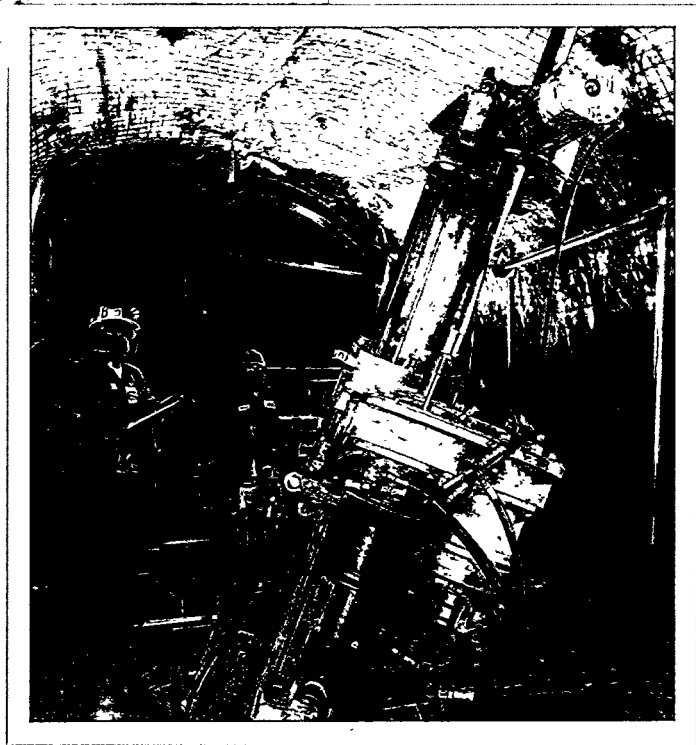
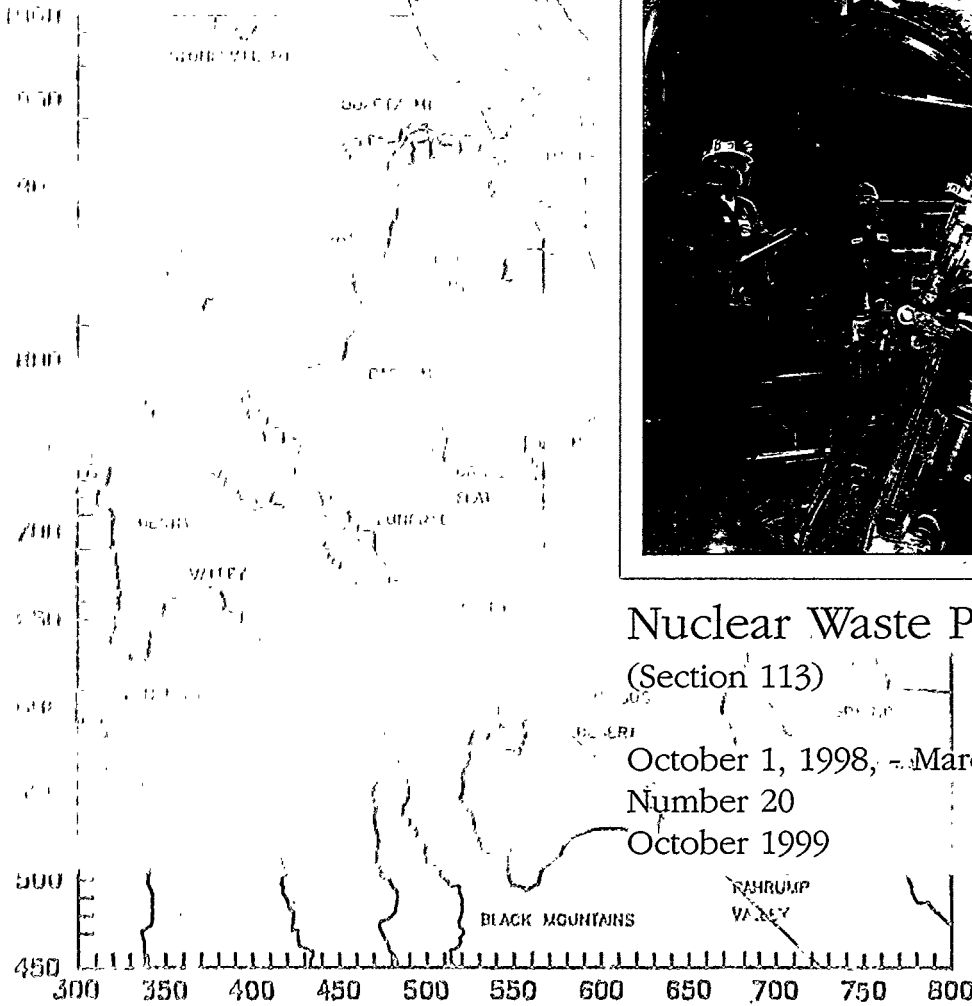


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Site Characterization Progress Report

Yucca Mountain, Nevada



Nuclear Waste Policy Act
 (Section 113)
 October 1, 1998, - March 30, 1999
 Number 20
 October 1999



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

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The Nuclear Waste Policy Act of 1982, as amended, established the U.S. Department of Energy Office of Civilian Radioactive Waste Management. The Nuclear Waste Policy Act directs the Office of Civilian Radioactive Waste Management to dispose of the nation's high-level radioactive waste and spent nuclear fuel in a geologic repository, and prescribes other related activities. The Nuclear Waste Policy Act, as codified in 42 U.S.C. 10133 (b)(3), requires a semiannual report on site characterization progress. 10 CFR 60.18(g) (Title 10 of the Code of Federal Regulations, Part 60, Disposal of High-Level Radioactive Wastes in Geologic Repositories) requires the report to:

- Describe the progress of site characterization activities and information developed to date
- Identify decision points reached and schedule modifications
- Describe waste form and waste package research and development
- Identify new issues and plans to resolve these issues
- Discuss any planned studies eliminated because they are no longer necessary to site characterization.

This is the 20th progress report issued by the U.S. Department of Energy. This report provides a summary-level discussion of Yucca Mountain Site Characterization Project progress. Accomplishments this period are presented in a format that identifies important progress achieved and conveys how that progress supports the near-term objectives in the U.S. Department of Energy's schedule. Greater detail is documented in the cited references and in deliverables listed in Appendix A to this report. Readers may request specific U.S. Department of Energy-approved program documents that are listed in Section 7, References, and Appendix A by contacting the Office of Civilian Radioactive Waste Management Information Line at 1-800-225-6972.

This document provides a discussion of recently completed and ongoing activities conducted by the Yucca Mountain Site Characterization Project during the six-month reporting period from October 1, 1998, through March 31, 1999. Some information presented herein is by necessity preliminary, because some deliverables and reports that support the discussions have not been finalized. Projected future deliverables and reports are listed in Appendix B and are noted in the text as works in progress. Appendix C lists the status of milestone reports referenced in previous progress reports. A glossary of Yucca Mountain Site Characterization Project-specific terms used in this report is given in Appendix D.

Documentation of Program Change, last published in June 1999 as Revision 01 (CRWMS M&O 1999a), provides an update to changes to and status of site characterization activities in relation to the 1988 *Site Characterization Plan: Yucca Mountain Site, Nevada Research and Development Area* (DOE 1988). *Documentation of Program Change* (CRWMS M&O 1999a) was previously Appendix A to past progress reports. This document was separated from the progress report for the reporting period of April 1997 through September 1997 and published as reference material on the Yucca Mountain Site Characterization Project's site characterization program. This document is now planned to be revised annually.

[Cover inset photo (YM-18631.jpg) is of core drilling operations in Niche #2 of the Exploratory Studies Facility Main at Station 36+50.]

