress for 258 weeks. A readiness review and QA Grading were completed at ANL to upgrade the status of the N2 and N3 tests. On September 15, 1992, a draft of "High-Level Nuclear Waste Borosilicate Glass: A Compendium of Characteristics" was released for review. An international team of independent reviewers currently is reviewing the document. A DOE management review is planned for January 1993.

Work continued on the analyses of glasses that have been reacted in water vapor (100 percent relative humidity) at 75 °C for time periods up to three years.

A series of parametric tests are still ongoing. Because of limited volume in the test vessels, a number of the tests were sampled to avoid allowing the standing water level to contact the glass. Solutions were collected for 11 tests and will be saved for later analysis when free time becomes available on the ICP/MS. The solutions were analyzed for pH, C, and anion content as these analyses are performed in-house at ANL. Samples were taken for colloid analysis to be done on the Transmission Electron Microscope (TEM).

Subactivities 1.5.2.2.2 and 1.5.2.2.3. No progress during the reporting period due to lack of funding.

Forecast: The long-term glass waste form alteration testing at ANL will be maintained but no characterization activities will be done at existing funding allocations. Available glass waste form information will be incorporated into the Waste Form Characteristics Report for design and Performance Assessment use.

2.6.2.4 Activity 1.5.3.1 - Integrate scenarios for release from waste packages

Subactivity 1.5.3.1.1 - Develop scenario identifications. Staff attended the NRC Technical Exchange on Scenario Development meeting in Albuquerque, New Mexico, on April 28-29, 1992.

Subactivity 1.5.3.1.2 - Separate scenarios into anticipated and unanticipated categories. No progress during the reporting period due to lack of funding.

Subactivity 1.5.3.1.3 - Development of parameters describing the scenarios. Development continued of the Yucca Mountain Integrating model (YMIM) to analyze scenario inputs.

Subactivity 1.5.3.1.4 - Determine adequacy of design envelope of waste package. The YMIM model began preliminary design analyses. First results were presented at the PA Support to Design and Testing Meeting, July 14-15, 1992, in Las Vegas.

Forecast: The primary effort will be continued development of the Yucca Mountain Integrating model (YMIM) simple integrating Engineered Barrier/Near Field (EBVS/NFE) model and applications to scenario analyses and sensitivity studies. When the next TSPA iteration begins, EBS/NFE scenarios will be proposed for analysis.

2.6.2.5 Activity 1.5.3.2 - Develop geochemical speciation and reaction model

Subactivity 1.5.3.2.1 - Develop data base for geochemical modeling. GEMBOCHS programs DBAPP and D0OUT were used to generate three revised suites of thermodynamic datafiles (DATA0 suites R14-R16) that support the EQ3/6 geochemical modeling package (version 7.0). These new datafiles together with the corresponding DATA1 suites were transferred to the Alliant FX/80 where they can be accessed by local EQ3/6 users.

The GEMBOCHS data base was restructured and all data transferred into the new table structure; associated modifications to DBAPP and D0OUT were completed. This update facilitated significantly improved performance of DBAPP and D0OUT. A separate DBAPP update expanded the capabilities of this software to facilitate interactive review of all GEMBOCHS data, tightened access controls on user modification of these data, and broadened the range of information that can be included in the data base.

The GEMBOCHS staff completed development (including extensive beta testing) of the CNGBOCHS software system and submitted a paper entitled "CNGBOCHS: an Integrated Ingres-Email-Interleaf System for Processing Change Requests Associated with the GEMBOCHS Thermodynamic Database and EQ3/6 Software Package" (Daveler et al.). This paper is now in internal review.

The GEMBOCHS staff began transferring the GEMBOCHS data base and software library from the local sun 3/260 server to a dedicated sun SPARCstation 2. Completion of this transfer will result in dramatically improved performance for each data base and software module in the GEMBOCHS system.

ISPs for three GEMBOCHS programs (CNGBOCHS, DBAPP and D0OUT) were generated, reviewed, revised, and accepted by the LLNL-YMP software QA program.

"The LLNL GEMBOCHS Database" document was submitted to YMPO. The "Software Library: YMP-TDB Quarterly Report: [First, Second] Quarter, 1992" document was submitted to YMPO.

PROGRESS REPORT #7

The requested set of GEMBOCHS parameter screens was generated and submitted to YMPO for inclusion in the YMP-TDB Parameter Dictionary. The GEMBOCHS chapter of the YMP-TDB handbook, to be published this fall, was generated and submitted to YMPO. A Technical Data Workshop, intended to familiarize project investigators with recent developments in the technical data management system was held at LLNL on July 27, 1992.

The R14 datafiles were used with the EQ3/6 test case library. A few problems were detected and were reported to the GEMBOCHS Administrator. The R15 datafiles were partially checked by running them through the test library.

An OCRWM audit of LLNL on August 10-14, 1992, reviewed EQ3/6 code maintenance and GEMBOCHS maintenance/development. The audit evaluated a variety of activities related to record management of changes and developments. No findings were issued in this area.

LLNL staff presented a talk entitled "Reverse/Re-Engineering an Existing Database" at the INGRES World '92 Conference held in Tarpon Spring, Florida, on May 17-21, 1992. This presentation has been submitted to YMPO for approval and after approval will be submitted as a journal article to INGRES. LLNL staff presented a talk entitled "The GEMBOCHS Database and Software Library: Overview of Contents, Components, and Applications" at the quarterly meeting of the YMP-TDB Administrators Working Group (Las Vegas, Nevada, June 30, 1992), at the YMP-TDB meeting " Overview of Technical Data Management" (LLNL, July 27, 1992), and during the OCRWM audit (LLNL, August 10, 1992).

Subactivity 1.5.3.2.2 - Develop geochemical modeling code. Planning for development of version 8.0 of EQ3/6 continued. Several major new capabilities are being planned, including pressure corrections, redox disequilibrium, and redox kinetics. In addition, incorporation of surface chemistry models and their linkage to rate law models, as for redox processes and mineral dissolution and growth is also being addressed. However, these may have to be put off to version 9.0.

The pressure corrections may be of considerable importance in the near future in order to deal with analyses of deep ground waters and samples of waters from proposed natural analog studies. Currently, the effect of pressure on thermodynamic properties is fixed as a function of temperature; 1.013 bar (1 atm) up to 100 °C and the steam/liquid water equilibrium pressure up to 300 °C. Actual pressures in systems of interest may be higher by as much as 300 to 500 bars (hydrostatic pressure alone corresponds to a gradient of 100 bars/km). Pressure corrections require additional thermodynamic data for volume functions. Much of this data is presently in the GEMBOCHS relational data base, but is not passed on to EQ3/6.

PROGRESS REPORT #7

A guideline was prepared documenting the rationale for the organization of chemical species and reactions in future versions of the EQ3/6 data files. The organization of the data file is very important to code usage, as the code utilizes reaction coefficients to define mass balance relations. Depending on how these reactions are written, the mass balance totals for chemical components may or may not correspond to the quantities reported by chemical analysts.

The restructuring of the sets of basis and auxiliary basis aqueous species used in EQ3/6 calculations was completed. This resulted in significantly improved flexibility with regard to the range of geochemical problems that can be addressed using the EQ3/6 package.

Version 7.0 of EQ3/6 was submitted to the Energy Science and Technology Software Center (ESTSC) at Oak Ridge, Tennessee. As part of the submittal, an abstract was prepared in the ESTSC-required format. This abstract will replace the old FIPS abstract. This software transmittal to the ESTSC fulfills a requirement under DOE Order 1360.4B. Version 7.1 was subsequently also submitted.

New data files were run through the EQ3/6 test case library to catch any errors associated with the recent rewrite of a significant subset of reactions. This testing was necessary to facilitate proper use of the software. EQ3/6 was ported to a Silicon Graphics workstation and test cases were run. Problems were identified which appeared to be associated with the Fortran compiler. After further examination, the problems were resolved.

At the direction of YMPO, the most recent version of the EQ3/6 software package and a set of the pre-release code manuals was transmitted to NAGRA under the provisions of the DOE/NAGRA bilateral agreement. In addition, the most recent version of the EQ3/6 software package and a set of the pre-release code manuals were transmitted by LLNL to representatives of LANL, PNL, and the technical staff of the NWTRB.

An ISP was completed and approved for Maintenance, Code Release and Documentation of EQ3/6 version 7. A separate ISP was completed and approved for Initial Qualification of EQ3/6 version 7. An ISP will next be prepared for all activities pertaining to version 8. If the necessary funding is received, development of version 8.0 will begin at the start of FY 1993.

A YMPO QA surveillance was conducted on EQ3/6 on June 15-17, 1992. Corrective action in response to a CAR was completed by incorporating all known bug fixes regarding EQ3/6 version 7.0 into a version 7.1, using the approved configuration management system. A letter concerning this matter and a set of floppy disks containing version 7.1 have been transmitted to all YMP parties who earlier received version 7.0 or version 7.0x. Version 7.0x was the major focus of the CAR. Version 7.1 also contains the new set of data files (R15).

Corrective action in response to a second CAR was completed by inventorying records and submitting all inactive records to the LRC. Active records not submitted are less than one year old.

The first of the four geochemical code user manuals entitled "EQ3/6, A Software Package for Geochemical Modeling of Aqueous Systems: Package Overview and Installation Guide, Version 7.0, Part I" (Wolery) was approved by YMPO on September 2, 1992, and will be published as an LLNL report. The second geochemical code user manual entitled "EQPT, A Data File Preprocessor for the EQ3/6 Software Package: User's Guide and Related Documentation, Version 7.0, Part II" (Daveler and Wolery) completed the technical review process. Comments made by the reviewer have been addressed by the author and the draft has been returned to the reviewer for re-review. The third geochemical code user manual entitled "EQ3NR, A Computer Program for Geochemical Aqueous Speciation-Solubility Calculations: Theoretical Manual, User's Guide and Related Documentation, Version 7.0, Part III" (Wolery) was sent to YMPO for programmatic review on September 30, 1992. The fourth geochemical code user manual entitled "EQ6, A Computer Program for Reaction Path Modeling of Aqueous Geochemical Systems: Theoretical Manual, User's Guide and Related Documentation, Version 7.0, Part IV" (Wolery and Daveler) is in internal review.

LLNL participated in the September 30, 1992, dry run in Las Vegas, Nevada for the October 14, 1992, NWTRB full board meeting.

A paper entitled "Hydrolysis and Carbonate Complexation of Dioxoplutonium (V)" (Bennett et al.) was approved by YMPO and was submitted to Radiochimica Acta. A paper entitled "Chemical Thermodynamics of Technetium V" (Rard) was approved by YMPO on April 27, 1992, and submitted for inclusion in the book "Chemical Thermodynamics of Technetium." An LBL/LLNL collaborative paper entitled "Photoacoustic Spectroscopy and the Effect of Amplified Spontaneous Emission (ASE)" (Klunder et al.) was approved by YMPO on April 6 and submitted to Journal of Analytical Chemistry.

Forecast: During FY 1993, the paper "CNGBOCHS: an Integrated Ingres-Email-Interleaf System for Processing Change Requests Associated with the GEMBOCHS Thermodynamic Database and EQ3/6 Software Package" (Daveler et al.) will complete internal review; the GEMBOCHS chapter of the YMP-TDB handbook will be published; development of version 8 of EQ3/6 will begin; and LLNL will participate in the October 1992 NWTRB full board meeting.

GEMBOCHS activities will include maintenance of the GEMBOCHS thermodynamic data base and associated software library (which includes CNGBOCHS, DAPP, D0OUT, etc.) for use with EQ3/6 and other geochemical modeling packages. As needed, support will be provided to revise thermodynamic datafiles for use with the EQ3/6 geochemical modeling

package. New and revised thermodynamic data and extrapolation algorithms will be incorporated into GEMBOCHS and D0OUT. Development of a windows/4GL version of DBAPP will begin.

2.6.2.6 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. No progress during the reporting period due to lack of funding.

Forecast: No activity is planned for FY 1993.

2.6.2.7 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. No progress during the reporting period due to lack of funding.

Forecast: No activity is planned for FY 1993.

2.6.2.8 Activity 1.5.3.5 - Waste package performance assessment model development

Subactivity 1.5.3.5.1 - Development of system model. The ISP for PANDORA version 1.1 development was released as an LLNL controlled document. The user's manual entitled "PANDORA 1.1 User's Manual" (Lewis and Hardenbrook) and a report entitled "Post-Closure Performance Assessment of Waste Packages for the Yucca Mountain Project" (O'Connell et al.) were completed and are now in internal review.

Version 1.1 includes expanded treatment of the flow-through and bathtub water contact modes and gaseous release mode to accommodate a wide range of input values. Additional external data files, new program control of time stepping, program control of solubility-based and alteration-based limiting factors on release rate, and a check on exhaustion of inventory of solubility-limited radionuclides were implemented. PANDORA 1.1 was tested extensively during and after implementation.

The waste form alteration and release submodels of the YMIM of the EBS, near field and PANDORA were compared. The differences between the base-case models were large and are due to different model assumptions and base-case parameter values. The differences are within the range of possible system performances, and arise from differing intent. PANDORA intends to show presently supportable bounds on system performance, using conservatism to compensate for present uncertainties and for nonmodeled features. YMIM is intended for sensitivity analysis or "what-if" analysis, exploring the implications of possible

assumptions or parameter values. The main subject for YMIM's hypothesis analysis is the coupling among the many processes linking the EBS and the near field. Either program could be changed to substantially match the waste form alteration and release assumptions of the other, by data changes and a few model changes.

LLNL participated in the Source Term/Near Source Effects meeting held at Berkeley, California, on May 27, 1992. Discussions were held on source term, waste package, temperature effects and hydrological flow.

As requested at the May 27, 1992, DOE-EPRI PA meeting, representatives of LLNL and Ohio State University (EPRI support) met on June 26, 1992, to discuss implementation of LLNL hydrothermal calculations into the EPRI total system PA model.

A paper entitled "Diffusion Releases Through One and Two Finite Planar Zones" (Ueng and O'Connell) was approved by YMPO on June 15, 1992, and was published as a LLNL report in July 1992. A paper entitled "Simplified Source Term Model for Total System Performance Assessment" (O'Connell) is in internal review.

Subactivity 1.5.3.5.2 - Development of uncertainty methodology. The following paper was presented at the 1992 IHLRWM Conference held in Las Vegas, "Demands Placed on Waste Package Performance Testing and Modeling by Some General Results on Reliability Analysis" (Chesnut, 1992).

Forecast: The LLNL EBS system model (PANDORA 1.1) will be used internally to support sensitivity studies and development of the EBS source term for the TSPA. Work will resume on a controlled sampling system to describe a heterogeneous ensemble of waste packages.

2.6.2.9 Activity 1.5.4.1 - Deterministic calculation of releases from the waste package

No progress during the reporting period due to lack of funding.

Forecast: No activity is planned for FY 1993.

2.6.2.10 Activity 1.5.4.2 - Probabilistic calculation of releases from the waste package

This activity in currently in the prototype and planning stage. The revised SIP for waste package PA has been approved for interim use and has been submitted to YMPO.

Forecast: During FY 1993, LLNL will prepare an individual software plan for upgrade of PANDORA 1.1 to 1.5.

2.6.2.11 Activity 1.5.5.1 - Determine radionuclide transport parameters

Subactivity 1.5.5.1.1 - Radionuclide distribution in tuff wafers.

Work in this area that is also pertinent to determining the radionuclide distribution in tuff cores is reported under subactivity 1.5.5.1.2. No significant activity occurred pertaining exclusively to distributions of radionuclides in tuff wafers due to reduced funding levels in FY 1992.

Subactivity 1.5.5.1.2 - Radionuclide distribution in tuff cores. LLNL staff attended a meeting on August 24, 1992, in Las Vegas and presented a summary of work related to characterization of natural colloids in NTS waters. Other presentations by Technical University of Munich, Germany, LANL, UNM, and USGS also focused on colloids and their role in radionuclide transport. Other attendees were LBL, USGS, and YMPO.