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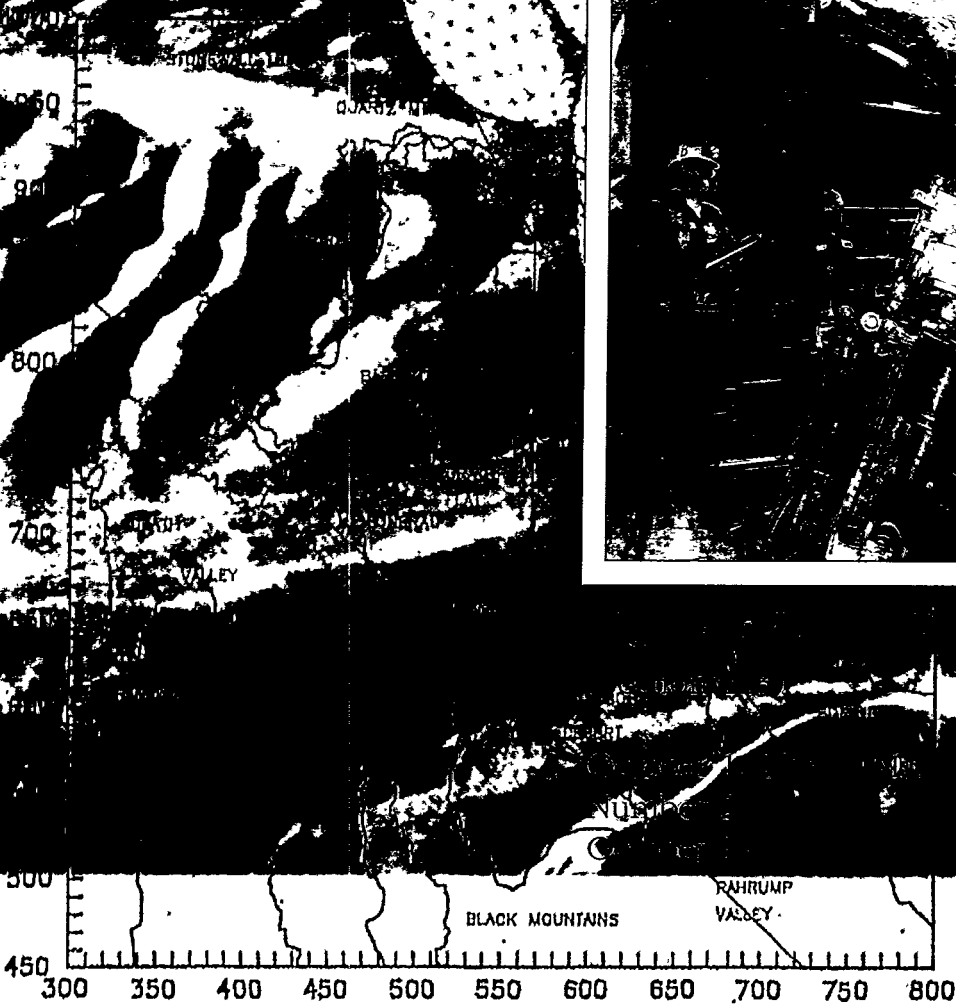
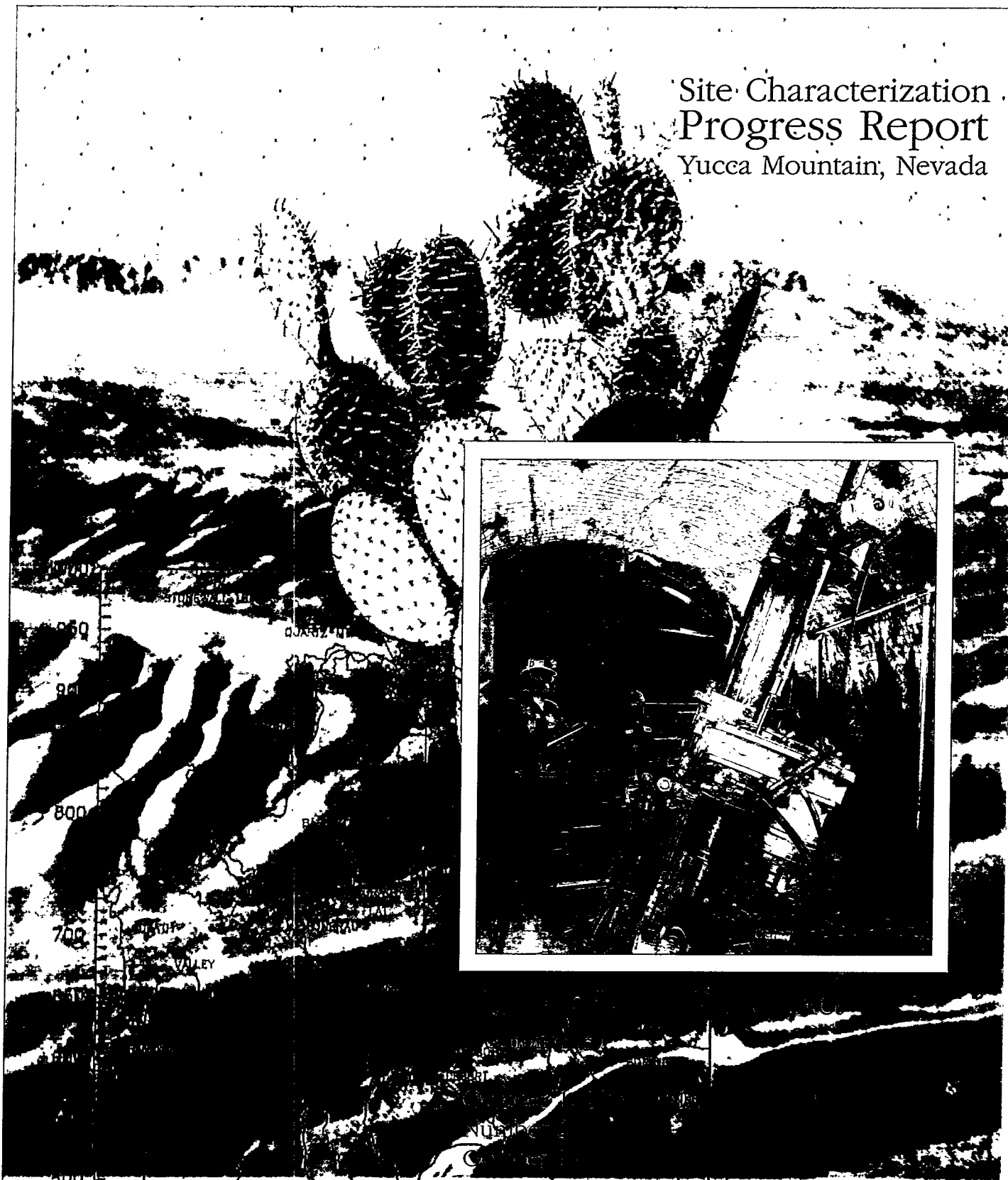
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Site Characterization Progress Report

Yucca Mountain, Nevada



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

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ACRONYMS AND SYMBOLS

ACRONYMS

DBE	design basis event
DOE	U.S. Department of Energy
ECRB	enhanced characterization of the repository block
EDA	enhanced design alternative
EIS	Environmental Impact Statement
ESF	Exploratory Studies Facility
FR	Federal Register
IRSR	issue resolution status report
KTI	key technical issue
LADS	license application design selection
NRC	U.S. Nuclear Regulatory Commission
NWPA	Nuclear Waste Policy Act of 1982, as amended
PVAR	process validation and re-engineering
QA	quality assurance
SNF	spent nuclear fuel
SR	site recommendation
SRR	Site Recommendation Report
TSPA	total system performance assessment
VA	Viability Assessment of a Repository at Yucca Mountain
YMP	Yucca Mountain Site Characterization Project

SYMBOLS

PTn	Paintbrush nonwelded hydrogeologic unit
TSw/CHn	Topopah Spring welded hydrogeologic/Calico Hill nonwelded hydrogeologic unit
Tptpll	Topopah Spring crystal-poor lower lithophysal zone
Tptpln	Topopah Spring Tuff crystal-poor lower nonlithophysal zone
Tptpmn	Topopah Spring crystal-poor middle nonlithophysal zone
Tptpul	Topopah Spring crystal-poor upper lithophysal zone

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SECTION 1 – EXECUTIVE SUMMARY

The 20th semiannual report of the Yucca Mountain Site Characterization Project (YMP) summarizes activities during the period from October 1, 1998 through March 31, 1999. YMP activities are aimed at evaluating Yucca Mountain as a suitable site for permanent geologic disposal of nuclear materials, as directed by the Nuclear Waste Policy Act (NWPA).

The progress report documents activities this period that contributed to completing the YMP's near-term programmatic and statutory objectives. These objectives include completing the *Viability Assessment of a Repository at Yucca Mountain* (VA), the Environmental Impact Statement (EIS), a possible U.S. Department of Energy (DOE) Secretarial Site Recommendation to the President, and, if the recommendation is approved, submittal of a license application to the U.S. Nuclear Regulatory Commission (NRC). The first of these objectives was attained with submittal of the VA (DOE 1998) to the President and the Congress. The other objectives are scheduled for completion in the next several years. The YMP's science and engineering work is now focused on supporting a decision on a site recommendation. YMP work this period continued to be concentrated in three integrated activities: site characterization, engineering design and construction, and repository performance. Accomplishments this period and their relation to near-term objectives are briefly summarized below. The near-term objectives and the three integrated activities are presented in more detail in Sections 2 through 6.

Program Progress and Plans—On December 18, 1998 the DOE issued the VA (DOE 1998). The VA overview states that DOE believes that Yucca Mountain remains a promising site for a geologic repository and that work should proceed to support a decision in 2001 on whether to recommend the site to the President for development as a repository. The overview acknowledges that uncertainties remain about key natural processes, the preliminary design, and how the site and design would interact. To address these uncertainties, DOE plans to advance the design, complete critical tests and analyses, and prepare draft and final EISs. When this planned work is completed in 2001 a decision will be made by the Secretary of Energy on whether to recommend the site to the President. Additional summary-level conclusions from the VA are presented in Section 2 of this Progress Report.

The next near-term objective, the EIS, is required by the NWPA to support any site recommendation. The YMP continues analyses in the many disciplines required for an EIS and is scheduled to complete the draft EIS by the summer of 1999. The technical analyses that support the draft EIS will later be updated to reflect progress in site studies and address, as needed, public comments on the draft EIS to support a final EIS in August 2000.

Following the EIS and after site characterization is complete, the Secretary will decide, with input from the public, states, Native American tribes, and the NRC, whether or not to recommend approval of the site to the President. Any recommendation and a comprehensive statement of the basis for the recommendation would then be submitted to the President, as required by the NWPA.