On August 26, 1992, LLNL, LANL, YMPO, SNL, USGS staff met to plan and organize a workshop to focus on the role of colloids in the transport of radionuclides in a potential repository at Yucca Mountain. A tentative agenda was developed, and prospective speakers are being invited.

Microscopic examination of autoradiography film that was exposed to tuff core wafers and a sample of Climax Stock granite revealed the presence of alpha tracks. Samples had been exposed for 11 days to three weeks. Additional autoradiography on tuffs has not shown any observable radiographic patterns. Because of the low level of alpha activity in the tuff core wafers, it has been difficult optimizing exposure and development times. An alpha sample with sufficient activity (lantern mantel) was obtained and its alpha emission measured. This sample will be used to optimize the autoradiography technique.

The testing and calibration of the flow-through system continued. This system is designed to study the adsorption and hydrology of pore fluid with radionuclide tracers. The calibration of the transducers along with the pressure-transmitting diaphragm was completed. A water cooling system has been constructed to cool the water flowed through the heated sample. The flow-through apparatus was tested at room temperature using a core with a "saw cut" fracture. A two-order-of-magnitude decrease in permeability occurred. Samples were taken of the outflow fluid to look for evidence of bacterial growth. Based on particle morphology, outflow solutions collected at two flow rates at room temperature, contained both inorganic and organic particles. The organic particles were all similar and appeared to be bacteria. Their concentration was significantly greater at the higher flow rate. Thus, the

reduction in permeability in the core is apparently due to plugging caused by microbial growth. Samples of the outflow solution from the apparatus run at 150 °C were also examined. In addition to particles with bacterial morphology, other particles indicative of pieces of organic material were also present. The inorganic particles present in all the outflow solutions were similar in morphology to the particles identified previously in J-13 and other NTS waters. The core will be disassembled, and further examination will continue. The upstream and downstream Teflon valves proved to be too pliable to maintain a steady flow rate in the system. Gold-plated stainless steel valves will be used in the next test. The tests will be continued at elevated temperatures.

TEM and optical microscopic analysis of colloids separated from UO_2 leach solutions was conducted. Results indicate that some of these particles may be contaminants. After further examination, colloidal C particles were identified from the holey C film used to coat the TEM sample support grids as the major source of this contamination. The potential for contamination of fluids by particles used in the "finishing" of plastic sample bottles is also being investigated.

The photon correlation spectrometer was repaired and analysis of the particle size distribution of colloids in spent fuel leach fluids continued.

The adsorption of uranyl ion onto goethite at 70 °C has been completed over the pH range of 4 to 9. Preliminary analysis of the data suggests that adsorption is enhanced relative to adsorption at 25 °C.

A paper entitled "Colloid Formation During Waste Form Reaction: Implications for Nuclear Waste Disposal" (Bates et al.) was approved by YMPO and submitted to Science.

Forecast: The diffusion profiles of Cs, Sr, and U will be measured in single crystals of clinoptilolite at various temperatures. The transport of non-radioactive elements through fractured and saw-cut cores will be studied at elevated temperatures.

2.6.3 Characteristics and configurations of the waste packages (SCP Section 8.3.4.3)

Various concepts were evaluated during the ACD phase of waste package development. Seven concepts were selected for detailed evaluation during ACD. These concepts include: large, metallic multibarrier (partially shielded); metallic multibarrier (totally shielded); small, metallic multibarrier (borehole); nonmetallic multibarrier; overpacked, multi-element sealed canister; universal cask waste package; and the reference SCP single-wall design. The evaluation will include thermal, structural, criticality, and shielding calculations.

PROGRESS REPORT #7

The initial thermal evaluation of the 21-PWR, in-drift waste package design concept was completed. Three configurations were evaluated: the first assumed that heat is transferred directly to the fuel basket; the second included an air gap between the assemblies and the basket; and the third assumed that the package was lying in the drift with half of the package contents in contact with the package and half with an air gap. The results indicated that the aluminum-boron fuel basket with a stainless steel cylinder provided the best thermal performance of the three options, not exceeding internal temperatures of 350 °C .

Preliminary waste page criticality and shielding analyses were performed. The analysis consisted of an initial parametric evaluation of a 21 PWR waste package. The criticality results indicated that burn-up credit will be required or additional poison elements will need to be installed in the waste package. In highly enriched fuel with high burn-up, burn-up credit and additional poison material will be required to meet 10 CFR 60 criticality requirements. The results of the parametric review indicate that the large multibarrier waste package is possible within standard engineering processes.

A major finding of the shielding evaluation was that a waste package that holds 12 or more PWR assemblies will not require anymore shielding because of fuel assembly self-shielding. The evaluation was performed using metallic shielding materials. The shielding materials perform two functions: first and foremost, they are the corrosion barriers for waste containment; secondly, they provide the nuclear shielding. The evaluation indicated that a thickness of 30.5 cm (12 in.) of iron would be required for 33 GWD/MTU, 10-year-old fuel.

All preparations were concluded for starting the waste package ACD phase of the program. The readiness review team reviewed the documentation, training records, facilities, equipment, etc. All material was found to be in order.

Forecast: The ACD phase of the waste package/EBS design will be initiated early in FY 1993. This will permit the initiation of detailed thermal, structural, shielding, and criticality evaluation of the seven design concepts. Performance analysis of these concepts will also be initiated.

2.6.4 Waste package production technologies (SCP Section 8.3.4.4)

No progress during the reporting period due to lack of funding.

Forecast: No activity is planned for FY 1993.

2.6.5 Waste package performance (SCP Section 8.3.5.9)

2.6.5.1 Activity 1.4.1.1 - Integrate design and materials information (metal container)

Subactivities 1.4.1.1.1 and 1.4.1.1.2. No progress during the reporting period due to lack of funding.

Subactivity 1.4.1.1.3 - Physical properties. Repository scale thermal conduction calculations for drift emplaced robust waste packages with APDs up to 125 kW/acre (309 kW/ha) with 60-year-old fuel are ongoing to address the temperature profiles throughout the repository, as a function of time, out to 10,000 years. The TOPAZ calculations are done using two different models, a three-dimensional model for the far field, and a two-dimensional model to evaluate temperature profiles in the waste package. The first twenty runs have produced enough data to derive parametric relationships for quantifying additional mass loading scenarios. The maximum drift wall temperatures have varied between 35 °C and 390 °C depending on the mass loading and the age of the fuel. These temperatures correspond to 13.6 MTUs/acre with 30-year old fuel to 284.7 MTUs/acre with 10-year-old fuel. To date, only 33 GWD/MTU burnup spent fuel has been used in the calculations. The calculations determine the maximum temperatures around the drift as a function of time, plot temperature isotherms at various time steps out to 10,000 years, and determine the effect of backfilling at any specified time.

A code-to-code verification exercise was completed. One run from SNL, one run using the LLNL-Engineering code TOPAZ, and one run using the LLNL-Hydrology V-TOUGH code were compared. The runs used 30-year-old spent fuel, thermal loadings of 100 and 114 kW/acre (247 and 282 kW/ha), and homogenous rock properties (the entire mountain at TSw2 properties). After the results were scaled to a common thermal loading of 100 kW/acre (247 kW/ha), the temperature was plotted as a function of time, and the results were within a 10-percent band. The agreement is even closer at late times.

A draft summary of the corrosion of weathering steels was prepared and provided to the M&O design team. LLNL is leading a task team on corrosion; the team is one of several discipline-oriented teams summarizing issues needing to be resolved in order to make a thermal loading decision.

LLNL staff attended a meeting in April 1992 with YMPO and M&O representatives to discuss waste package strategy and LLNL responsibilities.

LLNL attended a meeting at the M&O office in Las Vegas, Nevada on July 8-9, 1992, to review and compare thermal calculations with representatives of SNL and the M&O. There is close agreement between the LLNL and SNL results even though the thermal models are quite different.

PROGRESS REPORT #7

LLNL staff attended the YMPO Thermal meeting in Las Vegas, Nevada on August 20-21, 1992, to define the method and time table to settle thermal issues. Many of the issues addressed tie very closely with the thermal calculations being done at LLNL. Several task teams were formed to summarize issues needing resolution prior to specifying repository thermal loading.

Subactivities 1.4.1.1.4 through 1.4.1.1.6. No progress during the reporting period due to lack of funding.

Forecast: During FY 1993, LLNL will continue the degradation mode survey of corrosion allowance materials.

2.6.5.2 Activity 1.4.1.2 - Integrate design and materials information (alternate barriers investigation)

Subactivities 1.4.1.2.1 through 1.4.1.2.5. No progress during the reporting period due to lack of funding.

Forecast: No activity is planned for FY 1993.

2.6.5.3 Activity 1.4.2.1 - Selection of the container materials for the license application design

Subactivity 1.4.2.1.1 - Establishment of selection criteria and their weighting factors. No progress during the reporting period due to lack of funding.

Subactivity 1.4.2.1.2 - Material selection. A paper entitled "Selection of Candidate Container Materials for the Conceptual Waste Package Design for a Potential High Package Design for a Potential High Level Waste Repository at Yucca Mountain" (Van Konynenburg et al.) is in internal review.

Forecast: During FY 1993, the paper "Selection of Candidate Container Materials for the Conceptual Waste Package Design for a Potential High Level Waste Repository at Yucca Mountain" (Van Konynenburg et al.) will be published. No other activity is planned for FY 1993.

2.6.5.4 Activity 1.4.2.2 - Degradation modes affecting candidate copper-based container materials

Subactivities 1.4.2.2.1 through 1.4.2.2.8. No progress during the reporting period due to lack of funding.

Forecast: No activity is planned for FY 1993.

2.6.5.5 Activity 1.4.2.3 - Degradation modes affecting candidate austenitic materials

Subactivities 1.4.2.3.1 through 1.4.2.3.9. No progress during the reporting period due to lack of funding.

Forecast: No activity is planned for FY 1993.

2.6.5.6 Activity 1.4.2.4 - Degradation modes affecting the ceramic-metal, bi-metallic/single metal, or coatings and filler systems

Subactivities 1.4.2.4.1 through 1.4.2.4.6. No progress during the reporting period due to lack of funding.

Forecast: No activity is planned for FY 1993.

2.6.5.7 Activity 1.4.3.1 - Models for copper and copper-alloy degradation

Subactivities 1.4.3.1.1 through 1.4.3.1.7. No progress during the reporting period due to lack of funding.

Forecast: No activity is planned for FY 1993.

2.6.5.8 Activity 1.4.3.2 - Models for austenitic material degradation

Subactivities 1.4.3.2.1 through 1.4.3.2.8. No progress during the reporting period due to lack of funding.

Forecast: No activity is planned for FY 1993.

2.6.5.9 Activity 1.4.3.3 - Models for degradation of ceramic-metal, bi-metallic/single metal, and coatings and filler alternative systems

Subactivities 1.4.3.3.1 through 1.4.3.3.3. No progress during the reporting period due to lack of funding.

Forecast: No activity is planned for FY 1993.

2.6.5.10 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

Subactivities 1.4.4.1.1 and 1.4.4.1.2. No progress during the reporting period; these are out-year activities.

Forecast: No activity is planned for FY 1993.

2.6.5.11 Activity 1.4.5.1 - Determination of whether the substantially complete containment requirement is satisfied

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

Forecast: No activity is planned for FY 1993.

2.6.5.12 Activity 1.5.5.2 - Radionuclide transport modeling in the near-field waste package environment

Subactivities 1.5.5.2.1 and 1.5.5.2.2. No progress during the reporting period; these are out-year activities.

Forecast: No activity is planned for FY 1993.

2.7 PERFORMANCE ASSESSMENT

2.7.1 Waste retrievability (SCP Section 8.3.5.2) No progress during the reporting period; this is an out-year activity.

Forecast: No activity is planned for FY 1993.

2.7.2 Public radiological exposure - normal conditions (SCP Section 8.3.5.3) Throughout this reporting period, SNL staff met regularly with DOE and T&MSS staff to discuss the development and application of methodologies for evaluating Items Important to Safety (IITS) and Waste Isolation, work which is being performed. Before commencing work on IITS, several meetings were held with M&O contractor reviewers to resolve comments on "Identification of Structures, Systems, and Components Important to Safety at the Potential Repository at Yucca Mountain" (Hartman and Miller). A presentation on the methodology proposed for evaluating Items Important to Waste Isolation (IITWI) and the results of its application to unconsolidated surficial deposits was made in September 1992.

A report entitled "Disturbance Criteria for Items Important to Waste Isolation: A Methodology and an Application to Unconsolidated Surficial Deposits" (Schelling et al.) has been completed and provided to the YMP Assessment Team.

Efforts continue to apply standard probabilistic risk assessment methods to the ESF design, with the objective of determining the impact of ESF design changes (from the original vertical shaft configuration to the current dual ramp configuration) on previous radiological risk evaluations, and to evaluate the level of uncertainty in the assessment. The results of this work will be used by the Assessment Team to identify the IITS for the ESF, if any.

Forecast: Activity in FY 1993 will focus on compiling and evaluating available information regarding the waste isolation characteristics and performance of natural barriers. This information will be reported to the Assessment Team for use in establishing an IITWI component of the Q-List and for defining necessary controls on impact activities. A report on ESF IITS, tentatively entitled "Preclosure Radiological Safety Evaluation - Exploratory Studies Facility" will be completed, reviewed, and provided to the Assessment Team. Additional safety analysis work will be performed primarily by the M&O. SNL will work with the M&O to ensure a continuous transition of this work.

Upon completion of the natural barrier report, SNL will continue to provide PA support for addressing concerns regarding waste isolation impacts of specific barrier-impacting activities. SNL work in the design area of assessing radiological safety risks is

expected to be complete with release of the ESF IITS report. Future IITS work will be done by the M&O design team, but is not expected to be a significant project priority until a more definitive repository design basis is established.

2.7.3 Worker radiological safety - normal conditions (SCP Section 8.3.5.4)

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

Forecast: No activity is planned for FY 1993.

2.7.4 Accidental radiological release (SCP Section 8.3.5.5)

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

Forecast: No activity is planned for FY 1993.

2.7.5 Groundwater travel time (SCP Section 8.3.5.12)

2.7.5.1 Activity 1.6.2.1 - Model development

Subactivity 1.6.2.1.1 - Development of a theoretical framework for calculational models. The development of a mathematical framework for the modeling of ground-water flow and contaminant transport, as well as for other purposes, currently depends heavily on the acquisition of experimental data. The SCP activity under which such data are acquired is Activity 1.6.2.2.2, and the current work is summarized there.

Subactivity 1.6.2.1.2 - Development of calculational models.

Forecast: The forecast for Activity 1.6.2.2 also applies to Activity 1.6.2.1.

2.7.5.2 Activity 1.6.2.2 - Verification and validation

Subactivity 1.6.2.2.1 - Verification of codes. Performance Assessment - Software development progressed through a number of activities important to the future computational needs of PA. The TOUGH2 code, which will be used in the near future in support of validation activities, was installed for use on the YMP local-area network at SNL. The NORIA-SP code, which models flow and transport, was debugged and corrected to produce a certified version for quality-assurance purposes; this code was placed under a source-code

control system that will also be useful for QA. Several steps were taken in improving visualization capabilities that are essential to the complex analyses underway in PA and its support to design and validation. An applications-visualization system (AVS) became part of the use of certain codes. For example, the interface between TOUGH2 and the AVS was developed during the past six months. Several three-dimensional test problems were acquired for testing the AVS on the hardware and software that were developed during this reporting period. A demonstration of the AVS was given for officials of DOE and the M&O. A related effort was the development of a visual-interface system that links performance-assessment calculations closely to the data bases on which they rest. As part of this effort, SNL evaluated the use of a particular data base, INFORMIX, and its embedded query language for this purpose.

SNL staff have been analyzing field data obtained from boreholes UZ-1 and UE-25a for the purpose of backing out pore pressure as a function of altitude. These pressures may prove beneficial as boundary conditions for numerical calculations. One set of these pressures were used at the left boundary of a Yucca Mountain model, with 1.0 mm/yr infiltration applied to the top boundary. A steady-state solution was obtained using LLUVIA-II on the SUN machine. The boundary pressures result in the mix of positive and negative vertical velocities that smooth into exclusively downward flow approximately 100 m from the boundary. These results will be compared with the numerical solutions.

A report entitled "Boundary Integral Method for Steady Unsaturated Flow in Homogeneous Media" (Martinez, 1992) completed internal SNL technical and management review and YMP policy review. The paper was presented at the 7th International Conference on Boundary Element Technology, June 3-5, 1992, in Albuquerque, New Mexico.

SNL staff attended the PA Flow and Transport meeting in Las Vegas, Nevada, on May 5-6, 1992. A number of presentations were given, including "Some Aspects of Modeling Liquid Flow in Fractures" (Martinez) and "Boundary Integral Methods for Unsaturated Flow in Nonhomogeneous Media" (Martinez, 1992), and "Application of Unit-Boundary Conditions" (Eaton).

Results of one- and two-dimensional benchmarking problems have previously been reported as part of the evaluation of JACQ3D and COYOTE-II. These codes are being investigated to determine whether modern, state-of-the-art numerical methods can efficiently solve flow problems of interest to the YMP. The next step in this process is to apply these codes to a problem in three dimensions. The problem to be solved is similar to the earlier two-dimensional problem with the domain extended to three dimensions. The input infiltration will not be fully extended in the third dimension to ensure a three-dimensional flow field. Both codes have been readied to solve this problem and the mesh is being defined. A large (~20,000 unknowns) three-dimensional problem of flow through an unsaturated, heterogeneous domain was defined to test the applicability of JACQ3D and

COYOTE-II to this class of problem. The performance results for JACQ3D indicate a fairly efficient algorithm for large problems. However, experience indicated that the solver loses efficiency or even fails to converge when the conductivity varies over more than five to six orders of magnitude. This condition can occur when applying infiltration into an initially very dry medium. The solver in COYOTE-II is very efficient and capable of handling drier problems than JACQ3D, but the matrix assembly requires substantial central processing unit time. These results were documented in a memo and distributed.

A Picard solver was added to the DUAL code, which incorporates a dual-porosity model for solving flow problems. This direct solver provides an initial guess for the Newton solver, and, for the test case run, appears to eliminate the large number of iterations in the Newton solver and results in much faster execution times.

A paper entitled "Some Modeling Issues in Nuclear Waste Isolation" (Martinez and McTigue) was presented at the Environmental Studies workshop, University of Minnesota, July 5-10, 1992. The meeting was sponsored by the Institute for Mathematics and its Applications with the objective of providing an interdisciplinary forum for joint exploration of recent advances in environment studies. The talk discussed mathematical challenges associated with modeling transport in unsaturated fractured porous materials and presented some modeling examples.

Staff participated in a scoping meeting to outline studies to be incorporated into the 1993 Total Systems Performance Analysis report (Barnard et al., 1992). The contributions proposed include results of matrix/fracture vapor flow studies and a summary of the importance of dimensionality.

SNL staff met with members of the M&O in August 1992 to discuss code development as part of the M&O role in coordinating PA. The areas of interest included methods for modeling flow in fractures, boundary integrals, method-of-lines procedures, and parallel processing.

Subactivity 1.6.2.2.2 - Validation of models. A tour of the SNL Flow and Contaminant Transport Model Validation Laboratory was given to OCRWM, YMP, and M&0 management staff on May 29, 1992. During the tour, the approach to model development and validation was discussed and the integrated physical and numerical experimental efforts were demonstrated for flow and transport through single fractures, fracture/matrix interaction, and development of scaling laws for heterogeneous media.

The YMP Flow and Contaminant Transport Model Validation Laboratory supported research and educational opportunities for four doctoral students, four masters candidates, and

nine undergraduates during the past six months. All students were supported through a variety of DOE and SNL Fellowship programs designed to promote interest in science and engineering related to waste management issues.

Unsaturated Flow Through Single Fractures - Gravity-driven fingering occurs in nonhorizontal fractures supplied with water along the top edge. A systematic experimental approach for studying gravity-driven fingering in unsaturated fractures was presented at the 1992 IHLRWM Conference, "Gravity-Driven Fingering in Unsaturated Fractures" (Nicholl et al., 1992). As a first step toward understanding this system, experiments were performed in an analog fracture consisting of two roughened glass plates held in close contact. Results imply that increasing the volume of fluid contained in the front leads to increases in both finger width and velocity. Finger velocity was also found to increase with gravitational gradient. Further experiments conducted to complete the data set are being incorporated into a second paper for submittal to a scientific journal. Experiments to support two additional studies of gravity-driven fingering in nonhorizontal fractures have also been completed. Extended summaries of these studies, "Small-Scale Behavior of Single Gravity-Driven Fingers in an Initially Dry Fracture" (Nicholl et al.), and "Wetting Front Instability in an Initially Wet Unsaturated Fracture" (Nicholl et al.), have been prepared and submitted for presentation at the 1993 IHLRWM Conference.

Percolation theory modified to include gravity and multiple-neck pore filling facilitation was applied to gravity-driven fingering in porous media (Glass and Yarrington). SNL staff are in the process of extending this work to analyze gravity-driven fingering in rough walled fractures at angles between 0 and 90 degrees with respect to vertical. The purpose of this analysis is to better understand the aperture-scale mechanics of gravity-driven fingering, including: (1) influence of aperture distribution in random spatial field, (2) influence of correlated spatial aperture field, and (3) influence of gravity versus aperture field spatial structure in determining the wetted structure within a fracture. An extended summary of this work, "Modeling Gravity-Driven Fingering Using Modified Percolation Theory" (Glass), has been prepared and submitted for presentation at the 1993 IHLRWM Conference.

In a collaborative effort with LANL, a preliminary validation study of flow models for saturated flow in fractures performed in an analog rough-walled fracture was extended to a natural fracture in welded tuff. Aperture fields were characterized by surface profiling using a laser profilometer. The Reynolds equation was solved numerically for both statistically generated and measured aperture fields at several spatial resolutions. Permeabilities calculated from numerical simulations were compared to those obtained in the laboratory. An extended summary of this validation study, "Surface and Aperture Characteristics for Saturated Fluid Flow in a Natural Fracture" (Reimus et al.), was prepared and submitted for presentation at the 1993 IHLRWM Conference.

PROGRESS REPORT #7

Fracture Matrix Interaction - A paper entitled "Wetted-Region Structure in Horizontal Unsaturated Fractures: Water Entry Through the Surrounding Porous Matrix" (Glass and Norton, 1992) was presented at the 1992 IHLRWM Conference. In the presentation, SNL staff reported the research investigating small-scale processes that influence wetted structure within the plane of a horizontal fracture as the fracture wets or drains through the matrix. The research approach integrates both aperture-scale modeling and physical experimentation. Several types of aperture-scale models have been defined and implemented. A series of physical experimental systems have been designed that allow the measurement of wetted-region structure as a function of system parameters and water pressure head in analog fractures. In the preliminary proof-of-concept experiment, hysteresis is clearly evident in the measured saturation/pressure relation, as is the process of air entrapment, which causes a reduction in the connected areas between blocks and the wetted region available for flow in the plane of the fracture. A percolation threshold where the system is quickly spanned, allowing fluid conduction in the fracture plane, is observed that is analogous to that found in the aperture-scale models. A fractal wetted and entrapped-region structure is suggested by both experiment and modeling. This structure implies that flow tortuosity for both flow in the fracture and for interblock fluid transfer is a scale-dependent function of pressure head. SNL staff extended this preliminary study in the past six months to include systematic experiments performed on five analog fractures. Measurements were made to define hysteretic saturation/pressure relations including primary, secondary and tertiary wetting and drying curves. Similarities between these curves and those of generic porous media are clearly identified. An extended summary detailing the results of these recent experiments, "Wetted Structure Development in Analog Horizontal Unsaturated Rock Fractures" (Glass and Norton), has been prepared and submitted for presentation at the 1993 IHLRWM Conference.

Studies aimed at understanding the influence of matrix imbibition on fracture flow in thin, two-dimensional systems cut normal to the plane of the fracture continued. As part of this program, a collaborative effort has been established between SNL and the University of New Mexico Medical Center to allow access to a Sieman's Polytron real-time x-ray device. This equipment allows x-ray imaging to be performed at a much higher temporal resolution than that available with film-based x-ray imaging. Preliminary experiments were planned and initiated. These studies have been documented in an abstract entitled "An Experimental Investigation of Matrix Interaction on Fracture Flow," submitted for the 1993 AGU Fall Meeting, and an extended summary, "An Experimental Investigation of Fracture-Matrix Interaction with Comparison to Numerical Simulation" (Foltz et al.), submitted for presentation at the 1993 IHLRWM Conference.

Field, Lab, and Numerical Experimentation to Determine Scaling Laws for Effective Media Properties in Heterogeneous Media. A paper entitled "Field Research Program for Unsaturated Flow and Transport Experimentation" (Tidwell et al., 1992) was presented at the 1992 IHLRWM Conference. The presentation described the field research program aimed at

refining and validating models for flow and transport through unsaturated fractured rock. This field program emphasizes natural analogs and compliments the fully developed laboratory research program.

Work has continued on the gas permeameter that is to be used to collect data for challenging effective media property models and the development of their scaling laws. To facilitate data acquisition, an automated gas permeameter test system has been designed for use in the laboratory. The system is composed of a computer-driven x-y positioning system, electronic gas permeameter integrated with data acquisition and analysis capabilities. Construction of the permeameter will begin when the system components have arrived (by early October 1992). An extended summary entitled "Influence of Measurement Scale on Gas Permeability Data" (Tidwell et al., 1991) was submitted for presentation at the 1993 IHLRWM Conference. This summary outlines a preliminary suite of experiments aimed at refining the automated permeameter test system and challenging basic property scaling concepts.

As part of the effort to develop scaling laws for saturated and unsaturated systems containing micro-layering and cross-bedding heterogeneities, several preliminary experiments were conducted. Such heterogeneities are found in all the alluvial sediments at and around Yucca Mountain and in the bedded tuffs units within Yucca Mountain. Incomplete knowledge of the effect of these heterogeneities within a larger scale geologic "layer" raises important questions about the validity of current calculations for TSPA and in support of the ESF. The preliminary experiments, conducted in conjunction with the LANL intermediate-scale caisson experiment, were presented at the 1992 IHLRWM Conference. Subsequent experiments have been included in an extended summary, "Testing Models of Flow and Transport in Unsaturated Porous Media" (Springer et al.), which has been submitted for presentation at the 1993 IHLRWM Conference. In the experiments, micro-layering and cross-bedding heterogeneities are created in thin slabs of sand that will compose the LANL caisson. Using a full-field moisture-content technique based on light transmission, a sequence of infiltration and drainage experiments will be monitored. The experimental sequence allows the measurement of chamber-scale hysteretic moisture-characteristic curves, saturated and relative permeabilities, and solute dispersion coefficients. These effective chamber-scale properties will be measured in a series of experiments with the type and intensity of the heterogeneity varied systematically. In addition, measured transient moisture content and solute concentration fields will be compared with numerical simulations.

Development of Experimental Capabilities - SNL staff continued to develop x-ray absorption and transmitted light as techniques for measuring moisture content in porous media. Each is a high-resolution, rapid, full-field moisture-sensing technique that has been developed for use in two-dimensional, thin-slab experimental systems. Current activities have focused on evaluation of measurement precision and accuracy as well as the reporting of results. A report entitled "X-Ray and Visible Light Transmission as Two-Dimensional,

Full-Field Moisture-Sensing Techniques: A Preliminary Presentation" (Tidwell and Glass, 1992) was presented at the IHLRWM Conference in April 1992. The additional evaluation of precision and accuracy is being incorporated into a journal article covering this work.

To enhance the imaging capabilities of the SNL laboratory, efforts to purchase a dedicated x-ray generator and tube head were initiated. Available equipment was researched and a Phillips 160 System was selected. Acquisition of the unit is currently under way.

Scoping Sorption Studies - To reduce the confounding influence of disequilibrium with atmospheric CO_2 on pH measurements, methods to carry out batch experiments under CO_2-free conditions were developed. These included a low-flow Ar purge system with a two-stage scrubber and draft protocols for preparing nominally CO_2-free 0.01 M NaCl electrolyte and tracer solutions. A computer-driven autotitrator for acidimetric and alkalimetric determination of mineral surface hydrolysis constants was acquired from Stanford University. Problems encountered in mineral surface titrations due to slow dissolution and diffusion reactions and the exchange of CO_2 with the atmosphere were partially solved with the autotitrator.

The sensitivity, accuracy and precision of the technique used for nickel (Ni) analysis were improved. Methods to correct for black body radiation and carry-over of Ni from one sample to the next were developed. Optimization of the measurement protocol has reduced measurement time by one-third and extended the usable dynamic range to 0.3-100 parts per billion (ppb) without sacrificing precision or accuracy.

Caisson Experiment - An intermediate-scale experiment is being carried out by SNL and LANL to demonstrate a strategy to validate key geochemical and hydrological assumptions in PA models. The experiment involves the detection and prediction of the migration of fluid and tracers through a 6-m-high x 3-m-diameter caisson filled with a porous medium.

Materials Characterization - The caisson is being filled with Wedron 510 sand, a commercially available silica sand (Wedron Silica, Wedron Ill. 60557). According to bulk chemistry and mineralogy, Wedron 510 sand is nearly pure quartz, but characterization of some of its surface properties as described below suggests that it contains at least four components: quartz, carbonate, Fe, oxyhydroxide, and kaolinite. Estimates of the amount of carbonate coating the surfaces of grains in the quartz sand were made by three methods: pH shifts during equilibration with 0.01 M NaCl in CO_2-free batch systems; leaching of soluble Ca and Mg with 6 N HCl; and petrographic analysis of polished grain mounts. The first two methods indicated that the grains contained approximately 0.8 micrograms/carbonate per gram of sand. This agrees well with the visual observations that the coatings account for less than 0.1 percent of the mode.

Significant Fe (0.575 μmol/g) was leached during treatment of an aliquot of Wedron 510 with 6 N HCl. Studies of thin-sections under an optical microscope reveal that the sand grains are coated with a yellowish material; thus the majority of the Fe is likely to be present as a thin coating of hematite and/or goethite on the sand grains. Dispersed colloidal material associated with the sand comprises 0.05 percent of the original mass of the sand and appears by x-ray diffraction to be essentially pure kaolinite. A few sand grains were examined by SEM with energy-dispersive spectroscopy. Flakes of high-alumina material (kaolinite) were common, but no Fe-rich coatings on the well-rounded quartz grains were observed.

The initial design of the caisson experiment included a limonite-rich layer sandwich between two layers of pure Wedron 510 sand. Chemical and x-ray analysis of samples from candidate limonite showed it to be very heterogeneous. In addition to goethite, many of the sampled splits contain abundant quartz, clays, and sulfates. Analysis of splits taken from the bulk of the material that was delivered to the caisson site at LANL showed it contains a strong acidic component as indicated by the low pH of deionized water placed in contact with them. Because of the uncertainty in adsorption behavior that the pH change would cause in the caisson, the final caisson design did not include the limonite component.

A suite of reactive tracers that spans a variety of chemical behaviors was considered for the caisson experiment. The tracers that were chosen for the final design include: Ni (Ni), a transition metal that forms strong surface complexes with geologic materials and is representative of waste elements released from the structural materials in the high-level waste; Li, a tracer that forms relatively weak surface complexes; bromide, a conservative tracer that can be used to track the movement of water in the caisson; and B, a tracer that forms the anionic complexes that adsorb weakly to geologic materials under alkaline pH.

Ni sorption has been measured in batch experiments equilibrated for at least 48 hours at solid: solution ratios of 1:1 over the pH range 5 to 9.5. Initial Ni concentration was 50 ng/ml, and final Ni concentrations were measured by graphite-furnace atomic absorption spectroscopy. The pH-sorption curve shows a distinct sorption edge at pH ~6.5, reaching maximum sorbance at pH 8.0, followed by slowly declining sorbance with further increases in pH. Preliminary measurements of sorption of Li and B by Wedron 510 sand as a function of pH have been carried out. The results suggest that Li adsorption is low and dependent on pH; B sorption by sand was negligible over the pH range studied.