During this reporting period, the YMP continued pre-licensing interactions with the NRC to gain assurance that the technical work completed to date and planned would be sufficient to support the safety case in a license application. The YMP also continued development of technical guidance for preparing a license application (YMP 1998a) and began development of a working draft license application outline. The primary purpose of this work is to establish a workable process to support subsequent development of a potential license application to be submitted to the NRC.

The YMP continues to apply substantial resources to addressing cross-cutting quality assurance (QA) deficiencies identified during the prior reporting period. The purpose of this work is to make necessary changes at all levels of the program to ensure that important QA issues are expeditiously resolved and that

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actions are taken to prevent recurrence of significant QA problems. Significant accomplishments included approval of an integrated management plan for bringing current activities into full compliance with QA requirements, establishment of a process to identify and verify prior work products impacted by these deficiencies, and completion and acceptance of root cause determinations.

Another major QA activity initiated was process validation and re-engineering (PVAR). This work is intended to standardize quality-related technical, science, and engineering procedures; provide clearer guidance to end-users; eliminate procedure redundancy; better establish ownership of processes and procedures; and establish a more effective training program.

The YMP also began to plan for development of selected site- and performance assessment-related analyses and documents needed to support a site recommendation and license application. The various analyses and documents will be summarized in nine process model reports that will be direct references to a site recommendation and license application. Each process model report will provide a complete description of a given process model, including descriptions and references for submodels, analyses, and abstractions that support development of the model and its use in performance assessment. Documents and analyses developed in conjunction with these process model reports will ensure that information required to comply with QA requirements is, in fact, compliant. The intent of this new effort is to focus the YMP's limited resources on ensuring that the information needed to support the YMP's crucial upcoming milestones (site recommendation and licensing) fully complies with QA requirements.

Site Characterization—Work continued to support DOE's future decision on whether to recommend the site as host for a high-level nuclear waste repository. Information to support this decision comes through the collection of scientific data and computer modeling to help predict how natural and human-induced features, events, and processes may affect the natural system at Yucca Mountain. The model results are needed for evaluating repository designs and assessing performance of the natural and engineered systems. The data and models address topics such as site geology, potential thermal effects on the rock and water near the repository, and water flow and radionuclide transport through the unsaturated and saturated zones.

Two additional niches (Niche 3107 [#3] and Niche 4788 [#4]) (Figure 1) were excavated. Post-excavation air-permeability tests were completed in Niche 3107 and were initiated in Niche 4788. Permeability increases due to niche excavation could be interpreted as the results of fracture aperture openings induced by rock-stress releases. The increases in permeability and porosity of the fractured flow paths could suppress seepage into the drift because more water would be required to fill the fracture and initiate seepage.

A second infiltration test was started in the Exploratory Studies Facility (ESF) Upper Tiva Canyon Alcove (Alcove #1) on February 19, 1999. Through March 23, 1999 about 45,420 L (12,000 gal.) of water have been applied to the land surface above the alcove. Water began dripping into the alcove 35 m (115 ft) below the land surface on March 6, 1999, only 15 days after the start of the test, compared to the 58 days required for the first test. As of the data-download date of March 23, 1999, 1,628 L (430 gal.) of water had been collected in the alcove. These results are preliminary, and no conclusions have yet been drawn from them.

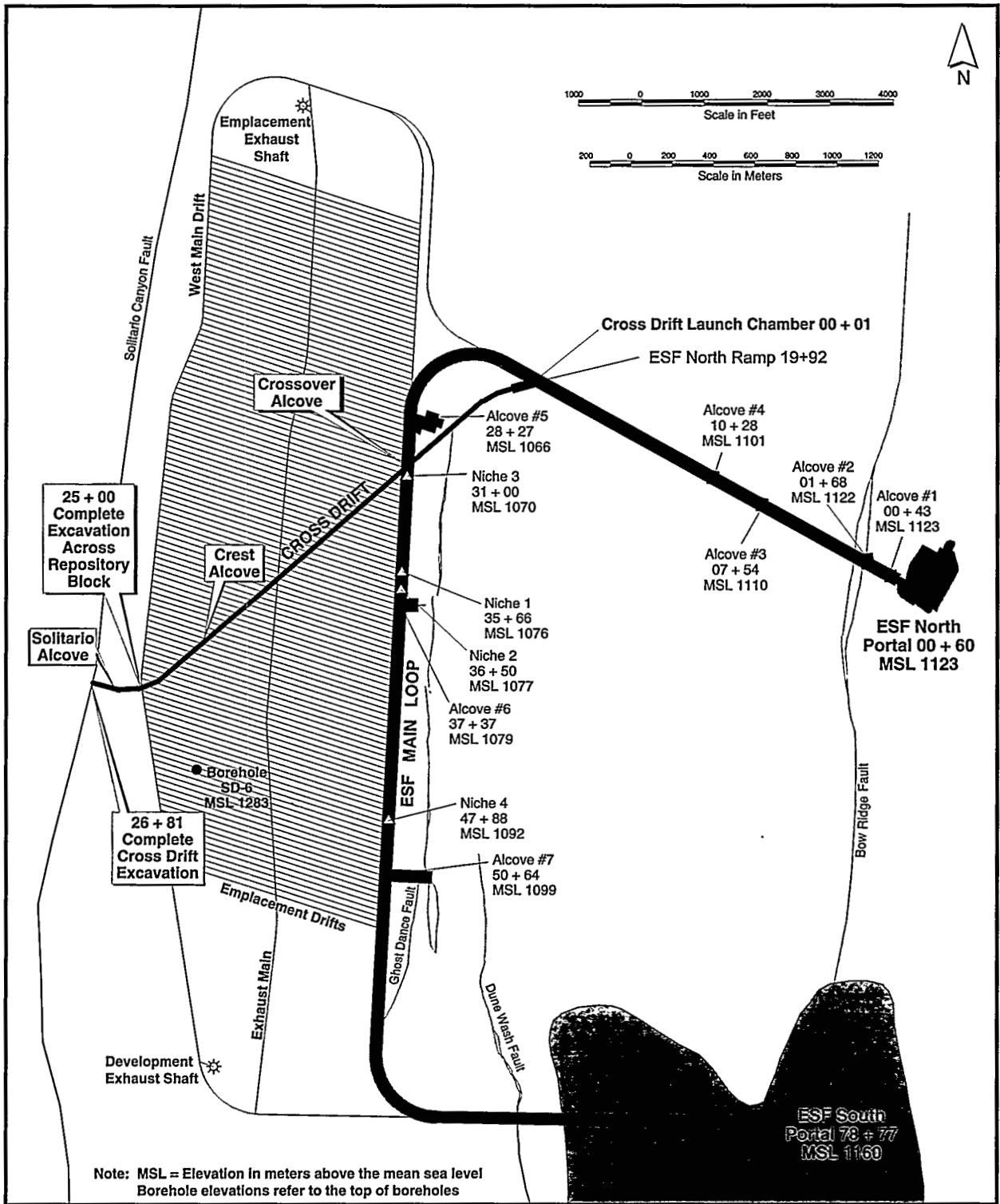


FIG1.PPT.125.PROGRESS.PR207-19-99

Figure 1. Exploratory Studies Facility, Showing Main Loop and Enhanced Characterization of the Repository Block Cross Drift

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For site geology, the Geologic Framework Model was updated to version GFM3.1 [EARTHVISION V4.0 CSCI: 30035 V4.0, TBV-692], which now includes new data from boreholes USW SD-6 and USW WT-24, and the enhanced characterization of the repository block (ECRB) cross drift. These boreholes and the cross drift are part of continued exploration of the interior of Yucca Mountain (see Figures 1 and 2). Data from these tests have correlated well with predictions from the model and therefore have increased confidence in the validity of the models that predict geologic variability at Yucca Mountain, which in turn increases confidence in the models used for water-flow and radionuclide transport.

Temperature, relative humidity, and wind-speed data were collected at various monitoring stations along the cross drift and at the discharge of the cross-drift vent line. Periodic neutron-moisture logging of 50 boreholes was performed to monitor drying of the tunnel walls. Water-potential measurements from 106 heat-dissipation probes installed in 2-m-deep (6.6-ft-deep) boreholes at 25-m (82-ft) intervals in the cross drift indicate that the rock mass is wetter than predicted from either pre-existing rock core or in situ water-potential measurements, and somewhat wetter than predicted by the unsaturated zone site-scale flow model. The significance of these measurements for the unsaturated zone model is being investigated.

To assess potential thermal effects of the wastes, the drift-scale heater test continued. On March 3, 1999, after 15 months of the planned four years of heating, the drift-wall temperatures reached 160°C (320°F). Laboratory tests were also conducted to study flow of heated water in fractured rock. The goal of these tests is to gain an increased understanding and refine models of thermal effects both near the waste packages and on a scale of the entire mountain.

Transport testing continued at Busted Butte (see Figure 2). Tests on fracture-matrix interactions using conservative and reactive tracers and microspheres were completed. Observations on the ingress of fluorescent tracers into the fractured rock mass are consistent with previously obtained data indicating that fracture flow does not occur in rock in and immediately above the Calico Hills Formation, unless accompanied by substantial matrix flow. This observation indicates that radionuclide sorption is expected even with fracture-flow present. Other observations from Busted Butte activities include: (1) matrix flow is dominant in the vitric Calico Hills, even in the presence of fracture or fault zones, and (2) interfaces between lithologic horizons tend to act as transient hydrologic barriers that may induce substantial lateral flow.

Work continued to understand crustal deformation at Yucca Mountain. Results of a 1998 resurvey of a geodetic array centered on the site, along with data from earlier surveys, indicate the residual strain rate at Yucca Mountain is significantly less than that calculated by Wernicke et al. (1998) and is not significant (Savage et al. 1998).

The Project collected 83 samples systematically at 25-meter (82-foot) intervals from fractures, faults, and intact matrix in the cross drift, and 17 of these were analyzed for chlorine-36. The major objective of the cross-drift samples is to test the accuracy of the predictions about the distribution of chlorine-36 in the drift, including occurrence of bomb-pulse chlorine-36. Bomb-pulse chlorine-36 was present in the vicinity of the eastern main splay of the Solitario Canyon fault and in the Sundance fault zone, as predicted. Pore-water samples extracted from cross-drift drill core samples had chloride concentrations ranging from 10 to 45 mg/L. These concentrations correspond to surface infiltration rates on the order of 3 to 10 mm/yr and are largely consistent with the infiltration model.

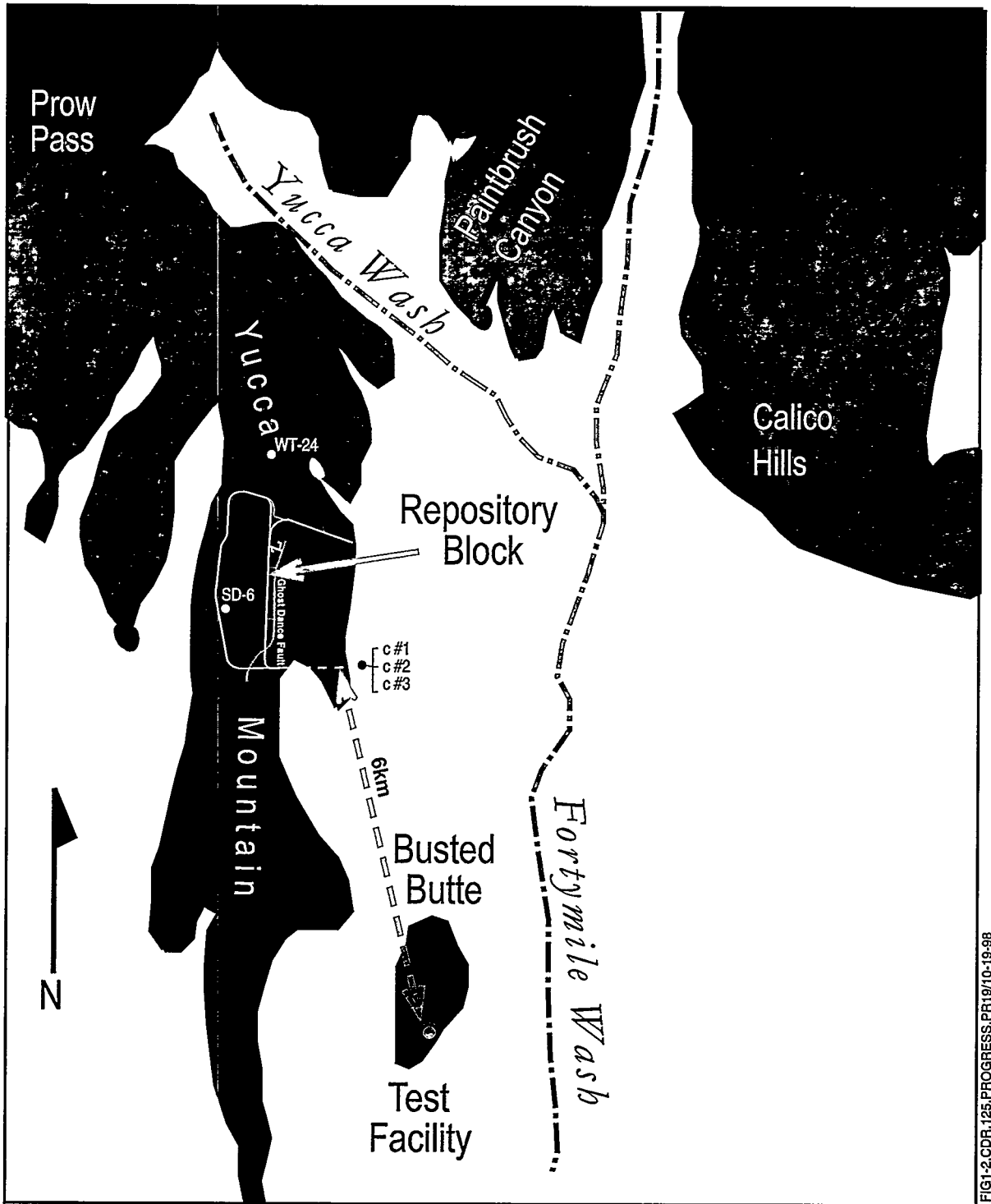


FIG 1-2. CDR. 125. PROGRESS. PR19/10-19-98

Figure 2. Location of Test Facilities, Yucca Mountain, Nevada

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Progress continues in developing the new site-scale saturated zone flow and transport model [FEHMN, TBV-569], which is to be used for total system performance assessment (TSPA). A three-dimensional numerical transport methodology that incorporates dispersion, matrix diffusion, sorption, and colloid transport was developed and tested. The methodology allows for representation of small dispersivity values and minimizes numerical dispersion.

Engineering Design and Construction—Activities this period centered on continued study of design features and design alternatives that will be the basis for selecting the reference design for a site recommendation and (if the site is recommended) for a license application.

In addition, testing of waste forms, waste package materials, and construction materials continued, as did ECRB cross drift construction.

Following completion of design work to support the VA, the YMP continued design work to support site recommendation and licensing. The YMP completed 17 Compliance Program Guidance Packages (CRWMS M&O 1999b through 1999r), which serve as regulatory input to design and licensing documents to support a license application. The *Mined Geologic Disposal System Requirements Document* (YMP 1998b) was updated to revise the description of the monitored geologic repository concept. The revised concept will allow for a repository that can be kept open for up to 300 years. In addition, one repository design technical report was nearly completed to support the EIS activities (see Appendix B, work in progress 1). Two reports were completed and one report neared completion in support of the site recommendation and license application repository design (CRWMS M&O 1999t, 1999u; see also Appendix B, work in progress 2). Other major activities for the YMP's repository design effort included the design alternative studies for selecting a reference design to support a site recommendation and (if the site is recommended) a license application. These studies included consideration of a diverse set of enhanced design alternatives (EDAs) that could enhance repository performance.

The *Disposal Criticality Analysis Methodology Topical Report* (CRWMS M&O 1998a) was submitted to the NRC for review. This document describes a probabilistic postclosure criticality analysis methodology that is intended to support risk-informed demonstration that public health and safety are protected against postclosure criticality in the repository.

Laboratory testing of concrete drift liner in the VA reference design at elevated temperatures was completed. The test showed that the concrete would retain adequate strength and stiffness for the anticipated range of repository temperatures and loads (CRWMS M&O 1999t, p. vii). Other ongoing testing, using a ¼-scale model emplacement drift and waste package, will allow the YMP to evaluate the effectiveness of emplacement drift backfill in preventing infiltrated water from contacting the waste packages. The model is performing as expected by diverting water around the waste packages (see Appendix B, work in progress 2).

Significant waste package testing was performed to support license application design selection (LADS) alternatives investigations. Long-term corrosion testing of waste package candidate materials continued. Additional materials were added to the test matrix based on an evaluation of alternate waste package designs. In other waste package testing, a short-term test program was initiated to support waste package material degradation studies. The test program focused on determining the appropriate test environment representing saturated aqueous conditions on the waste package surface.

The YMP completed an additional 103 m (338 ft) of excavation of the ECRB cross drift in the repository block; the excavation now extends to 2,681 m (8,796 ft). DOE terminated excavation at this point and declared excavation of the cross drift complete.

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Repository Performance—Repository performance assessment activities centered on three topics: preclosure radiological safety assessment, postclosure performance assessment, and performance confirmation.

For preclosure radiological safety assessment, a revision of the classification document, *Classification of the Preliminary MGDS Repository Design* (CRWMS M&O 1999w), was issued. This document provides input to the design bases for structures, systems, and components of the monitored geologic repository. In addition, evaluations of candidate design basis events (DBEs) involving DOE spent nuclear fuel (SNF) were performed and summarized in *DOE Spent Nuclear Fuel Design Basis Event Analysis Fiscal Year 1998* (CRWMS M&O 1999x) for the National Spent Nuclear Fuel Program. Work addressed in this report included identification of the characteristics of DOE SNF, determination of a preliminary list of candidate DBEs, determination of bounds isotopic inventory, establishment of preliminary grouping of DOE SNF, and performance of a limited number of preliminary DBE analyses.

Postclosure performance assessment work continued in support of repository design activities. Total system analyses were performed for EDAs as part of the LADS process. TSPA analyses were also conducted for the draft EIS. These analyses used most aspects of the VA design and used the TSPA-VA component models to support the draft EIS. In addition, technical workshops were conducted to address and document important technical issues and work planning related to TSPAs that will support a site recommendation and (if the site is recommended) a license application. Development of the TSPA-Site Recommendation (SR) Methods and Assumptions Document was initiated to identify the minimal, necessary, and sufficient work required for TSPA-SR analyses. Lastly, documentation of the technical basis for the TSPA-VA was finalized (CRWMS M&O 1998b through 1998i). All these efforts supported the transition to work focused on developing and refining the repository performance for SR.