Batch and flow-through tests were initiated to determine the equilibrium pH and the extent of sorption of tracers by samplers that will be used in the caisson (ceramic cups and electrodialysis tubing). The preliminary results indicate that the electrodialysis tubing contains an acidic component (equilibrated pH = 5.8), and that sorption at the equilibrium pH was negligible. The pH of solutions in contact with the ceramic cups samplers was alkaline (8.4 - 10.6). Sorption ratios of approximately 70, 0 and 0 mL/g were measured for Ni, bromide, and B respectively in batch experiments. The initial results of the flow experiments

were consistent with the batch sorption studies. Ni sorption on four plastics used for sample collection, storage and sorption experiments was investigated as a function of solution head space and pH to guide the choice of sample storage vials of the caisson and to estimate the stability of collected solutions that are stored for later chemical analysis. Initial results suggest that moderate sorption occurs at neutral pH over 2-9 day periods in containers with large headspace. Sorption studies at lower headspace under the more acidic conditions are currently underway.

Transient Chemical Conditions in the Caisson - Ni sorption by the Wedron 510 is very sensitive to pH under near neutral conditions. Surface titration curves indicate that the sand contains several minerals that affect the solution pH. The pH profile in the caisson will be controlled by dissolution of carbonate cement, diffusion of atmospheric CO_2 into pore fluids, hydrolysis of silanol (SiOH) groups and hydrolysis of FeOOH surface groups. It is anticipated that chemical conditions within the caisson will initially be transient but that a steady-state chemical profile may eventually develop. The flow velocity, dissolution rate of carbonate cement and the CO_2 diffusion rate will control the approach to steady-state concentration profiles in the caisson; the amount of carbonate cement will determine the duration of the steady-state profile. A computer model that calculates the pH as a function of these processes is currently under development. Data from small-scale column experiments will be used to validate the code. Small-scale column experiments to study the changes in column pH as functions of time and saturation state are being carried out. A 0.01 M NaCl solution (pH $\cong$ 6) is pumped through columns (7 cm I.D. x 24 cm) filled with Wedron 510 sand at several degrees of saturation (50-100 percent). The pH of the influent and effluent solutions are measured in flow-through cells. In preliminary saturated-condition experiments, the pH of the initial effluent was neutral and rose to an alkaline steady-state pH (> 8.7) after six pore volumes had been eluted from the column. Under unsaturated conditions (50 -70 percent saturation) the effluent pH dropped to a steady-state range of 7.2 to 8.0 after elution of approximately two to five pore volumes. The differences between the pH measured by electrodes placed in in-line flow-through cells and those measured in open containers were evaluated as a function of eluted pore volumes, in order to determine if in-line pH monitors are required in the caisson experiment. Under unsaturated conditions, the pH of the in-line and open vessel samplers differed only by 0.1 - 0.15 pH units after two pore volumes had been eluted from the column.

Reactive Transport Model Development/Experimentation - A first draft of a User's Manual for the LEHGC code was completed by G. T. Yeh of the Pennsylvania State University. Efforts have been initiated to implement the LEHGC coupled reaction-transport computer code on the Computational and Computer Sciences and Mathematics Center's nCUBE, which has 1024 processors. In the initial modifications to the code, the geochemical equilibrium calculations will be performed in parallel and the transport calculations will be

carried out on a single node. The potential benefits of this effort include lower costs for CPU time, less real time spent per simulation and increasing the size and complexity of acceptable problems.

Development of an Adsorption Model for Mineral Mixtures - Experiments to determine the effect that trace surface coatings and admixed grains have on the surface properties of natural materials were initiated. The properties of the Wedron 510 sand and the limonite sample are being investigated to develop an approach to the formulation of an adsorption model for mineral mixtures. The properties of the pure quartz component of the Wedron sand are being estimated by potentiometric characterization of reference quartz samples. Data has been collected for the titration of a reference silica (untreated Min-U-Sil) in batch experiments under CO_2-free conditions. The batch systems contained a Min-U-Sil surface area similar to that of the Wedron 510 sand systems but had much less pH buffering capacity than the 510 sand. Li and B sorption experiments were carried out with a mixture of limonite (3 percent by weight) and Wedron 510 sand. Both elements exhibit low but measurable amounts of sorption in both the mixture and pure sand over the neutral pH range. Isotherm experiments to determine the linear range of sorption are currently being conducted.

Reports and Presentations:

A paper entitled "Design of an Intermediate-Scale Experiment to Validate Unsaturated-Zone Transport Models" (Siegel et al., 1992) was presented at the 1992 IHLRWM Conference, Las Vegas, Nevada, April 12-16, 1992.

A poster session entitled "Measurement and Modeling of Ni Adsorption in Mixtures of Sand and Limonite for a Large-Scale Column Test" (Ward and Siegel) was presented at the Spring 1992 meeting of the AGU in Montreal, Canada, May 11-15, 1992.

"Efforts to Verify and Validate the Lagrangian-Eulerian Model of Hydrogeochemical Transport (LEHGC)" (Hopkins et al.) was submitted for presentation at the 1992 Fall Annual Meeting of the AGU.

A summary entitled "Characterization of Materials for a Reactive Transport Model Validation Experiment" (Siegel et al.) was submitted for presentation at the 1993 IHLRWM Conference.

Forecast: During FY 1993, enhancement of pre- and post-processing will investigate the use of standardized input and binary output data base files for use in SNL's two- and three-dimensional partial differential equation codes. Routines will also be written to convert the output files to be compatible with visualization packages. A memo reporting the results and recommendations for implementation will be completed. The activity entitled "Enhancement of Computational Efficiency for Codes" will evaluate candidate flow and

transport codes on the basis of performance in solving three-dimensional flow calculations. Massive parallelization of codes will be explored to simulate flow and transport processes in partially saturated porous media. The first deliverable, due early in FY 1993, will be a memo outlining the strategy developed in this work.

Other activities planned for FY 1993 are continuation of surface chemistry of natural and analog materials characterization for caisson experiment and obtaining ion exchange and surface complexation constants describing potential sorption of tracers (B, I, Ni, Li); formulation of model for chemical evolution of water in caisson under steady and transient unsaturated and saturated flow and model reactive transport in caisson using the LEHGC code; development of model for sorption of Ni onto mixtures of minerals and develop a method for measurements of K_d in unsaturated media to assess applicability of sorption partition coefficients measured under saturated conditions to unsaturated conditions; completion of publication of User's Manual for LEGHC and initiate modifications of the LEHGC code to run the code on a massively parallel computer.

2.7.5.3 Activity 1.6.3.1 - Analysis of unsaturated flow system

Subactivity 1.6.3.1.1 - Unsaturated zone flow analysis. Staff attended a meeting to discuss the INTRAVAL test case involving large-scale flow and transport experiments at Yucca Mountain on May 9, 1992. Site data obtained from Yucca Mountain will be used to model infiltration of water into the tuffaceous units. The SNL effort will be focused on developing two-dimensional geometric and numerical models of the UZ that will be evaluated during the calibration and prediction phases of the project. Emphasis will be placed on incorporating data describing physical properties, hydrologic parameters, boundary conditions, and other state variables in a currently uninvestigated part of the system. An analysis of the reliability and the uncertainties in the site data will also be conducted as part of the exercise.

Staff at LBL constructed a grid design for an east-west cross section from 800 meters west of the Solitario Canyon fault to the Ghost Dance fault. The grid will be used, along with boundary conditions for infiltration along the ridges and slopes of Yucca Mountain and sample data from 26 vertical transects, in a study to analyze the modeling effects of boundary conditions. The data set from the transect and information from USGS neutron holes N-54 and N-55 are also being proposed as part of the data set to be included in the INTRAVAL studies. Preliminary numerical simulations were conducted under the boundary condition study ongoing at LBL to test grid problems. Only minor potential distortions were noted. A two-dimensional model of Solitario Canyon was run by workers at LBL. The model uses layers having different porosity and permeability values. The run was used to learn whether rock property contrast would affect the performance of the model. An outline of the report to document the boundary-condition study was submitted.

PROGRESS REPORT #7

As part of the continuing analysis of site data, the geometry was set up for two cross sections, one perpendicular and one parallel to the wash where boreholes N54 and N55 are located. The data received from the INTRAVAL study will be incorporated into the cross sections for analyses that will be run in the next few months. An adaptive mesh generator was written to accept output from a geostatistical program. It was also designed to generate a grid for flow codes that allows each individual block to be as homogeneous as possible. Future work will be done to formulate the interfaces for all programs. In preparation for continued efforts in the analysis of site and analog data, a request was made to install ARCVIEW. ARCVIEW is a software package that allows easy access and interactive graphical manipulation of data that have been formatted for ARCINFO. The ARCVIEW installation was successful. Efforts are now underway to tailor the installation specific needs and to add as much information to the data base as possible.

SNL hosted the organizational meeting on July 10, 1992, for the INTRAVAL study group. A proposed outline for integrating the INTRAVAL data, geostatistical simulator, and the two-dimensional flow codes was presented to the participants in the study group.

Geostatistical simulation of porosity between USW-N54 and USW-N55 for the Yucca Mountain INTRAVAL Test Case has been successfully demonstrated. In addition, an adaptive grid routine has been written to adjust to each geostatistical simulation in preparation for modeling the flow field between the two holes. Current efforts are centered on generating a model for the characteristic curves for the INTRAVAL Test Case. The geostatistical-simulation program and documentation were obtained, and a two-dimensional cross section of the first INTRAVAL problem was generated. The geostatistical adaptive grid generator (GAG) was written to take output from the geostatistical simulator and produce grids and input files for the flow simulator. The basic idea of this algorithm is to minimize the standard deviation within each element of the grid by adapting the grid. This modification makes GAG much more robust and produces better grids. Subroutines are being added to GAG to produce the input files for both flow codes (NORIA and DUAL). The geostatistical simulator produces simulated values for porosity. The other variables have to be automatically generated by GAG. More analysis of correlations between porosity and the other material properties was required to implement the statistical generation of these properties in GAG. Statistical evaluation of the INTRAVAL data is nearing completion. Results are being written up for internal distribution to solicit suggestions and comments before being incorporated into GAG and the flow codes.

A newer version of the geostatistical simulator from Stanford's GLIB was implemented along with an increase of the anisotropy from 5:1 to 10:1. The two-dimensional variogram program has also been implemented. By the end of September 1992, modifications should be completed to allow them to run using a common input file.

PROGRESS REPORT #7

The incomplete gamma function was added to DUAL for use in saturation curves. Use of the gamma function allows for upscaling of saturation curves from a local scale to an element scale. Three realizations were generated by the geostatistical simulator and run through the system of codes to test the system and produce preliminary results. Graphical images were also produced to assist in interpretation and for use in outside presentations. There still remains detailed checking of input and cleaning up and debugging codes.

SNL staff attended the July 14, 1992, meeting on future directions in PA and contributed some input regarding the INTRAVAL studies relation to future PA. Staff also attended the annual Society for Industrial and Applied Mathematicians (SIAM) meeting July 20-23, 1992, to obtain information on recent research in nonsymmetric preconditioners for linear-equation solvers.

SNL staff made a short presentation on the fundamental unsaturated flow issues at a technical exchange sponsored by the YMP in Albuquerque, New Mexico, on April 1, 1992, and also made a presentation on "Unsaturated Zone Hydrologic Data Base and Elicitation of Expert Opinion" (Kaplan) at the NWTRB meeting in Dallas, Texas, on April 7, 1992.

A number of SNL staff attended the 1992 IHLRWM Conference in Las Vegas. Among the papers presented by SNL was "Comparison of Two Conceptual Models of Flow Using the TSA" (Wilson, 1992).

A report entitled "Conceptual, Experimental and Computational Approaches to Support Performance Assessment of Hydrology and Chemical Transport at Yucca Mountain" (Narasimhan and Wang, 1992) was printed and distributed.

The authors of "Processes, Mechanisms, Parameters and Modeling Approaches for Partially Saturated Flow in Soil and Rock Media" (Wang and Narasimhan) are addressing review comments and have submitted a camera-ready draft for publication.

A summary of a forthcoming paper, "The Most Likely Groundwater Flux through the Unsaturated Tuff Matrix at USW H-1" (Gauthier), was submitted for presentation at the 1993 IHLRWM Conference.

SNL staff attended the joint meeting of the Geochemistry and Hydrology Integration Teams in Denver, Colorado, on June 9-10, 1992.

Subactivity 1.6.3.1.2 - Saturated zone flow analysis. A cross-sectional model for the saturated-flow model was constructed during the reporting period. The cross-sectional and areal models of the portion of Yucca Mountain being analyzed for flow in the SZ has been simulated in two dimensions using the code ISOQUAD. The next step will be to attempt duplication of the two-dimensional results in three dimensions using STAFF3D simulations.

The simulations that have been run use alternative boundary conditions and material properties through a cross section of Yucca Mountain that includes a "drain" in the vicinity of the high hydraulic gradient northwest of the potential repository block. Preliminary results indicate that the drain postulated by the USGS could produce gradients similar to those observed. The results of the modeling were presented at the Hydrology Integration Team meeting hosted by SNL on July 28, 1992. Staff from LANL, LLNL, the USGS, YMPO, and the M&O were present to discuss, among other topics, the results of the saturated-zone modeling effort underway at SNL.

Forecast: Work to be accomplished in the analysis of the unsaturated and saturated flow systems is described in the forecast for Activity 1.6.4.1.

2.7.5.4 Activity 1.6.4.1 - Calculation of pre-waste-emplacement groundwater travel time

Subactivity 1.6.4.1.1 - Performance allocation for Issue 1.6. Analysis material that might be used in reallocation of PA activities is discussed under Subactivity 1.6.4.1.3.

Subactivity 1.6.4.1.2 - Sensitivity and uncertainty analyses of groundwater travel time. Work performed under this topic is discussed in Subactivity 1.6.4.1.3.

Subactivity 1.6.4.1.3 - Determination of the pre-waste-emplacement groundwater travel time. "Pre-Waste-Emplacement Groundwater Travel Time Sensitivity and Uncertainty Analyses For Yucca Mountain, Nevada" (Kaplan) completed SNL management and technical review and was sent to the YMP for policy review. The document has been reviewed by the YMP and returned with minor comments that will be addressed.

A paper entitled "Model Domains and Hydrologic Data Base to Support Early Site Suitability and Total-System Performance Assessment Models" (Gainer et al.) is being prepared for internal technical review. This report documents the sources of the data used in both ESSE and TSPA analyses, as well as the logic used to develop the probability distribution functions for all of the parameters.

Simulations of GWTT are using the two-dimensional flow code LLUVIA2D. Graphical interpretations of the simulations are being investigated using PV-WAVE.

SNL staff investigated the origin of value of 970 years for GWTT in the UZ claimed by the State of Nevada. The investigation showed that the number was derived from a review of the Draft Environmental Assessment conducted by the Desert Research Institute (DRI) at

the request of the State and published with the State's review comments in 1985. A draft letter was submitted to the Project Office reviewing both the comments by DRI and the State of Nevada.

A three-day short course entitled "Reliability-Based Design in Civil Engineering" was held August 3-5, 1992 and attended by SNL staff. The course was taught by Dr. M. Harr of Purdue University. The course stressed probabilistic approaches to estimates of system reliability. Application of some of the course material to PA of the Yucca Mountain site--in particular, to the estimation of GWTT--was demonstrated by SNL staff.

A presentation entitled "Preliminary Uncertainty and Sensitivity Results for Pre-Waste-Emplacement Groundwater Travel Time" (Kaplan, 1992) was given at the 1992 IHLRWM Conference in Las Vegas.

On August 6, 1992, SNL staff met with representatives of the YMPO in Las Vegas, Nevada, to discuss realistic estimates of system reliability for the Yucca Mountain site. SNL staff was requested to prepare a short white paper on uncertainty that can be used to explain the concept to the public.

SNL staff met with a member of the Harry Reid Environmental Center at UNLV on August 26, 1992, to discuss the Center's chemical analysis of selected springs in southern Nevada.

Forecast: Planning for a workshop on GWTT, to be held in 1994, will be completed in FY 1993. Simulations using available data to predict GWTT, including some uncertainty and sensitivity studies, will be documented in a report in May 1993. In addition, memos on the adaptation of the code LLUVIA to desktop computers and workstations will be distributed in September 1993. Model development will include work on probability models used to quantify uncertainties in the site data base, the conceptual process models, and the prediction of compliance with the regulatory criteria. A report on the conceptual basis for estimating compliance with the regulatory criteria is scheduled for July 1993. Geohydrologic data development is continuing, and the status and evaluation of current data in support of GWTT will be discussed in a report in June 1993.

2.7.5.5 Activity 1.6.5.1 - Groundwater travel time after repository construction and waste emplacement

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

Forecast: No activity is planned for FY 1993.

2.7.5.6 Activity 1.6.5.2 - Definition of the disturbed zone

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

Forecast: No activity is planned for FY 1993.

2.7.6 Total system performance (SCP Section 8.3.5.13)

2.7.6.1 Performance Assessment Activity 1.1.2.1 - Preliminary identification of potentially significant release scenario classes

Subactivity 1.1.2.1.1 - Preliminary identification of potentially significant sequences of events and processes at the Yucca Mountain repository site. A paper entitled "Progress Report on the Construction of Event Trees in Support of Scenario Development: Tectonics" (Barnard et al.) has completed internal technical review and the authors are responding to comments generated during management review. This document was revised to reflect general tectonic models of importance identified during the EPRI expert elicitation on seismic risk in the Yucca Mountain region.

Subactivity 1.1.2.1.2 - Preliminary identification of potentially significant release scenario classes. Staff attended and supported the NRC Technical Exchange on Scenario Development and CCDF Construction in Albuquerque, New Mexico, on April 28-29, 1992. Presentations related to scenario development given by SNL staff were "Definition of Terms" (Bingham) and "Construction of Scenarios" (Barr). A dry run for all presenters held prior to the meeting was hosted by SNL on April 21, 1992.

A paper entitled "Scenarios Constructed for Basaltic Igneous Activity at Yucca Mountain and Vicinity" (Barr et al.) was submitted for internal SNL technical review. Resolution of review comments has required a major reorganization of one of the branches of the tree. Upon completion of this reorganization, the document will be reviewed by the LANL coauthors and SNL management. Much of the work accomplished during this reporting period was on the artwork/graphics used to depict the complex scenarios related in the text. The artwork is essential for visualizing and constructing many of the numerical and analytical models related to basaltic igneous activity. The authors intend to use similar representations for the remaining scenario construction documents.

Work has resumed on a document on the construction of scenarios for nominal ground- water flow. Work is being done on the nominal-flow scenarios to better describe the interactions of groundwater with thermal, mechanical, and radiation-induced alterations to the

near field. The nominal-flow scenario report has undergone a major revision as a branch has been added to the tree describing scenarios assuming there is no net influx of water into the mountain.

Forecast: The development and selection of scenarios for modeling will continue during FY 1993. Deliverables will include completion of the report for basaltic volcanism in January 1993, for tectonic phenomena in January 1993, and for nominal flow in September 1993. Any progress on scenarios for human intrusion will be reported in a memo due September 1993.

2.7.6.2 Performance Assessment Activity 1.1.2.2 - Final selection of significant release scenario classes to be used in licensing assessments

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

Forecast: No activity is planned for FY 1993.

2.7.6.3 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 release along the water pathways. Work related to this subactivity is described under Activity 1.6.3.1 and PA Activity 1.1.5.1.

Subactivity 1.1.3.1.2 - Development of a model for gas-phase releases. A number of papers on various aspects of gas flow in Yucca Mountain have been submitted or completed by workers at Disposal Safety, Inc. (DSI). These reports include: "Numerical Studies of Rock-Gas Flow in Yucca Mountain" (Amter et al., 1992) which was printed and distributed; "Predicted Gas-Phase Movement of C-14 from a Radioactive Waste Repository" (Ross et al.) which is in internal SNL technical review and will ultimately be submitted to Science; "A Semianalytical Method of Path Line Computation for Transient Finite-Difference Models" (Lu) which is currently in technical review at SNL and will be submitted to Water Resources Research; "A Coupled Model of Gas Flow and Heat Transport in Porous Media" (Ross et al.) which was submitted to the AGU Spring Meeting in Montreal, Canada; and "Implications of Stability Analysis for Heat Transfer at Yucca Mountain" (Ross et al.) which was submitted for presentation at the 1993 IHLRWM Conference.

Subactivity 1.1.3.1.3 - Development of a model of releases through basaltic volcanism. SNL staff met with staff from M&O/Woodward-Clyde to discuss how the work reported in

"Scenarios Constructed for Basaltic Ingeneous Activity at Yucca Mountain and Vicinity" (Barr et al.) might be used to help resolve NRC comments on the Study Plan related to basaltic-volcanism issues.

Subactivity 1.1.3.1.4 - Development of a model of releases through human intrusion. No progress during the reporting period; this is an out-year activity.

Forecast: During FY 1993, a gas-flow model for total-system analysis will be extended to include the effects of barometric pumping, capability for handling higher temperatures, and other improvements. The code that includes the gas-flow model, TGIF2, will be benchmarked. The deliverable for this activity includes a report describing the code and the results obtained with it in September 1993.

2.7.6.4 Performance Assessment Activity 1.1.4.1 - The screening of potentially significant scenario classes against the criterion of relative consequences

Reported under Activity 1.1.2.1.

2.7.6.5 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 mentioned in proposed 10 CFR 112 and 60.115

Reported in under Activity 1.1.5.1.

2.7.6.6 Performance Assessment Activity 1.1.5.1 - Calculation of an empirical complementary cumulative distribution function

Total System Performance Assessment - Results of the TSPA - 1991 (Barnard et al., 1992) were presented to the NWTRB. Presentations included: "Total-System Performance Assessment (TSPA-1991) Problem Definition" (Dockery), "Unsaturated-Zone Hydrologic Data Set and Elicitation of Expert Opinion" (Kaplan), "TSPA Aqueous and Gaseous Release Calculations" (Wilson), and Human Intrusion, Basaltic Igneous Activity, and Combining CCDFs" (Barnard). Results of the TSPA-1991 were also presented (Barnard and Dockery) to visiting members of the Svensk Karna Vranslehantring (SKB) at a technical interchange held in Las Vegas, Nevada, on April 9, 1992.

A large effort was expended to revise and finalize the final version of "TSPA 1991: An Initial Total-System Performance Assessment for Yucca Mountain" (Barnard et al., 1992). Response to YMP review comments and the final figures were incorporated into the text in

preparation for printing. The TSPA-91 document was printed and distributed in July 1992. The final document is substantially the same as preliminary versions released in April prior to the NWTRB presentations. However, a number of editorial revisions resulting from YMP review were incorporated into the final version. A paper based on this report was solicited for submission to Radioactive Waste Management and the Nuclear Fuel Cycle. "A Preliminary Total-System Performance Assessment for the Potential Repository Site at Yucca Mountain" (Wilson et al.) completed SNL's internal reviews and has been sent to YMPO for policy review.

SNL staff attended a second-cycle TSPA planning meeting July 21, 1992, in Vienna, Virginia. Representatives of INTERA, TRW, and YMPO were also present. Members of SNL's TSPA team have begun planning the next cycle of SNL's TSPA. The areas that have been identified for study include sensitivity studies on parameters used in aqueous flow; thermal loading effects; effects of geochemistry, enhanced source term, and tectonic activity; improvement on current gas flow models and infiltration models; and a number of other problems.

SNL staff attended the ANS annual meeting in Boston, Massachusetts, on June 10, 1992, to present three papers, including: "A Six-Step Method for Systematic Performance Assessment" (Barnard, 1992), "Approach to Geologic Repository Postclosure System Performance Assessment" (Pahwa et al., 1992), and "Total-System Performance Assessment for the Yucca Mountain Project" (Wilson, 1992). Summaries of the presentations were published in Transactions of the American Nuclear Society.

On June 25, 1992, SNL hosted a meeting stimulated by EPRI to provide input on the development of enhancements to the source term/near field component of their total-system model. Representatives from EPRI, INTERA, DOE, Risk Engineering Inc., DSI, TRW, and SNL were present. The list of items recommended for inclusion into their model in the near term included modeling the distribution of container failures (by various processes), thermal effects (such as thermally accelerated geochemical processes), and hydrologic effects (such as near-field flow processes) Although the meeting was mainly concerned with discussions of waste-package and near-field issues, some far-field flow and transport issues were discussed as well.

Staff have been developing source-term inventories (using the ORIGEN data base) that reflect the changes in isotopic compositions due to reactor type, amount of burnup, and length of decay since discharge from the reactors. These data will be used to evaluate the importance of using such detailed source terms in TSPA calculations, compared with the averaged source term of 60-percent PWR (at 33,000-MWd burnup) and 40-percent BWR (at 27,500-MWd burnup). Analyses are being run on inventory as a function of burnup and decay to investigate whether the typical model using a lumped source inventory is a

reasonable representation. The lumped source model ignores several potentially important radionuclides. Therefore, it may be important to represent the source term using a more realistic inventory.

SNL staff prepared recommendations for DOE to provide EPA revisions that would address human intrusion in the environmental standards governing repositories based on the "three-bucket approach" proposed by the NRC staff. The human-intrusion work used results of the TSPA as a basis for its recommendations. Additional calculations were prepared for the analysis of the three-bucket approach. These calculations showed that in some simulations the three-bucket approach is more restrictive than the original standard. In other simulations, it is less restrictive. A report entitled "A Comparison of the 1985 EPA Standard with the Three-Bucket Approach" (Wilson) was completed and attached to the material sent by the YMP to the EPA.

Further effort in support of YMPO assistance to the EPA took the form of presentations to a special board of the NAS. This board was formed at the request of the EPA to review the material that the YMPO had sent as technical assistance. SNL staff presented the YMPO material on human intrusion and participated in the board's inquiries. The board did not examine the YMPO material on the three-bucket approach.

The calculations evaluating the three-bucket approach were the basis for a technical exchange with the NRC on July 22, 1992. At that exchange, "An Analysis of the Three-Bucket Approach" (Wilson) was presented. Other SNL staff also participated.

SNL staff attended a meeting with members of the Geochemistry Integration Team for the purpose of setting up a workshop on colloids and their implications for Yucca Mountain PA.

The WINGZ effort was redirected to use INFORMIX software and will be referred to as the Visual Integrated Data Base (VIDB). The INFORMIX software has been received and the data base system is now being constructed. (See Activity 1.6.2.2.)

SNL staff attended a meeting hosted by EPRI on the use of expert elicitation in PA in Palo Alto, California, on April 30, 1992.

A class on Expert Judgment, taught by Dr. S. Hora of the University of Hawaii, was presented in Albuquerque, New Mexico, on July 6, 1992. In addition to SNL staff, attendees included staff from YMPO, SAIC, and the M&O.

Forecast: During FY 1993, the second cycle of TSPA will proceed through analyses to enhance the first cycle, completed in FY 1992. These analyses will cover the topics listed above as areas identified for study. A report containing the results of these analyses will be

completed in September 1993. A memo describing the performance of the VIDB data base will be delivered in September 1993. A memo on the planning status of a generic methodology for using expert judgement and a report on the elicitation of probability distributions will be completed by September 1993.

2.7.7 Individual protection (SCP Section 8.3.5.14)

2.7.7.1 Activity 1.2.1.1 - Calculation of doses through the groundwater pathway

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

Forecast: No activity is planned for FY 1993.

2.7.7.2 Activity 1.2.2.1 - Calculation of transport of gaseous carbon-14 dioxide through the overburden

Reported under Subactivity 1.1.3.1.2.

2.7.7.3 Activity 1.2.2.2 - Calculation of land-surface dose and dose to the public in the accessible environment through the gaseous pathway of carbon-14

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

Forecast: No activity is planned for FY 1993.

2.7.8 Groundwater protection (SCP Section 8.3.5.15)

2.7.8.1 Analysis 1.3.1.1 - Determine whether any aquifers near the site meet the Class I or special source criteria

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

Forecast: No activity is planned for FY 1993.

2.7.8.2 Analysis 1.3.2.1 - Determine the concentrations of waste products in any special source of groundwater during the first 1,000 years after disposal

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

Forecast: No activity is planned for FY 1993.

2.7.9 Performance confirmation (SCP Section 8.3.5.16)

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

Forecast: No activity is planned for FY 1993.

2.7.10 NRC siting criteria (SCP Section 8.3.5.17)

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

Forecast: No activity is planned for FY 1993.

2.7.11 Higher-level findings--postclosure system and technical guidelines (SCP Section 8.3.5.18)

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

Forecast: No activity is planned for FY 1993.

3.0 SCHEDULE

In late November 1989, a new proposed program schedule was announced in the Secretary's report to Congress (DOE, 1989). The new schedule was based on consideration of the duration required to obtain Yucca Mountain site access from the NRC, the State of Nevada, and others; and the work scope described in the SCP and the more-detailed Study Plans. In January 1990, the schedule presented in the Secretary's report to Congress was finalized by OCRWM in the Program Cost and Schedule Baseline (DOE, 1990). This Program Cost and Schedule Baseline was revised in March 1991, in November 1991, and again in September 1992. Factors external to the program, including uncertainties associated with obtaining future environmental permits, program funding levels, and Study Plan review, may continue to affect the program schedule.

This section presents the schedule baseline for the YMP as of the end of this reporting period (September 30, 1992). More detailed schedules are maintained at the YMPO, in combination with work scopes and the dollars needed to accomplish this work. The schedule focuses on the early evaluation of site suitability of the Yucca Mountain site.

Table 3.1 presents the summary milestones for the YMP. Figure 3.1 shows the relationship of the summary milestones to the major activities.

Table 3.1 Summary Milestones [1]

	Baseline Date	Actual Date
Surface-Based Testing		
Obtain Permits	12/91	7/91
Start New Surface-Based Testing	1/92	7/91
Complete Deep Unsaturated Zone Hydrologic Hole Drilling	6/95	
ESF		
Start Final ESF Title II Design	10/91	10/91
Start ESF Site Preparation	11/92	
Start ESF In Situ Test Phase	6/96	
Complete ESF Development Drifting	11/97	
Provide Engineering Barrier System Data to Waste Package License Application Design	7/98	
Waste Package/Repository Design		
Complete Repository Program Plan	3/91	9/91
Start Waste Package/Repository Advanced Conceptual Design	10/92	10/92
Start Waste Package/Repository License Application Design	6/96	
Environmental Impact Statement		
Issue EIS Notice of Intent	5/97	
Issue EIS Implementation Plan	2/98	
Notify State of Proposed Site Selection	10/99	
Issue Draft EIS	10/99	
Issue Final EIS	3/01	
Notify State of Site Selection	3/01	
Issue Record of Decision	4/01	
Issue Site Recommendation Report to the President	4/01	
License Application		
Provide Recommendation to the Director, OCRWM, on Alternative License Application Strategies for Review	8/91	8/91
Submit License Application to the NRC	10/01	

[1]Table shows approved Program Schedule Baseline and actual completion dates as of September 30, 1992