The *Final Report Total System Performance Assessment Peer Review Panel* (Budnitz et al. 1999) was issued. The report documented results of an independent peer review of the completed TSPA-VA. It included comments, concerns, conclusions, and recommendations that could be used to improve a TSPA to support a license application. The report recommended that bounds analyses and design changes be considered to address systems or events for which it is not feasible to produce realistic models supported by data. It also recommended that the YMP begin future performance assessment efforts with a simpler set of analyses, and that it then evaluate the more complex issues through either sensitivity studies or evaluations of bounds.

Performance confirmation work included development of several evaluations of the impacts on performance confirmation of design features, design alternatives, and EDAs in support of the LADS process. In addition, criteria were developed for data acquisition and monitoring system description documents that will support performance confirmation.

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SECTION 2 – PROGRESS TOWARD NEAR-TERM OBJECTIVES

During the reporting period, YMP activities supported all the near-term objectives. The first of these objectives was attained with completion, approval, and distribution of the VA. This section also describes how the activities discussed in Sections 3 through 5 of this report relate to the remaining near-term objectives of an EIS, site recommendation, and licensing.

The YMP continued refining its postclosure safety approach, and Revision 2 of the Repository Safety Strategy (YMP 1998c) was completed. This strategy reflected (1) design modifications made for the VA, (2) performance assessments incorporating both those design changes and improvements to the performance assessment models, and (3) considerations of design options that might further enhance performance. Since then, the Repository Safety Strategy has been under further revision to reflect potential design enhancements under consideration for the site recommendation and license application reference design and associated changes in the performance assessments. The Strategy is also being revised to address the requirements of the proposed rule for the Yucca Mountain site, 10 CFR 63 (published as a proposed rule at 64 FR 8640). The draft strategy will be used to support identification of the specific testing, performance assessment modeling, and other needs to complete the postclosure safety case for a site recommendation and the license application, if the site is found suitable.

While continuing to move forward toward achieving the YMP's near-term milestones, YMP management determined that it was necessary to focus on addressing cross-cutting QA deficiencies identified during the prior reporting period. These deficiencies had been noted by YMP audits and have been of substantial concern to the DOE, the NRC, and other external oversight organizations and stakeholders. The purpose of the refocused work is to make necessary changes at all levels of the YMP to ensure that important QA issues are resolved and that actions are taken to prevent recurrence of significant QA problems. An integrated, management corrective-action plan that contains the integrated actions necessary to bring current activities into full compliance with the QA program requirements (Corrective Action Reports LVMO-98-C-002, VAMO-98-C-005, LVMO-98-C-006, and LVMO-98-C-010, all in preparation) was approved by YMP management. The integrated plan ensures identification, verification, and correction of the data, procurements, software codes, and models required for technical support to, and inclusion in, a site recommendation and license application. A number of "tiger teams" were established to identify and verify prior work products impacted by these deficiencies.

Formal root cause determinations for the QA deficiencies have been completed and accepted by YMP management. The root cause determinations validated the apparent causes identified earlier during the YMP's preliminary investigation of the issues. The formal root cause determinations found that the actions already in progress to address the apparent causes were sufficient to correct the programmatic causes of the deficiencies. Other actions initiated during the last reporting period, when completed, will help address the cultural aspects related to the root causes of these deficiencies. The actions are intended to foster behavior supportive of excellence in all aspects of the YMP. Such behavior includes taking responsibility for the quality of work performed, ensuring communication, avoiding complacency, and requiring accountability at all levels of the YMP staff. To this end, senior management has conducted training for YMP staff to clearly identify the required behavior, the reasons they are needed, and management's clear expectation that they be assimilated in the YMP's work. These principles have also been implemented in management processes for evaluating individual performance of personnel assigned to the YMP. In addition, formal lessons learned documents will be prepared and disseminated to the entire staff in order to raise individual awareness of the causes of these deficiencies and to assist in precluding similar deficiencies in the future.

Near the end of the reporting period, substantial additional resources were redirected to new work to address QA issues. The work will first define information (data, models, and abstractions) needed to

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support site recommendation and licensing. Then it will entail development of specific documents and analyses to ensure information required to be in compliance with QA requirements is, in fact, compliant. Ultimately, many of these analyses will be reflected and summarized in nine process model reports. Each process model report will provide a description of a given process model (e.g., the saturated zone flow and transport model), including descriptions and references for the submodels, analyses, and abstractions that support development of the model and its use in performance assessment. The nine reports, to be developed during Fiscal Year 2000, describe the following process models:

- Integrated site model
- Near-field environment
- Waste package degradation
- Waste form degradation
- Unsaturated zone flow and transport
- Saturated zone flow and transport
- Engineered barrier system degradation
- Biosphere
- Tectonic hazards.

Another important YMP activity initiated was PVAR. This work is intended to accomplish the following objectives for quality-related technical, science, and engineering processes:

- Standardize procedures for all program participants
- Eliminate procedure redundancy
- Provide clearer, concise guidance to process end-users
- Better establish ownership of processes and procedures
- Establish a more effective, formal training program.

To achieve these objectives, PVAR is proceeding through five phases. A description and status of each phase follows:

- **Process Review and Validation**—Review existing processes and procedures to validate continued utility or need for change. This phase is completed.
- **Process Integration**—Integrate results of the process review and validation phase by conducting a series of subject matter expert information and issue resolution meetings. This phase is completed.
- **Development**—Develop 25 new Administrative Procedures applicable to all program participants. Forty-nine redundant, existing procedures were tagged for elimination. Subject matter experts conducted informal reviews of the procedures prior to formal review and comment resolution. This phase is completed.
- **Implementation Planning**—Identify the approach and roles and responsibilities for implementation of the procedures. This phase is completed.
- **Implementation**—Conduct formal review, comment resolution, procedure validation, approval, training, and infrastructure development required for the procedures to become effective. The expected effective date for the PVAR procedures is June 30, 1999. These activities support full implementation of the PVAR process at the working level in all Project activities within the scope of PVAR.

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- In another important area, a defense-in-depth approach using analysis of the multiple natural and man-made barriers is being implemented to evaluate whether the natural and engineered barriers work in combination to enhance the resiliency of the repository and to increase confidence that the postclosure performance objectives will be met. This information will ultimately be used to support a site recommendation and (if the site is recommended) a license application. This process was initially applied to the VA design. This assessment showed that, although calculated performance of the system meets the proposed regulatory criteria by several orders of magnitude, the VA design places very high reliance on the waste package corrosion-resistant barrier. The results suggest the need for design enhancements to provide one or more additional barriers to decrease the degree of reliance upon the behavior of wetted waste packages for waste isolation and containment.
- The barrier assessment approach will next be applied to a site recommendation and license application design. This evaluation will assess the repository system that will go forward to licensing. It will evaluate the contribution of each of the principal barriers of the system to postclosure performance and the importance of the uncertainties remaining in performance of each of these barriers.

2.1 VIABILITY ASSESSMENT

On December 18, 1998 the DOE issued the *Viability Assessment of a Repository at Yucca Mountain* (DOE 1998). The overview states that the DOE believes that Yucca Mountain remains a promising site for a geologic repository and that work should proceed to support a decision in 2001 on whether to recommend the site to the President for development as a repository. The overview acknowledges that uncertainties remain about key natural processes, the preliminary design, and how the site and design would interact. To address these uncertainties, the DOE plans to advance the design, complete additional tests and analyses, and prepare draft and final EISs. When this planned work is completed in 2001 a decision will be made by the Secretary of Energy on whether to recommend the site to the President.

The VA discusses several advantages of Yucca Mountain as a potential repository site. These include its location on unpopulated land distant from population centers, its semiarid climate, and the deep groundwater table in an isolated, closed regional basin.

The report states that the preliminary repository design includes a long-lived waste package and takes advantage of the desert environment and geologic features of Yucca Mountain. Together, the natural and engineered barriers can keep water away from the waste for thousands of years. Analyses of the preliminary design using mathematical models, though subject to uncertainties, indicate that public health and the environment can be protected. People living near Yucca Mountain are calculated to receive little or no increase in radiation exposure for 10,000 years after the repository is closed. The maximum radiation exposure from the repository is calculated to occur after about 300,000 years. People living approximately 20 km (12 mi.) from Yucca Mountain at that time might receive additional radiation exposures from the repository equivalent to present-day background radiation in the Yucca Mountain region.

Although the VA states that current assessments of repository performance are encouraging, the report notes that more work is needed before the site can be recommended and a license application for construction of a repository can be submitted to the NRC. Therefore, the VA states that DOE will:

- Obtain more information on key natural processes, including how radionuclides could be transported by groundwater beneath the repository

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- Test the performance of candidate waste package materials and evaluate alternative repository designs
- Continue analyzing the expected interaction between the repository and the natural processes
- Prepare an EIS, publish it for public comment in 1999 and finalize it in 2000.

The VA estimate of costs to complete these tasks is approximately \$1.1 billion. The document states that, if the site is suitable and DOE submits a license application in 2002, the estimated cost to successfully complete the licensing process, build a licensed repository, emplace the waste, and monitor and close the repository is approximately \$18.7 billion, in constant 1998 dollars. Given adequate funding for completion of scientific and engineering work needed to support the licensing process, the first waste could be emplaced in a repository in 2010 and the last waste in 2033. With NRC approval, a repository could be closed and sealed as early as 10 years after the last waste is emplaced; or it could be kept open and actively monitored for hundreds of years, if it appears desirable to do so. The \$18.7 billion cost estimate assumes a monitoring period of 100 years, beginning with initial waste emplacement. The repository is being designed to allow future generations to decide how long the repository should be monitored, and whether and when to close and seal it.

Because a monitored geologic repository is one component of a total waste management system, the VA also addresses the total estimated future cost to complete the program. Including transportation of waste, that estimated cost is \$36.6 billion, in constant 1998 dollars. This includes costs from 1999 through closure and decommissioning, assumed for cost estimation purposes to begin in 2110 and to be completed in 2116.

2.2 ENVIRONMENTAL IMPACT STATEMENT

The NWPA requires that a final EIS serve as one of the supporting elements for a decision on site recommendation and that it accompany any Secretarial site recommendation to the President (42 U.S.C. 10134(f)(1)). During this period, the YMP continued drafting the EIS for the Yucca Mountain site. Numerous internal reviews are being performed to ensure accuracy and consistency of information, data, and analyses. Development of the draft EIS is scheduled for completion in the summer of 1999. Once the draft is released, all interested persons are encouraged to take part in review of the draft, including federal agencies, Native American tribal organizations, state and local government agencies, public interest groups, industry and utility organizations, and the general public. The DOE will provide several methods for people to express their views. The draft EIS will be subject to a public comment period. It will be made available to the public in printed form, compact disc form, and on the Internet. During the comment period, the public may comment on the draft EIS in public meetings scheduled for 13 locations within Nevada and across the country, make written comments to DOE, and send comments to DOE electronically. All comments made on the draft EIS will be addressed in the final EIS.

The YMP completed the environmental baseline files necessary to compile data and analyses to support topics to be covered in the EIS. Data topics include aesthetics, air quality, archeology, biology, energy, environmental justice, facilities, health and safety, noise, regulatory issues, repository performance, sensitive ecosystems, socioeconomics, soils, subsurface activities, transportation, utilities, waste package design, and water resources. These data and analyses are being used to evaluate the environmental impacts of repository development at the Yucca Mountain site.

Before the final EIS is issued (scheduled for the year 2000), the technical analyses supporting the EIS will be updated as appropriate to reflect the ongoing progress of site studies. Updates will also be made, as needed, to resolve public, agency, or Native American Indian tribal comments on the draft EIS. This

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activity will be integrated with YMP work in site testing, design, performance assessment, and license application preparation activities.

2.3 SITE RECOMMENDATION

The DOE completed initial planning for a Site Recommendation Report (SRR), which will provide the information to be considered by the Secretary of Energy in deciding whether or not to recommend the site to the President. The SRR will provide information called for by 42 U.S.C. 10134(a)(1) of the NWPA and also will provide an analysis of the site's compliance with DOE's repository siting guidelines. Plans for the SRR are documented in the *Annotated Outline of the Site Recommendation Report* (see Appendix B, work in progress 3) and in the *Management Plan for the Development of the Yucca Mountain Site Recommendation Report* (see Appendix B, work in progress 4).

The Management Plan (see Appendix B, work in progress 4) describes the management approach to preparing the SRR, the procedural controls that will be applied to the preparation and review of the SRR, and the schedule for preparation and review of the SRR.

Volume 1 of the SRR will contain the information required by 42 U.S.C. 10134(a)(1)(A), (B), and (C):

- (A) a description of the proposed repository, including preliminary engineering specifications for the facility;
- (B) a description of the waste form or packaging proposed for use at such repository, and an explanation of the relationship between such waste form or packaging and the geologic medium of such site;
- (C) a discussion of data, obtained in site characterization activities, relating to the safety of such site.

Volume 2 of the SRR will contain a compliance analysis of the Yucca Mountain site and repository system in accordance with DOE siting guidelines.

Volume 3 of the SRR will contain the views and comments of the Governor and Legislature of any state, or the governing body of any affected Native American Indian tribe, together with the response of the Secretary (NWPA, 42 U.S.C. 10134(a)(1)(F)). It will also include other information that the Secretary considers appropriate (42 U.S.C. 10134(a)(1)(G)), and any impact report under section 10136(c)(2)(8) submitted by the State of Nevada (42 U.S.C. 10134(a)(1)(H)).

Volume 4 will present the preliminary comments of the NRC concerning the extent to which the site characterization analysis and the waste form proposal for the site seem to be sufficient for inclusion in any license application (42 U.S.C. 10134 (a)(1)(E)).

As required by 42 U.S.C. 10134 (a)(1)(D), the SRR will be accompanied by the final EIS for the YMP.

2.4 LICENSING

Although the near-term focus of YMP work will be on supporting the Secretary's decision whether or not to recommend the site, the YMP is continuing interactions with the NRC to ensure that its activities are consistent with NRC's expectations for submittal of a high-quality repository license application in 2002, should the Yucca Mountain site be recommended. One step forward was commencement of development of the working draft license application outline. This document, scheduled for completion in the summer of 1999, is intended to ensure that a workable process is in place to support timely development and

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submittal of any license application. Other objectives include supporting YMP management's review of progress in developing a license application, as well as giving the authors an opportunity to begin making the necessary safety case.

On February 22, 1999 the NRC published its proposed licensing criteria specific to Yucca Mountain. The proposed regulations, "Disposal of High-Level Radioactive Wastes in a Proposed Geologic Repository at Yucca Mountain, Nevada," 64 FR 8640 (to be codified as 10 CFR 63) (proposed February 22, 1999) would significantly change the NRC's approach to evaluating repository performance. The new proposed regulations are risk-informed and performance-based. They also require use of multiple barriers to provide defense in depth against releases of radioactive materials and to enhance confidence that repository performance objectives will be met. The DOE plans to provide written comments to the NRC on the proposed regulations. The proposed regulations would appear in a new separate 10 CFR 63. The NRC would leave in place its existing generic regulations as 10 CFR 60, but would indicate that those regulations do not apply nor may be the subject of litigation in any NRC licensing proceedings for a repository at Yucca Mountain.

Interactions with the NRC continue to focus on the NRC's 10 key technical issues (KTI) and on the associated NRC issue resolution status reports (IRSRs) that provide a framework for addressing KTIs. The NRC identified the KTIs as the topics the NRC considers most important to performance of a repository at Yucca Mountain. This reporting period, the YMP reviewed, analyzed, and developed comments on eight NRC IRSRs (NRC 1998a through 1998h).

The DOE and NRC conducted two public meetings on DBEs. These public meetings helped to identify issues regarding DBEs in which there is agreement and those that require additional work. They were particularly useful in addressing DOE's concerns and questions regarding the DBE regulations in the proposed 10 CFR 63 (64 FR 8640).

In addition to the technical exchanges, one quarterly QA/management meeting and six Appendix 7 Meetings were conducted during this reporting period. These interactions facilitated information exchange with NRC on various topics, including QA, disruptive events, disposal criticality, DBEs, igneous activity, and natural analogs. Interactions with the Advisory Committee on Nuclear Waste and the Nuclear Waste Technical Review Board continued to provide an opportunity for DOE to explain various technical and programmatic aspects of the YMP and gain understanding of external issues and concerns.

2.5 KEY PLANNED ACTIVITIES THROUGH SEPTEMBER 30, 1999

Key site characterization studies, design and construction, performance, and programmatic activities planned for the remainder of Fiscal Year 1999 (April 1, 1999 to September 30, 1999) will include:

Progress Toward Near-Term Objectives

- Commencing development of process model reports to support a site recommendation and license application (see Appendix B, works in progress 5 through 7).
- Completing the draft EIS (see Appendix B, works in progress 8 and 9).
- Continuing development of an SRR (see Appendix B, works in progress 3 and 4).

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- Updating the Repository Safety Strategy to reflect new site information, evaluations of design alternatives and options, updated model abstractions, the proposed 10 CFR 63 (64 FR 8640), and the proposed U.S. Environmental Protection Agency standard, if available.
- Completing a revision to the *Technical Guidance Document for License Application Preparation* (YMP 1998a) to incorporate additional regulatory analyses and the NRC's proposed site-specific regulations in 10 CFR 63 (see 64 FR 8640).
- Transmitting to the NRC the DOE comments from reviews of the NRC IRSRs.