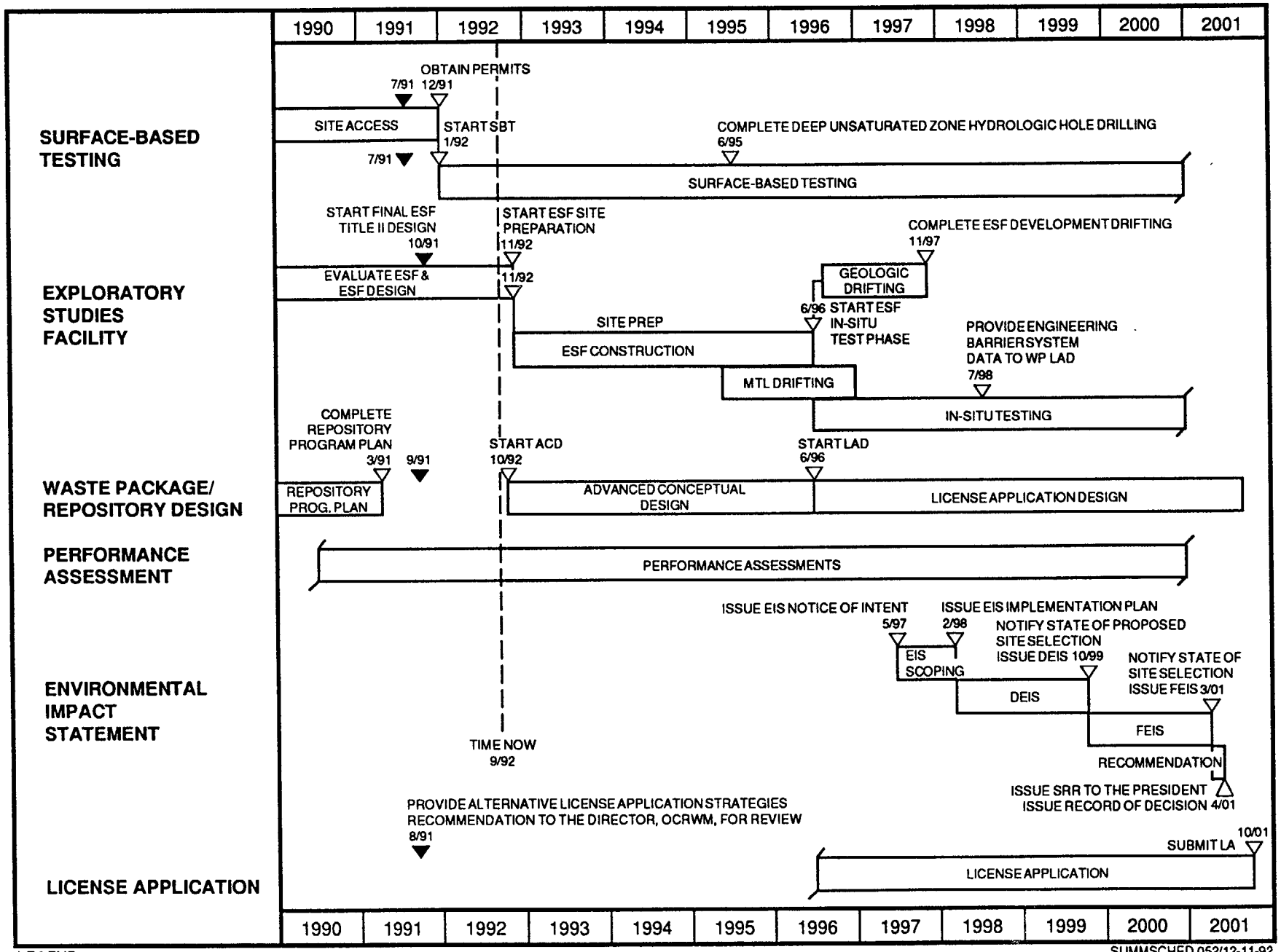

Figure 3.1. Site Characterization Summary Schedule.

LEGEND

▽ PROGRAM COST AND SCHEDULE BASELINE MILESTONE

▼ ACTUAL START/COMPLETION DATE

PROGRESS REPORT #7

4.0 EPILOGUE

This section provides a brief summary of key events that occurred after the close of the reporting period on September 30, 1992.

Congress passed the Comprehensive National Energy Policy Act of 1992 and the President signed it into law (Public Law 102-486) on October 24, 1992. Section 801 of the law directs the EPA to "...prescribe the maximum annual effective doses equivalent to individual members of the public from releases to the accessible environment from radioactive materials stored or disposed of in the repository (at Yucca Mountain)." The law also directs the EPA to consult the National Academy of Sciences on, among other topics, whether institutional controls would prevent humans from breaching the repository's engineered and natural barriers.

Section 803 of the Act requires the Secretary to report to the Congress and the President within one year on the adequacy of current waste management disposal plans to accommodate additional volumes of spent fuel and high-level waste from an expanded nuclear industry.

In October 1992, the State of Nevada issued to DOE a point source permit for dust control for the Cone Gravel Screening Plant which will be used during ESF site preparation and construction activities.

The draft ESF ramp size study was issued to DOE by RSN in October 1992. All comments from the ESF Design Package 1A Technical and Management Design Review have been resolved. The RSN Design Verification Review, and the design specifications and drawings were completed and submitted to YMPO for acceptance and review. YMPO reviewed and accepted these documents in November 1992. Also in November, DOE received the ESAAB approval to commence ESF excavation, and site preparation was initiated.

By letter dated November 2, 1992, the NRC notified DOE that based on the NRC staff's review of information provided by DOE in relevant portions of the ESFAS and CHRBA reports, NRC considers Objection 1 lifted and SCA Comments 12, 16, 35, 57, 72, 127, 128, 132, and SCA Question 61 resolved.

In November 1992, PNL issued the report, "Preliminary Total System Analysis of a Potential High-Level Nuclear Waste Repository at Yucca Mountain" (Eslinger et al., 1992). This document describes the work that was performed by PNL as part of DOE's 1991 TSPA.

PROGRESS REPORT #7

The draft Erosion Topical Report was completed and submitted to YMPO in November 1992 and YMPO completed the review in December. The draft Report will next be reviewed by the program Headquarters office.

The Request for Proposals for a Tunnel Boring Machine to be used in the excavation of the Exploratory Studies Facility at Yucca Mountain was released on December 16, 1992.

REFERENCES

All technical reports and research products published by participating organizations on the YMP are generally available through the Office of Scientific and Technical Information (OSTI) at Oak Ridge, Tennessee. OSTI is the national center for dissemination of non-classified scientific and technical information prepared from research sponsored by DOE. The references cited in this section are available through OSTI, the open literature, or through proceedings volumes for symposia and technical conferences.

Copies of YMP reports and other documents published by DOE and the participating organizations, which are available through OSTI, can be ordered from:

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

Annotated outlines of YMP-sponsored reports can be found in the YMP Bibliography. Updates are published every six months. The bibliography segments released to date are as follows:

DOE (U.S. Department of Energy), 1987. Nevada Nuclear Waste Storage Investigations, 1977-1985, A Bibliography, DOE/TIC-3406, Office of Scientific and Technical Information, Oak Ridge, Tennessee.

DOE (U.S. Department of Energy), 1988. Nevada Nuclear Waste Storage Investigations, 1986-1987, A Bibliography, DOE/OSTI-3406 (Suppl. 1), Office of Scientific and Technical Information, Oak Ridge, Tennessee.

DOE (U.S. Department of Energy), 1990. Yucca Mountain Project Bibliography, 1988-1989, DOE/OSTI-3406 (Suppl. 2), Office of Scientific and Technical Information, Oak Ridge, Tennessee.

DOE (U.S. Department of Energy), March 1991. Yucca Mountain Site Characterization Project Bibliography, January-June 1990, DOE/OSTI-3406 (Suppl. 2) (Add. 1), Office of Scientific and Technical Information, Oak Ridge, Tennessee.

DOE (U.S. Department of Energy), May 1991. Yucca Mountain Site Characterization Project Bibliography, July-December 1990, DOE/OSTI-3406 (Suppl. 2) (Add. 2), Office of Scientific and Technical Information, Oak Ridge, Tennessee.

DOE (U.S. Department of Energy), September 1991. Yucca Mountain Site Characterization Project Bibliography, January-June 1991, DOE/OSTI-3406 (Suppl. 2) (Add. 3), Office of Scientific and Technical Information, Oak Ridge, Tennessee

DOE (U.S. Department of Energy), June 1992. Yucca Mountain Site Characterization Project Bibliography, 1990-1991, DOE/OSTI-3406 (Suppl. 3) (Add. 4), Office of Scientific and Technical Information, Oak Ridge, Tennessee.

PROGRESS REPORT #7

REFERENCES

Albrecht, S.L., W.J. Arabasz, J.H. Bell, F.W. Cambray, S.W. Carothers, J.I. Drever, M.T. Einaudi, K.V. Hodges, R.H. Jones, D.K. Kreamer, W.G. Pariseau, T.A. Vogel, and T. Webb III, 1992. Report of the Peer Review Panel on the Early Site Suitability Evaluation of the Potential Repository Site at Yucca Mountain, Nevada, SAIC-91-8001, Technical and Management Support Services, Science Applications International Corporation, Las Vegas, Nevada.

Amter, S., N. Lu, and B. Ross, 1992. Numerical Studies of Rock Gas Flow in Yucca Mountain, SAND91-7034, Sandia National Laboratories, Albuquerque, New Mexico.

Barnard, R. W., and R. C. Dykhuizen, 1992. Groundwater Flow Code Verification "Benchmarking" Activity (Cove 2A): Analysis of Participant's Work, SAND89-2558, Sandia National Laboratories, Albuquerque, New Mexico.

Barnard, R.W, F.W. Bingham, H.A. Dockery, R.R. Eaton, J.H. Gauthier, P.G. Kaplan, T. H. Robey, and M. L. Wilson, 1992. TSPA 1991: An Initial Total-System Performance Assessment for Yucca Mountain, SAND91-2795, Sandia National Laboratories, Albuquerque, New Mexico.

Barnard, R. W., 1992. "A Six-Step Method for Systematic Performance Assessment," in Proceedings of the 1992 Annual Meeting, American Nuclear Society, La Grange, Illinois, pp. 55-7. (NNA.920629.0031)

Birdsell, K., K. Campbell, K. Eggert, and B. Travis, 1992. "Sensitivity Analysis of Integrated Radionuclide Transport Based on a Three-dimensional Geochemical/Geophysical Model," in Proceedings of the DOE/Yucca Mountain Site Characterization Project Radionuclide Adsorption Workshop, LA-12325-C, September 11-12, 1990, Los Alamos National Laboratory, Los Alamos, New Mexico, pp. 187-224.

Broxton, D.E., 1992. "Chemical Changes Associated with Zeolitization on the Tuffaceous Beds of Calico Hills at Yucca Mountain, Nevada," in Water-Rock Interaction Proceedings of the 7th International Symposium on Water-Rock Interaction, WRI-7, Park City, Utah, July 13-18, 1992, pp. 699-703.

Buscheck, T.A., and J.J. Nitao, 1992. "The Impact of Thermal Loading on Repository Performance at Yucca Mountain," UCRL-JC-109232, Lawrence Livermore National Laboratory, Livermore, California.

Canepa, J.A., 1992. "Proceedings of the DOE/Yucca Mountain Site Characterization Project Radionuclide Adsorption Workshop at Los Alamos National Laboratory," LA-12325-C, Los Alamos National Laboratory, Los Alamos, New Mexico.

Case, J.B., J.A. Fernandez, and J. Tyburski, 1992. "Supporting Hydration Calculations for Small- to Large-Scale Seal Tests in Unsaturated Tuff," in Proceedings of the 1992 International High-Level Radioactive Waste Management Conference, Las Vegas, Nevada, vol. 2, pp. 2298-2305.

Chen, E.P., 1986. "Two-Dimensional Continuum Model for Jointed Media With Orthogonal Sets of Joints," in Proceedings, 27th U.S. Symposium on Rock Mechanics, pp. 862-867.

Chesnut, D.A., 1992. "Characterizing the Altered Zone at Yucca Mountain: The Beginning of a Testing Strategy," UCRL-JC-109231, Lawrence Livermore National Laboratory, Livermore, California.

Chesnut, D.A., 1991. "Demands Placed on Waste Package Performance Testing and Modeling by Some General Results on Reliability Analysis," UCRL-106758, Lawrence Livermore National Laboratory, Livermore, California.

Coe, J.A., J.W. Whitney, P.A. Glancy, 1992. Photogrammetric Analysis of Modern Hillslope Erosion at Yucca Mountain, Nevada, Geological Society of America Abs. with programs, vol. 26, no 7., pl A296. [abs.]

Crowe, B.M., R. Picard, G. Valentine, and F. Perry, 1992a. "Recurrence Models of Volcanic Events: Application to Volcanic Risk Assessment," in Proceedings of the Third International High-Level Radioactive Waste Management Conference, Las Vegas, Nevada, vol. 2, pp. 2344-2355.

Crowe, B.M., G. Valentine, R. Morley, and F.V. Perry, 1992b. "Recent Progress in Volcanism Studies: Site Characterization Activities for the Yucca Mountain Project," in Waste Management '92, Arizona Board of Regents, Tucson, Arizona, vol. 1, pp. 921-928.

Crowe, B.M., R. Morley, S. Wells, J. Geissman, E. McDonald, L. McFadden, F. Perry, M. Murrell, J. Poths, and S. Forman, 1992c. "Lathrop Wells Volcanic Center: Status of Field and Geological Studies," in Proceedings of the Third International High-Level Radioactive Waste Management Conference, Las Vegas, Nevada, vol. 2, pp. 1997-2013.

Czarnecki, J.B., Kroitoru, Levy, Ronen, Daniel and Margaritz, Mordeckai, 1992(a). Does Localized Recharge Occur at a Discharge Area Within the Groundwater Flow System of Yucca Mountain, Nevada, in Proceedings, Waste Management 1992, Working towards a cleaner environment, March 1-5, 1992, Tucson, Arizona, vol. 1, p. 953-958.

Czarnecki, J.B., Ronen, Daniel, Margaritz, Mordeckai, and Kroitoru, Levy, 1992(b). A Hint of Recharge at Franklin Lake Playa, Inyo County,California, USA, Proceedings of the 7th International Symposium on Water-Rock Interaction, Park City, Utah, 7/13-18/92, pp. 631-634.

Dennis, A.W., (ed.), 1991. Exploratory Studies Facility Alternatives Study: Final Report, SAND91-0025, 2 volumes, Sandia National Laboratories, Albuquerque, New Mexico.

Distel, W.B., 1992. "Erosion Rates of Yucca Mountain: Technical Assessment and Qualification of Data,", Woodward-Clyde Federal Services, Denver, Colorado.

DOE (U.S. Department of Energy), 1988. Site Characterization Plan: Yucca Mountain Site, Nevada Research and Development Area, Nevada, DOE/RW-0199, Office of Civilian Radioactive Waste Management, Washington D.C.

DOE (U.S. Department of Energy), 1991. Risk/Benefit Analysis of Alternative Strategies for Characterizing the Calico Hills Unit at Yucca Mountain, Record Memorandum YMP/90-3, 2 volumes, Yucca Mountain Site Characterization Project Office, Las Vegas, Nevada.

DOE (U.S. Department of Energy), 1992a. Title 1 Design Summary Report for the Exploratory Studies Facility, YMP/CC-0019, 5 volumes, Yucca Mountain Site Characterization Project Office, Las Vegas, Nevada.

DOE (U.S. Department of Energy), 1992b. Technical Assistance to the U.S. Environmental Protection Agency on 40 CFR Part 191, Yucca Mountain Site Characterization Project Office, Las Vegas, Nevada.

Dudley, A.L., J.H. Gauthier, R.R. Peters, L.H. Skinner, and M.L. Wilson, 1992. Total System Performance Assessment Code (TOSPAC) Volume 2: User's Guide, SAND85-0004, Sandia National Laboratories, Albuquerque, New Mexico.

Easterling, R.G., I.J. Hall, E.A. Klavetter, R.R. Peters, and B.M. Rutherford, 1992. Statistical Analysis of Hydrologic Data for Yucca Mountain, SAND87-2380, Sandia National Laboratories, Albuquerque, New Mexico.

Eaton, R.R., and P.L. Hopkins, 1992. LLUVIA-II: A Program for Two-Dimensional Transient Flow Through Partially Saturated Porous Media, SAND91-2416, Sandia National Laboratories, Albuquerque, New Mexico.

Ebinger, M., 1992. "Water-Rock Interactions and the pH Stability of Groundwaters from Yucca Mountain, Nevada," in Water-Rock Interaction, Proceedings of the 7th International Symposium on Water-Rock Interaction, WRI-7, Park City, Utah, July 13-18, 1992, A.A. Balkema, Rotterdam and Brookfield, pp. 783-786.

Einziger, R. E. , L. E.Thomas, H. C. Buchanan, and R. B. Stout, 1992. "Oxidation of Spent Fuel in Air at 175 °C to 195 °C" (previously entitled "Ceramographic Determination of Spent Fuel Oxidation Rate"), Pacific Northwest Laboratory and Lawrence Livermore National Laboratory.