Site Characterization

- Completing the Integrated Site Model 3.1 (ISM3.1) [EARTHVISION CSCI: 30035 V4.0, TBV-692], with incorporation of Geologic Framework Model 3.1 (GFM3.1) [EARTHVISION CSCI: 30035 V4.0, TBV-692] and updates of rock properties and mineralogical models with data from boreholes USW SD-6 and USW WT-24.
- Completing a topical report on seismic-design inputs (see Appendix B, work in progress 10).
- Continuing liquid release tests at Niche #3 to determine the value at which seepage would begin in that low-permeability site and to study the behavior of the capillary barrier and other mechanisms governing the seepage processes.
- Continuing infiltration and seepage testing in the ESF Upper Tiva Canyon Alcove to (1) improve understanding of the seepage of water into drifts, (2) evaluate potential fast-flow pathways intercepted by drifts, (3) obtain validation data for both the unsaturated zone site-scale flow model [TOUGH2 V1.3, TBV-563] and the drift-scale submodel, and (4) obtain an understanding of saturated flow in the drift-scale environment. A similar controlled infiltration experiment will be conducted between an alcove in the cross drift and ESF Niche #3 to provide quantitative information on fracture and matrix permeabilities and percolation fluxes through the Topopah Spring crystal-poor upper lithophysal (Ttptul) and middle nonlithophysal (Ttptmn) units at the repository horizon.
- Investigating the significance and implications of the measured water potentials in the cross drift for the unsaturated zone site-scale flow model [TOUGH2 V1.3, TBV-563].
- Continuing the drift-scale heater test.
- Continuing unsaturated zone transport testing at Busted Butte.
- Documenting calibration of the geometry and physical features of fault zones to available data and documenting conceptual understanding of the permeability structure of faults in three dimensions.

Engineering Design and Construction

- Completing 31 Compliance Program Guidance Packages as regulatory input to both design and licensing documents in support of preparation of a license application. Twenty-six of these packages will serve as inputs to system description documents, and five non-engineering topical packages will serve as inputs to the revision of the *Technical Guidance Document for License Application Preparation* (YMP 1998a).

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- Developing a document of technical assumptions for the reference design to support a site recommendation and (if the site is recommended) a license application. This document will replace the *Controlled Design Assumptions Document* (CRWMS M&O 1998m) used for VA design.
- Expanding the scope of the *Monitored Geologic Repository Project Description Document* as Revision 01 (See Appendix B, work in progress 11) to include allocation of functions, requirements, and criteria to system description documents.
- Completing an update to the *Performance Confirmation Plan* (CRWMS M&O 1997) based upon changes resulting from LADS and a reassessment of parameters important to postclosure performance (see Appendix B, work in progress 12).
- Completing several technical reports, analyses, and alternative design evaluations in support of the LADS effort process. Topics evaluated will include impacts on surface and subsurface facilities of various potential design features.
- Completing Pilot-Scale Test #3. This test will use a drip shield over the waste package instead of backfill to divert water from the waste package. The test will also use temperatures that mimic the expected temperatures of the repository emplacement drifts when water re-enters the drifts (see Appendix B, work in progress 2).
- Continuing waste form characterization with focus on providing more data and analyses of dissolution and releases to support TSPA.
- Continuing waste package testing and modeling with emphasis on materials and configurations for a site recommendation and license application design.
- Completing design and construction of the Cross-Over Alcove (Alcove #8) in the cross drift.
- Completing the design of Niche #5 in the cross drift.

Performance Assessment

- Continuing to develop process models for use in the TSPA-SR.
- Conducting the Near-Field Geothermal Modeling and Abstraction Workshop and the Waste Package Degradation Modeling and Abstraction Workshop.
- Writing the methods and assumptions document for TSPA-License Application (see Appendix B, work in progress 13).
- Completing a monitored geologic repository Internal Hazards Analysis to identify the preliminary design basis.
- Continuing to revise QAP-2-3, *Classification of Permanent Items*, to Revision 10 (CRWMS M&O 1998n).

SECTION 3 – SITE CHARACTERIZATION

This section summarizes progress on selected site characterization activities for this period.

3.1 GEOLOGIC INVESTIGATIONS

Geologic Framework Model/Integrated Site Model—The Geologic Framework Model, version GFM3.1 [EARTHVISION CSCI: 30035 V4.0, TBV-692] (MO9901MWDGFM31.00), which updates the previous model with new data from boreholes USW SD-6 and USW WT-24 and the ECRB cross drift, was completed during the reporting period. During the next reporting period, the Integrated Site Model 3.1 (ISM3.1) [EARTHVISION CSCI: 30035 V4.0, TBV-692] will be completed, with incorporation of GFM3.1 and updates of rock properties and mineralogical models with data from boreholes USW SD-6 and USW WT-24. Components of the Integrated Site Model are used in fluid flow, transport, and design-modeling activities. Documentation and qualification of input data for ISM3.1 are anticipated to be completed during Fiscal Year 1999; report documentation of ISM3.1 is scheduled for completion in early Fiscal Year 2000. It is anticipated that the model will undergo validation during Fiscal Year 2000 (see Appendix B, work in progress 14).

Enhanced Characterization of the Repository Block Cross Drift—A report was published that describes a preconstruction geologic section along the ECRB cross drift (Potter et al. 1998). The report and the accompanying 1:6,000-scale map and geologic section provided the geologic context for the cross drift prior to excavation, including lithostratigraphy and structural style of the rocks.

The cross-drift geotechnical mapping was completed to Station 26+81. This included mapping of the main splay of the Solitario Canyon fault, which was encountered between Stations 25+84 and 25+87. A report documenting the mapped geology of the cross drift is in progress. Efforts to support report development include processing and review of line surveys and full-periphery maps from the cross drift and preparation of detailed stratigraphic descriptions of lithostratigraphic units exposed in the cross drift (see Appendix B, work in progress 15).

Geologic Field Investigations—Cross sections, depictions of subsurface geologic structure, and text for the 1:50,000-scale geologic map compilation for the saturated zone flow and transport modeling area were completed and submitted for technical review. The map is anticipated to be completed during the second half of Fiscal Year 1999 (see Appendix B, work in progress 16).

Geologic logging support was provided to the Nye County Early Warning Drilling Program. Seven of the eight boreholes completed during the reporting period were logged using electrical methods. Lithologic descriptions of the borehole cuttings will continue in the second half of Fiscal Year 1999 (see Appendix B, work in progress 17).

Compilation was completed regarding characterizing the structure and material in fault zones in the ESF, the cross drift, and selected well-exposed faults downgradient of the potential repository. The objective is to augment understanding of the hydraulic characteristics of fault zones for refinement of flow and transport models of Yucca Mountain. The documentation, due in late Fiscal Year 1999, will include (1) calibration of the geometry and physical features of fault zones to available flow and permeability data, and (2) refinement of conceptual understanding of permeability structure of faults in three dimensions, with specific emphasis on the probable hydrologic character of faults in the rock units that underlie the potential repository (see Appendix B, work in progress 18).

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Samples collected in Fiscal Year 1998 for metallic resource assessment have been analyzed by laboratories for element content, and interpretation of the data is in progress (see Appendix B, work in progress 19).

Monitoring of the Southern Great Basin Seismic Network continues. Three portable seismometers were deployed to monitor an earthquake swarm (maximum M 4.7) that occurred in the Frenchman Flat area, about 50 km east of the repository block in January to February 1999. A preliminary review revealed that all measured ground motions at the site were below 0.01g. The highest acceleration measured was 0.0033g, recorded at the Field Operations Center; 0.0018g was measured at the crest of Yucca Mountain (see Appendix B, work in progress 20).

3.2 ALTERED-ZONE AND NEAR-FIELD ENVIRONMENT

Near-Field Environment—Experiments using columns of crushed tuff and water at temperatures up to 300EC have been conducted to evaluate the likely composition of water seeping into drifts at elevated temperatures. The results of these experiments have been replicated successfully by the GIMRT coupled thermal-hydrologic-chemical model [OG3D/GIMRT, TBV-557]. Multi-component radionuclide solubility laboratory experiments are being performed using Neptunium V and Uranium VI to enlarge the thermodynamic data base to support radionuclide-transport simulations.

Post-test analyses of the Large Block Test are continuing to collect field data that will be used to compare against pretest model predictions of the effects of coupled thermal-hydrologic and thermal-hydrologic-mechanical processes controlling rock-mass behavior during this field test. In addition, thermal-hydrologic modeling, using the multi-scale thermal-hydrologic abstraction tool developed for the TSPA-VA and entailing numerous model simulations to evaluate various repository thermal-loading and design options, was performed to support the LADS process.

Thermal Tests—*Drift Scale Test Progress Report No. 1* (CRWMS M&O 1998o) was completed. Test results indicated that temperatures along the drift wall have been elevated to more than 160EC (300EF) after 16 months of heating. Water and gas samples were collected from the Drift Scale Test block and are being analyzed in the laboratory. Two quarterly thermal-test workshops were held in which updates of the most recent sets of measurements and predictions were presented and discussed. Field activities related to the post-test characterization of the Large Block Test were completed. Activities for the next six-month period include continued data collection, laboratory testing, numerical simulations, and analyses, as well as completing the *Single Heater Test Final Report* (see Appendix B, work in progress 21) and conducting two workshops.

3.3 SITE UNSATURATED ZONE FLOW AND TRANSPORT

Exploratory Studies Facility Alcove and Niche Studies—Two additional niches, Niche 3107 (#3) and Niche 4788 (#4), were excavated, and postexcavation air-permeability tests were completed in Niche 3107 (#3) and were initiated in Niche 4788 (#4). Niche excavation increased the permeability values in the rock mass above the niche ceiling. The permeability increases could be interpreted as the result of fracture-aperture openings induced by rock-stress releases. The increases in permeability and porosity of the fracture flow paths could suppress seepage into the drift. High permeability values promote lateral diversion, and high porosities require more water to fill the fracture volume to initiate seepage. Due to the capillary barrier mechanism, seepage can be initiated only if locally saturated conditions in the fractures are reached at the niche ceiling. Liquid-release tests were ongoing at Niche 3107 (#3) to discover the value at which seepage would begin in that low-permeability site and to quantify the capillary barrier and other mechanisms governing the seepage processes.