Eslinger, P., L.A. Doremus, D.W. Engel, T.B. Miley, M.T. Murphy, W.E. Nichols, M.D. White, D.W. Langford, and S.J. Ouderkirk, 1992 (Dated 1993). "Preliminary Total System Analysis of a Potential High-Level Nuclear Waste Repository at Yucca Mountain," PNL-8444, Pacific Northwest Laboratory, Richmond, Washington.

Evernden, J.F. ,1992. Safety of Proposed Yucca Mountain Nuclear Repository as Regards Geological and Geophysical Factors: Evaluation of Minority Report by Archambeau and Price. U.S. Geological Survey Open-File Report 92-516, 95 p.

Fernandez, J.A., J.B. Case, and J. Tyburski, 1992. "Proposed Sealing Field Tests for a Potential High-Level Radioactive Waste Repository," in Proceedings of the 1992 International High-Level Radioactive Waste Management Conference, Las Vegas, Nevada, vol. 2, pp. 2290-2297.

Foltz, S.D., V.C. Tidwell, R.J. Glass, C.A. Kelsey, and R.R. Eaton, 1992. "An Experimental Investigation of Matrix Interaction On Fracture Flow," in Proceedings of the Fall 1992 American Geophysical Union Meeting, SAND92-1936A, Sandia National Laboratories, Albuquerque, New Mexico.

Glass, R.J., and D.L. Norton, 1992. "Wetted-Region Structure in Horizontal Unsaturated Fractures: Water Entry Through the Surrounding Porous Matrix," in Proceedings of the 1992 International High-Level Radioactive Waste Management Conference, Las Vegas, Nevada, SAND91-2030C, vol. 1, pp. 717-726.

Glassley, W.E., B.W. Christenson, 1992. "Water-Rock Interaction in New Zealand Hydrothermal Systems: Comparison of Some Simulated and Observed Geochemical Processes," in Proceedings of the 1992 International High-Level Radioactive Waste Management Conference, L-204, vol. 1, pp. 352-356.

Gray, W., L.E. Thomas, and R.E. Einziger, 1992. Pacific Northwest Laboratory, "Dissolution Rates of As-Received and Partially Oxidized Spent Fuel."

Grow, J.A., H.R. Blank, Jr., C.J. Potter, and J.J. Miller, 1992. Constraints on Extensional Fault Geometries in Eastern Railroad Valley, Nevada, Based on Seismic Reflection and Gravity Data: Geological Society of America, Abstracts with Programs, vol. 24, no. 6, p. 16. [abs.]

Hardy, M.P., and S.J. Bauer, 1991. Drift Design Methodology and Preliminary Application for the Yucca Mountain Site Characterization Project, SAND89-0837, Sandia National Laboratories, Albuquerque, New Mexico.

Harrington, C.D., and J.W. Whitney, 1991. Quaternary Erosion Rates on Hillslopes in the Yucca Mountain Region, Nevada: Geological Society of America Abs. with Programs, vol. 23, no. 5., p. A118. [abs.]

Harris, A.G., J.E. Repetski, J.L. Clayton, J.A. Grow, M.D. Carr, and T.A. Daws, 1992. Results from 1991 Wildcat Wells near Yucca Mountain, Nevada: Geological Society of America, Abstracts with Programs, vol. 24, no. 6, p. 17. [abs.]

Haupt, R.W., R.J. Martin III, R.H. Price, W.J. Dupree, and X. Tang, 1992. "Modulus Dispersion and Attenuation in Tuff and Granite," in Proceedings of the 33rd U.S. Symposium on Rock Mechanics SAND91-1926C, Sandia National Laboratories, Albuquerque, New Mexico.

Hay, R.L., R.E. Pexton, T.T. Teague, and T.K. Kyser, 1986. "Spring-Related Carbonates, Mg Clays, and Associated Minerals in Pliocene Deposits of the Amargosa Desert, Nevada and California," GSA Bulletin, vol. 97, pp. 1488-1507.

Haynes, C.V., 1967. Quaternary Geology of the Tule Springs Area, Clark County, Nevada, in H.M. Wormington, and D. Ellis, eds., Pleistocene Studies in Southern Nevada, Nevada State Museum of Anthropology Paper no. 13, Carson City Nevada, p. 1-104.

Hopkins, P.L., and R.W. Prindle, 1992. On Conditions and Parameters Important to Model Sensitivity for Unsaturated Flow Through Layered, Fractured Tuff: Results of Analyses for Hydrocoin Level 3 Case 2, SAND89-0652, Sandia National Laboratories, Albuquerque, New Mexico.

Hopkins, P.L., M.D. Siegal, and G.T. Yeh, 1992. "Efforts to Verify and Validate the Lagrangian-Eulerian Model of Hydrogeochemical Transport (LEHGC)," SAND92-2024A, Sandia National Laboratories Albuquerque, New Mexico.

Jung, J., and S. Brown, 1992. "Study of Discrete and Continuum Joint Modeling Techniques," SAND91-1730C, Sandia National Laboratories, Albuquerque, New Mexico.

Kume, Jack and J.P. Rousseau, 1992. Characterization of Liquid-Water Percolation in Tuffs in the Unsaturated Zone, Yucca Mountain, Nye County, Nevada, in Erickson, J.M., and Hoganson, J.W., eds., Proceedings of the F.D. Holland, Jr., Geological Symposium, April 14-15, 1989: Grand Fords, North Dakota, North Dakota Geological Survey Miscellaneous Series No. 76, pp. 297-301.

Langenheim, V.E., D.B. Hoover, and H.W. Oliver, 1991. Geophysical Characterization of Mineral and Energy Resources at Yucca Mountain and Vicinity, Nevada. U.S. Geological Survey Open-File Report 91-620, 7 pp.

Levy, S., 1992. "Surface-Discharging Hydrothermal Systems at Yucca Mountain - Examining the Evidence," November 30-December 4, 1992, Materials Research Society, Pittsburgh, Pennsylvania,
p. 165. [abs.]

Majer, E., L. Mar, J. Peterson, and Jung Mo Lee, 1992. "High-Resolution Seismic Imaging for Characterizing Fractures in Potential Sites for Nuclear Waste Repositories," in Proceedings of the Third International High Level Radioactive Waste Management Conference, Las Vegas, Nevada, vol. I, pp. 1111-1121.

Marshall B.D., J.F. Whelan , Z.E. Peterman , K. Futa , S.A. Mahan , and J.S. Stuckless, 1992. Isotopic Studies of Fracture Coatings at Yucca Mountain, Nevada, USA. In Karaka Y.K., and Maest A.S., eds., Water-Rock Interaction Conference: Proceedings of the 7th International Symposium on Water-Rock Interaction, Park City, Utah, July 13-18, 1992, vol. 1, pp. 737-740.

Martin, R.J. III, R.H. Price, P.J. Boyd, and J.S. Noel, 1992. "The Influence of Strain Rate and Sample Inhomogeneity on the Moduli and Strength of Welded Tuff," in Transactions of the American Geophysical Union SAND92-2152C, Sandia National Laboratories, Albuquerque, New Mexico.

Martin, R.J. III, R.H. Price, P.J. Boyd, and R.W. Haupt, 1992. Anisotropy of Topopah Spring Member Welded Tuff, SAND91-0894, Sandia National Laboratories, Albuquerque, New Mexico.

Martinez, M. J., 1992. "Boundary Integral Method for Steady Unsaturated Flow in Nonhomogeneous Media," SAND91-2555C, Sandia National Laboratories, Albuquerque, New Mexico.

Mattson S.R., B.R. Judd, S.R. Sinnock, and D.T. Hoxie, 1991. Testing Priorities at Yucca Mountain: Recommended Early Tests to Detect Potentially Unsuitable Conditions for a Nuclear Waste Repository, YMP/91-25, 2 vol., Yucca Mountain Site Characterization Project, Las Vegas, Nevada.

Meijer, A., 1992. "A Strategy for the Derivation and Use of Sorption Coefficients in Performance Assessment Calculations for the Yucca Mountain Site," in Proceedings of the DOE/Yucca Mountain Site Characterization Project Radionuclide Adsorption Workshop, 9/11-12/90, LA-12325-C, Los Alamos National Laboratory, Los Alamos, New Mexico, pp. 9-40.

Narasimhan, T.N., and J.S.Y. Wang, 1992. Conceptual, Experimental, and Computational Approaches to Support Performance Assessment of Hydrology and Chemical Transport at Yucca Mountain, SAND89-7018, Sandia National Laboratories, Albuquerque, New Mexico.

Nelson, P.H., D.C. Muller, U. Schimschal, and J.E. Kibler, 1991. Geophysical Logs and Core Measurements from Forty Boreholes at Yucca Mountain, Nevada, U.S. Geol. Surv. Geoph. Inv. Map GP-1001.

Nicholl, M.J., R.J. Glass, and H.A. Nguyen, 1992. "Gravity-Driven Fingering in Unsaturated Fractures,"SAND91-1985C, in Proceedings of the 1992 International High-Level Radioactive Waste Management Conference, Las Vegas, Nevada, vol. 1, pp. 321-331.

Nitao, J., 1992. "The Implications of Episodic Nonequilibrium Fracture-Matrix Flow on Site Suitability and Total System Performance", UCRL-JC-109216, Lawrence Livermore National Laboratory, Livermore, California.

O'Brien, G.M., 1992. Earthquake-Induced Water-Level Fluctuations at Yucca Mountain, Nevada, April, 1992: U.S. Geological Survey Open-File Report 92-137, 10 pp.

Pahwa, S.B., J.O. Duguid, and F.W. Bingham, 1992. "Approach to Geologic Repository Postclosure System Performance Assessment," SAND 92-1226C, INTERA, Austin, Texas.

Panchalingam, G., "Uncertainty Modeling of Many Correlated and Skewed Random Variables," doctoral dissertation, Purdue University, Lafayette, Indiana.

Perry, F.V., and B.M. Crowe, 1992. "Geochemical Evidence for Waning Magmatism and Polycyclic Volcanism at Crater Flat, Nevada," in Proceedings of the Third International High-Level Radioactive Waste Management Conference, Las Vegas, Nevada, vol. 2, pp 2356-2365.

Peterman Z.E., J.S. Stuckless, S.A. Mahan , B.D. Marshall , E.D. Gutentag , and J.S. Downey, 1992. Strontium Isotope Characterization of the Ash Meadows Ground-Water System, Southern Nevada, USA., in Karaka Y.K., and Maest A.S., eds., Water-Rock Interaction: Proceedings of the 7th International Symposium on Water-Rock Interaction Conference, vol. 1, pp. 825-829.

Peterman Z.E., J.S. Stuckless, B.D. Marshall , S.A. Mahan , and K. Futa , 1992. "Strontium Isotope Geochemistry of Calcite Fracture Fillings in Deep Core, Yucca Mountain, NV - a Progress Report," in Proceedings of the Third International High-Level Radioactive Waste Management Conference, Las Vegas, Nevada, vol. 2, pp. 1582-1586.

Peters, C.A., I.C. Yang, J.D. Higgins, and P.A. Burger, 1992. "A Preliminary Study of the Chemistry of Pore Water Extracted from Tuff by One-Dimensional Compression," in Proceedings of the 7th International Symposium on Water-Rock Interaction, Park City, Utah, July 13-18, 1992, pp. 631-634.

Pollard, D., and Y. Behl, 1992. "Simulation of the Arid Climate of the Southern Great Basin Using a Regional Climate Model," in Bulletin of the American Meteorological Society.

Polzer, W.L., M.G. Rao, H.R. Fuentes, and R.J. Beckman. "Thermodynamically Derived Relationships Between the Modified Langmuir Isotherm and Experimental Parameters," Environmental Science and Technology, vol. 26, pp. 1780-1786.

Quade J., 1986. "Late Quaternary Environmental Changes in the Upper Las Vegas Valley, Nevada," Quaternary Research, vol. 26, pp. 340-357.

Quade, J., and W.L. Pratt, 1989. "Late Wisconsin Groundwater Discharge Environments of the Southwestern Indian Springs Valley, Southern Nevada," Quaternary Research, vol. 31, pp. 357-370.

Raleigh, C.B., G.A. Thompson, W.F. Brace, B.H.G. Brady, J.D. Bredehoeft, R.M. Burke, R.O. Fournier, S.K. Garg, G.M. Hornberger, R.K. McGuire, A.M. Nur, H.J. Ramey, E. W. Roedder, D. Rumble, W.G. Spaulding, B.W. Wernicke, and M.L. Zoback, 1992. Ground Water at Yucca Mountain: How High Can It Rise? Final Report of the Panel on Coupled Hydrologic/Tectonic/Hydrothermal Systems at Yucca Mountain, Board on Radioactive Waste Management, Commission on Geosciences, Environment, and Resources, National Research Council, National Academy Press, Washington, D.C.

Rard, J.A., 1992. "Chemical Thermodynamics of Technetium V, UCRL-JC-109638, submitted for inclusion in the book "Chemical Thermodynamics of Technetium," Lawrence Livermore National Laboratory, Livermore, California.

Rautman, C.A., and A.L. Flint, 1992. "Deterministic Geologic Processes and Stochastic Modeling," in Proceedings of the Third International High Level Radioactive Waste Management Conference, Las Vegas, Nevada, vol. 2, pp. 1617-1624.

Rautman, C.A., and A.H. Treadway, 1991. "Geologic Uncertainty in a Regulatory Environment: An Example from the Potential Yucca Mountain Nuclear Waste Repository Site," in Environmental Geology and Water Science, vol. 18, no. 3, pp. 171-184.

Rautman, C.A., 1992a. "Applications of Geostatistics to Nuclear Waste Repository Programs," SAND92-0767A (also published informally as part of the 1992 Annual Report to SCRF [Standard Center for Reservoir Forecasting] participants), Sandia National Laboratories, Albuquerque, New Mexico.

Rautman, C. A., 1992b. "Advanced Geostatistical Methods Applied to the Yucca Mountain High-Level Nuclear Waste Program," in Abstracts, 29th International Geological Congress, Kyoto, Japan, vol. 3, p. 868.

Rogers, P., A.M. Meijer, and K.H. Kung, 1992. "Sorption Characteristics of Yucca Mountain Tuffs as a Function of Particle Size," November 30-December 4, 1992, Materials Research Society, Pittsburgh, Pennsylvania, p. 162.

Ryder, E., 1992. Equivalent Energy Density Concept: A Preliminary Reexamination of a Technique for Equating Thermal Loads, SAND91-1493, Sandia National Laboratories, Albuquerque, New Mexico.

Sandoval, R.P., Y.K., Behl, and S.L. Thompson, 1992. "An Overview of the Yucca Mountain Global/Regional Climate Modeling Program," in Proceedings of the 1992 International High-Level Radioactive Waste Management Conference, Las Vegas, Nevada, vol. 1, pp. 1188-1195.

Savard, C.S., 1992. "Looking for Chaos in Streamflow with Discharge Derivative Data," American Geophysical 1992 Spring Meeting, EOS Supplement, vol. 73, no. 14, April 7, 1992, p. 50. [abs.]

Schmidt, M.R., K.E. Kolm, and A.L. Flint, 1992. "Use of Statistically Distinct Genesislithology-Qualifier Map Units for Classifying Upland Soils at Yucca Mountain, Nevada by Geomorphology and Physical Properties Affecting Infiltration," Bulletin of the Association of Engineering Geologists, vol. XXIX, No. 1, pp. 33-47.

Schwartz, B.M., and C.S. Chocas, 1992. Linear Thermal Expansion Data for Tuffs From the Unsaturated Zone at Yucca Mountain, Nevada, SAND88-1581, Sandia National Laboratories, Albuquerque, New Mexico.

Scott, R.J., and J. Bonk, 1984. Preliminary Geologic Map of Yucca Mountain, Nye County, Nevada, with Geologic Sections, U.S. Geological Survey Open-File Report 84-494, Scale 1:12,000.

Siegel, M., P. Hopkins, R.J. Glass, and D. Ward, 1992. "Design of an Intermediate-Scale Experiment to Validate Unsaturated-Zone Transport Models," SAND91-2098C, in Proceedings of the 1992 International High-Level Radioactive Waste Management Conference, Las Vegas, Nevada, vol. 2, pp. 1972-1984.

Simmons, A.M. and J.A. Canepa, 1992. "Recent Developments in the Integrated Approach Toward Characteristics of Radionuclide Transport, Yucca Mountain, Nevada," in Waste Management '92, Arizona Board of Regents, Tucson, Arizona, vol. 1, pp. 947-951.

Stuckless, J.S., Z.E. Peterman, R.M. Forester, J.F. Whelan, D.T. Vaniman, B.D. Marshall, and E.M. Taylor, 1992. "Characterization of Fault-Filling Deposits in the Vicinity of Yucca Mountain," Nevada, in WM'92 Conference Proceedings, Tucson, Arizona, March 1-5, 1992, pp. 929-935.

Szymanski, J.S., 1989. 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, DOE Internal Report, Yucca Mountain Project Office, Las Vegas, Nevada, July 1989 (NNA.890920.0194).

Tait, C.D., D.E. Morris, S.A. Ekberg, P.D. Palmer, and J.M. Berg, 1992. "Plutonium Carbonate Speciation Changes with pH," 203rd ACS National Meeting San Francisco, California, 4/5-10/92, American Chemical Society, vol. 743. [abs.]

Taylor, E.M., 1986. Impact of Time and Climate on Quaternary Soils in the Yucca Mountain Area of the Nevada Test Site, M.S. Thesis, University of Colorado, Boulder, 267 p.

Taylor, E.M., 1991. Quaternary Spring Deposits at the Southern End of Crater Flat, Nye County, NV, EOS, Transactions, American Geophysical Union 1991 Fall Meeting Program and Abstracts, p. 162. [abs.]

Tidwell, V.C., C.A. Rautman, and R.J. Glass, 1991. "Influence of Measurement Scale on Gas Permeability Data,"SAND91-1957A, Sandia National Laboratories, Albuquerque, New Mexico.

Tidwell, V.C., and R.J. Glass, 1992. "X-Ray and Visible Light Transmission as Two-Dimensional, Full-Field Moisture-Sensing Techniques: A Preliminary Comparison," SAND91-1983C, in Proceedings of the 1992 International High-Level Radioactive Waste Management Conference, Las Vegas, Nevada, vol. 1, pp. 1099-1110.

Tidwell, V.C., C.A. Rautman, and R.J. Glass, 1992. "Field Research Program for Unsaturated Flow and Transport Experimentation," in Proceedings of the 1992 International High-Level Radioactive Waste Management Conference, Las Vegas, Nevada, vol. 1, pp. 704-709.

Triay, I.R., M.A. Ott, A.J. Mitchell, and C.M. Overly, 1992. "Transport of Np through Yucca Mountain Tuffs," in the Program of Materials Research Society, Pittsburgh, Pennsylvania. November 30- December 4, 1992, p. 163.

Triay, I.R., A.J. Mitchell, and M A. Ott, 1992. "Radionuclide Migration Studies for Validating Sorption Data - Past, Present, and Future," in Proceedings of the DOE/Yucca Mountain Site Characterization Project Radionuclide Adsorption Workshop, LA-12325-C, Los Alamos National Laboratory, Los Alamos, New Mexico, 9/11-12/90, pp. 91-110.

Valentine, G., B.M. Crowe, and F.V. Perry, 1992. "Physical Processes and the Effects of Magmatism in the Yucca Mountain Region," in Proceedings of the Third International High-Level Radioactive Waste Management Conference, Las Vegas, Nevada, vol. 2, pp. 2014-2024.

Vaniman, D., D. Bish, M. Ebinger S. Chipera, 1992. "Precipitation of Calcite, Dolomite, Sepiolite, and Silica from Evaporated Carbonate and Tuffaceous Waters of Southern Nevada," in Water-Rock Interaction, Proceedings of the 7th International Symposium on Water-Rock Interaction, WRI-7, Park City, Utah, July 13-18, 1992, A.A. Balkema, Rotterdam and Brookfield, pp. 687-692.

Viani, B.E. and C.J. Bruton, 1992. "Modeling Fluid-Rock Interaction at Yucca Mountain, Nevada: A Progress Report," UCRL-ID-109221, Lawrence Livermore National Laboratory, Livermore, California.

Viani, B.E. and C.J. Bruton, 1992. "Modeling Ion Exchange in Clinoptilolite Using EQ3/6 Geochemical Modeling Code," UCRL-JC-109952, Lawrence Livermore National Laboratory, Livermore, California.

Ward, D.B., and M.D. Siegel, 1992. "Measurement and Modeling of Ni Adsorption in Mixtures of Sand and Limonite for a Large-Scale Column Test," SAND92-2024A, Sandia National Laboratories, Albuquerque, New Mexico.

Wells, S.G., and B.M. Crowe, 1992. "Measuring the Age of the Lathrop Wells Volcanic Center at Yucca Mountain," Science, vol. 257, pp. 555-556.

Wesling, J.R., T.F. Bullard, F.H. Swan, R.C. Perman, M.M. Angell, and J.D. Gibson, 1992. Preliminary Mapping of Surficial Geology of Midway Valley, Yucca Mountain Project, Nye, County, Nevada: Interim data report, SAND91-067 (UC-814), Sandia National Laboratories, Albuquerque, New Mexico, 55 p.

Wesling, J.R., T.F. Bullard, F.H. Swan, R.C. Perman, M.M. Angell, and J.D. Gibson, 1992. "Preliminary Mapping of Surficial Geology of Midway Valley, Yucca Mountain Project, Nye County, Nevada," SAND91-0607, Sandia National Laboratories, Albuquerque, New Mexico.

Wibowo, J.T., B. Amadei, S. Sture, A.B. Robertson, and R.H. Price, 1992. "Shear Response of a Rock Joint Under Different Boundary Conditions: An Experimental Study," SAND92-0386C in Proceedings of the Fractured and Jointed Rock Masses Conference.

Wilson, M.L., 1992. "Total System Performance Assessment for the Yucca Mountain Project," SAND92-0208A, in Transactions of the American Nuclear Society, vol. 65, pp. 53-54.

Wittwer, C.S., G.S. Bodvarsson, M.P. Chornack, A.L. Flint, L.E. Flint, P.D. Lewis, R.W. Spengler, and C.A. Rautman, 1992. "Design of a Three-Dimensional Site-Scale Model for the Unsaturated Zone at Yucca Mountain, Nevada," in Proceedings of the Third International High-Level Radioactive Waste Management Conference, Las Vegas, Nevada, vol. 1, pp. 263-271.

WoldeGabriel, G., D.E. Broxton, D.L. Bish, S.J. Chipera, 1992. "Preliminary Assessment of Clinoptilolite K/AR Results from Yucca Mountain, Nevada: A Potential High-Level Radioactive Waste Repository Site," in Water-Rock Interaction, Proceedings of the 7th International Symposium on Water-Rock Interaction, WRI-7, Park City, Utah, 7/13-18, 1992, A.A. Balkema, Rotterdam and Brookfield, pp. 457-461.

Yang, I.C., 1992. "Flow and Transport Through Unsaturated Rock--Data from Two Test Holes, Yucca Mountain, Nevada," in Proceedings of the Third Annual High-Level Radioactive Waste Management Conference, Las Vegas, Nevada, vol. 1, pp. 732-737.

Younker, J.L., W.B. Andrews, G.A. Fasano, C.C. Herrington, S.R. Mattson, R.C. Murray, L.B. Ballou, M.A. Revelli, A.R. Ducharme, L.E. Shephard, W.W. Dudley, D.T. Hoxie, R.J. Herbst, E.A. Patera, B.R. Judd, J.A. Docka, and L.D. Rickertsen, 1992. Report of Early Site Suitability Evaluation of the Potential Repository Site at Yucca Mountain, Nevada, SAIC-91/8000, Technical and Management Support Services, Science Applications International Corporation, Las Vegas, Nevada.

Zimmerman, R.W., and G.S. Bodvarsson, 1992. Semi-analytical treatment of fracture/matrix flow in a dual-porosity simulator for unsaturated fractured rock masses, Proceedings of the Third International High Level Radioactive Waste Management Conference, Las Vegas, Nevada, vol. 1, pp. 272-278.

ACRONYMS/ABBREVIATIONS LIST

ACD	Advanced Conceptual Design
ACNW	Advisory Committee on Nuclear Waste
AECL	Atomic Energy of Canada Limited
AFM	atomic-force-microscopy
AGU	American Geophysical Union
ALARA	As Low As Reasonably Achievable
Am	americium
ANDRA	Agence Nationale pour la Gestion des Dechets Radioactifs
ANL	Argonne National Laboratory
ANS	American Nuclear Society
APDs	areal power densities
Ar	argon
ASCE	American Society of Civil Engineers
ASTM	American Society for Testing and Materials
ATDD	Atmospheric Turbulence and Diffusion Division
AVS	applications-visualization system
B	boron
BGRA	Branch of Geologic Risk Assessment
BLM	U.S. Bureau of Land Management
BRWM	Board on Radioactive Waste Management
C	carbon
Ca	calcium
CH	Calico Hills
CAR	Corrective Action Report
CHBRA	Calico Hills Risk/Benefit Analysis
CCB	Change Control Board
CCDF	complementary cumulative distribution function
CFCs	chlorofluorocarbons
CM	Construction Management
CO_2	carbon dioxide
CRWMS	Civilian Radioactive Waste Management System
Cs	cesium
CSM	Colorado School of Mines
DNA	Defense Nuclear Agency
DOE	U.S. Department of Energy
DP	detailed technical procedure
DRI	Desert Research Institute
DSI	Disposal Safety, Inc.
DVNM	Death Valley National Monument
EBS	engineered barrier system

PROGRESS REPORT #7

ACRONYMS/ABBREVIATIONS LIST

EEI	Edison Electric Institute
EPA	Environmental Protection Agency
EPRI	Edison Power Research Institute
ESAAB	Energy Systems Acquisition Advisory Board
ESCA	electron spectroscopy for chemical analysis
ESFAS	Exploratory Studies Facility Alternatives Study
ESFDR	Exploratory Studies Facility Design Requirements
ESSE	Early Site Suitability Evaluation
ESF	Exploratory Studies Facility
ESTSC	Energy Science and Technology Software Center
ET	Evapotranspiration Studies
Fe	iron
FEPs	features, events, and processes
FY	fiscal year
GCM	general circulation model
Gd	gadolinium
GIS	Geographic Information Systems
GIT	Geochemistry Integration Team
GMS	Geoscience Modeling System
GOES	Geostationary Operation Environmental Satellite
GPS	Global Positioning Satellite
GSIS	Geoscience Information System
GWTT	groundwater travel time
He	helium
HIT	Hydrology Integration Team
HLRW	high-level radioactive waste
HRF	Hydrologic Research Facility
HRUs	hydrologic response units
HVAC	heating, ventilating, and air conditioning
I	iodine
ICE	Independent Cost Estimation
ICP	inductively coupled plasma
IDAS	Integrated Data Acquisition System
IEA	Institutional and External Affairs
IGSG	Isotope and Geochemistry Support Group
IHLRWM	International High Level Radioactive Waste Management
IIS	insulated instrument shelter

ACRONYMS/ABBREVIATIONS LIST

IITS	items important to safety
IITWI	items important to waste isolation
INEL	Idaho National Energy Laboratory
ISP	Individual Software Plan
ISR	Institute for Standards Research
ITE	Integrated Test Evaluation
K	potassium
ksi	kilopounds per square inch
LAD	License Application Design
LANL	Los Alamos National Laboratory
LBL	Lawrence Berkeley Laboratory
Li	Lithium
LLNL	Lawrence Livermore National Laboratory
LRW	low-level radioactive waste
LT	low temperature
LVDT	linear variable differential transformer
M&O	Management and Operating
Mg	magnesium
MGDS	Mined Geologic Disposal System
MnO	manganese oxide
MPa	megapascal
MRS	Monitored Retrievable Storage
MS	mass spectrometry
MTU	metric tons of uranium
NaC1	sodium chloride
NAS/NRC	National Academy of Sciences/National Research Council
NCAR	National Center for Atmospheric Research
NCDC	National Climate Data Center
Nd	Neodymium
NER	New England Research, Inc.
NERSC	National Energy Research and Supercomputing
Ni	nickel
NIST	National Institute for Standards and Testing
NMR	nuclear magnetic resonance
NOAA	National Oceanic and Atmospheric Administration
Np	neptunium
NPS	U.S. National Park Service

ACRONYMS/ABBREVIATIONS LIST

NRC	U.S. Nuclear Regulatory Commission
NTS	Nevada Test Site
NWPA	Nuclear Waste Policy Act
NWTRB	Nuclear Waste Technical Review Board
O_2	oxygen
OCF	Open Computing Facility
OCRWM	Office of Civilian Radioactive Waste Management
OER	Office of External Relations
OQA	Office of Quality Assurance
OSTI	Office of Scientific and Technical Information
PA	performance assessment
PACS	Planning and Control System
PAS	photoacoustic spectroscopy
Pb	lead
ppb	parts per billion
ppm	parts per million
psi	pounds per square inch
PNL	Pacific Northwest Laboratory
PR	Progress Report
PRMS	precipitation-runoff modeling system
PTn	nonwelded Paintbrush Tuff
Pu	plutonium
PuO_2	plutonium dioxide
QA	quality assurance
QARD	Quality Assurance Requirements Documents
Rb	rubidium
RCM	regional climate model
REECo	Reynolds Electrical and Engineering Co.
RFP	request for proposal
RIB	Reference Information Base
RSN	Raytheon Services Nevada
SAB	Science Advisory Board
SAIC	Science Applications International Corporation
SCA	Site Characterization Analysis
sccm	standard cubic centimeter
SCP	Site Characterization Plan
SCPB	Site Characterization Program Baseline

ACRONYMS/ABBREVIATIONS LIST

SCRF	Stanford Center for Reservoir Forecasting
Se	selenium
SEB	Source Evaluation Board
SEM	scanning electron microscopy
SEPDB	Site and Engineering Properties Data Base
SF_6	sulphur hexafluoride
SGBSN	Southern Great Basin Seismic Network
SIAM	Society for Industrial and Applied Mathematics
SIIP	Scientific Investigation Implementation Package
SKB	Svensk Karnbranslehantering AB
SLAR	Side-Looking Airborne Radar
slpm	standard liters per minute
SNL	Sandia National Laboratories
SOC	Sample Overview Committee
SQAP	Software Quality Assurance Plan
Sr	strontium
STA	saturation test apparatus
SZ	saturated zone
T&MSS	Technical and Management Support Services
TBM	tunnel-boring machine
Tc	technetium
TCA	thermal conductivity analyzer
TCw	welded Tiva Canyon
TDB	Technical Data Base
TDR	time-domain reflectrometry
TEM	Transmission Electron microscope
TGA	Thermogravimetric Apparatus
Th	thorium
TM	Thematic Mapper
TPP	test planning package
TPT	Test Prioritization Task
TSPA	Total System Performance Assessment
TSw	welded Topopah Spring
U	uranium
UDEC	Universal Distinct Element Code
UNE	underground nuclear explosion
UNLV	University of Nevada-Las Vegas

PROGRESS REPORT #7

ACRONYMS/ABBREVIATIONS LIST

UNR	University of Nevada at Reno
UNRSL	University of Nevada-Reno Seismological Laboratory
USBR	U.S. Bureau of Reclamation
USGS	U.S. Geological Survey
UZ	unsaturated zone
VIDB	Visual Integrated Data Base
VSP	vertical seismic profiling
WIPP	Waste Isolation Pilot Plant
WSNSO	Weather Service office
XRD	x-ray diffraction
XPS	x-ray photoelectron spectroscopy
YMIM	Yucca Mountain Integrating model
YMIO	Yucca Mountain Information Office
YMP	Yucca Mountain Site Characterization Project
YMPO	Yucca Mountain Site Characterization Project Office
YMQAD	Yucca Mountain Quality Assurance Division
YMTF	Yucca Mountain Test Facility

* U.S. G.P.O.:1993-343-169:80070