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A series of liquid-injection tests were conducted in a borehole interval intersecting a fault at the Lower Paintbrush Tuff Contact Alcove in the Paintbrush nonwelded hydrogeological unit. More than 200 L (53 gal.) of water were injected and no water was observed in a slot 3 m (10 ft) below the injection interval. These preliminary results suggest that the flow pulse through the Paintbrush nonwelded hydrogeologic unit could be significantly attenuated. Additional tests are planned to quantify flow along the fault in this nonwelded tuff unit with strong matrix-imbibition capacity.

Fluid-inclusion studies of calcite deposits continued. Samples were collected from 10 sites in the ESF, and preliminary petrographic observations have been made. However, no data on the inclusions have been collected because the fluid-inclusion studies are being restructured and expanded to complement parallel investigations by scientists from the University of Nevada-Las Vegas. Many samples remain to be collected and analyzed for uranium-series and uranium-lead dating and for strontium and stable isotope dating. Fluid-inclusion studies of calcite deposits in the ESF are being done to evaluate the suggestion that two-phase inclusions, if present, may imply repeated upwelling of heated fluids into the unsaturated zone.

A second controlled infiltration experiment was initiated in the ESF Upper Tiva Canyon Alcove on February 19, 1999. Through March 23, 1999 about 45,420 L (12,000 gal.) of water had been applied to an area approximately 12.2 m by 12.2 m (40 ft by 40 ft) at the land surface above the alcove (this amount of water is equivalent to approximately 30 cm (12 in.) of rainfall on this area). Bromide-tagged water began dripping into the alcove, which is 35 m (115 ft) below the land surface, on March 6, 1999 only 15 days after the start of the experiment, compared to the 58 days required for the first experiment. As of March 31, 1999, 2,400 L (634 gal.) of water had been collected in the alcove. Further tracer testing and monitoring of this experiment is planned this fiscal year to examine the relationship between infiltration and seepage. A similar controlled infiltration experiment will be conducted between an alcove in the cross drift and ESF Niche 3 to provide quantitative information on fracture and matrix permeabilities, and percolation fluxes through the Tptpul and Tptpmn units at the repository horizon.

The initial draft of the ESF Northern Ghost Dance Fault Alcove Testing Report, which describes the results of air-permeability, tracer, and hydrochemistry testing, was completed and submitted for technical review.

The report on the hydrogeology of the unsaturated zone in the vicinity of the ESF north ramp was published (Rousseau et al. 1999).

Enhanced Characterization of the Repository Block—Temperature, relative humidity, and wind-speed data were collected at various monitoring stations along the cross drift and at the discharge of the cross drift vent line. Periodic neutron-moisture logging of 50 boreholes was performed to monitor drying of the tunnel walls. Water-potential measurements from 106 heat-dissipation probes installed in 2 m-deep (6.6 ft-deep) boreholes at 25 m (82 ft)-intervals in the cross drift indicate that the rock mass has a greater water potential than predicted from either pre-existing rock core or in situ water-potential measurements, and greater than that predicted by the unsaturated zone site-scale flow model [TOUGH2 V1.3, TBV-563]. Data are scheduled for submittal to the technical database by the end of Fiscal Year 1999 (see Appendix B, work in progress 22). The water-potential measurements also indicate that moisture is more uniformly distributed than predicted. In the first 150 m (492 ft) of the cross drift, water potentials in the Topopah Spring crystal-poor upper lithophysal zone (Tptpul) are relatively low (less than -2 bars), and then increase to greater than -1 bar throughout the rest of the Tptpul, with no apparent change at the Ghost Dance fault. Although water potentials in the Topopah Spring crystal-poor middle nonlithophysal zone (Tptpmn) average about -1 bar, they decrease sharply to less than -1.5 bars in the Sundance fault zone, and to less than -2 bars at the bottom of the Tptpmn, indicating some differential drying in these zones. Water potentials in the Topopah Spring crystal-poor lower lithophysal zone (Tptpll) are the

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highest of any of the units penetrated by the cross drift, averaging about -0.6 bar. The water-potential measurements also indicate that the rock mass surrounding the cross drift is drying from the drift walls into the rock. The significance and implications of the measured water potentials in the cross drift for the unsaturated zone site-scale flow model [TOUGH2 V1.3, TBV-563] are being investigated.

Preliminary calculations for the first 395 m (1,296 ft) of the cross drift indicate that about half of the water used during excavation was removed by evaporation, and the other half was lost to the fracture network in the Ttpul. Although about 64 L (17 gal.) of construction water were lost to the rock mass per meter of tunnel excavated, there was a net loss of water from the cross drift of about 11.4 L (3 gal.) per meter after excavation. Thus, the rock mass surrounding the cross drift is drier after excavation than it was before, as indicated by the moisture measurements.

A total of 83 samples were collected systematically at 25-m intervals from fractures, faults, and intact rock in the cross drift, and 17 of these were analyzed for chlorine-36. The major objective of the cross drift samples is to test the accuracy of the predictions about the distribution of chlorine-36 in the drift, including occurrence of bomb-pulse chlorine-36. Bomb-pulse chlorine-36 was present in the vicinity of the eastern main splay of the Solitario Canyon fault and in the Sundance fault zone, as predicted. It was also present in brecciated rock from two unnamed fault zones at Stations 21+54.5 and 22+38, which suggests these faults may penetrate the overlying Paintbrush nonwelded hydrogeologic unit (PTn) near these locations. No bomb-pulse chlorine-36 was found in the fault at Station 13+17.

Pore water samples extracted from cross drift drillcore samples had chloride concentrations ranging from 10 to 45 mg/L. These concentrations correspond to surface infiltration rates on the order of 3 to 10 mm/yr and are largely consistent with the infiltration model.

More than two-thirds of the potential repository horizon is planned to be located in the Ttppl. A location was selected along the cross drift for both the seepage test and the fracture-matrix interaction test in the lower lithophysal unit. The location at Station 16+20 in the cross drift is located near the center of the potential repository region and is in a zone with large lithophysal cavities, with cavity dimensions in the 10 cm-diameter range. The lithophysal cavities and the matrix-imbibition properties of the lower lithophysal unit govern the processes of seepage into drift and fracture-matrix interaction.

Unsaturated Zone Modeling—The infiltration model has been updated to include snowmelt infiltration as well as surface-water run off and infiltration at washes. These changes and other enhancements predict greater infiltration at Yucca Mountain crest, in the east-facing washes draining Yucca Mountain, and in Fortymile Wash. The modeling for the unsaturated zone has been consolidated into a single numerical code (TOUGH2). The Unsaturated Zone Flow and Transport Model [TOUGH2 V1.3, TBV-563] grid spacing has been refined from 100 m (328 ft) to 60 m (197 ft) over the repository area. This will allow the model to preserve the high degree of spatial resolution in the infiltration model and lessen the amount of averaging in model predictions. The model grid has been revised based on the updated stratigraphy contained in the Geologic Framework Model (GFM3.1) [EARTHVISION CSCI: 30035 V4.0, TBV-692], which now includes data from USW WT-24 and USW SD-6. The coupled thermal-hydrologic-chemical modeling has advanced in development and now predicts the dissolution, alteration, and precipitation of 20 simultaneous minerals. Preliminary mountain-scale thermal-hydrologic-chemical modeling, based on information from the drift-scale and single heater tests, has given early results that may change our understanding of the precipitation cap that has been predicted to form over part of the repository and significantly alter the post-thermal flow field. The initial findings suggest that these effects are less dramatic than earlier estimated.

The flow and transport model for TSPA-SR is currently being revised and updated. This will include a complete update based on all new information, as well as a more comprehensive evaluation of existing

information. The ambient geochemistry, temperature, and hydraulic data will be evaluated to obtain a synthesis of site information to formulate the revised conceptual and numerical models. Unsaturated zone flow and transport results will be reported in Fiscal Year 2000 as a process model report (see Appendix B, work in progress 6). This report will include the model abstractions to create a more seamless interface between data, interpretations, process models, alternative conceptualizations, natural analogues, and abstractions.

Field-Scale Unsaturated Zone Transport Test at Busted Butte—Phase 1B tests on fracture-matrix interactions at the Topopah Spring welded hydrogeologic unit and Calico Hill nonwelded hydrogeologic unit contact (TSw/CHn), initiated on May 12, 1998 are now complete after six months of unsaturated transport testing, using conservative and reactive tracers and microspheres. Digital photographic documentation of overcores from both injection and collection boreholes, and use of ultraviolet illumination, are providing insights into the behavior of fracture-matrix interactions in, and immediately above, the Calico Hills Formation. Observations on the ingress of fluorescent tracer into the fractured rock mass are consistent with “breakthrough” data obtained from collection pads over the past six months, namely that fracture flow does not occur in these lithologies unless accompanied by substantial matrix flow. These observations indicate that additional sorption of radionuclides is expected under fracture flow conditions. This is because the largest volume fraction of solutes involves the matrix component of flow even when fractures are present. Future work involves quantifying the fracture-matrix coupling term so that it can be incorporated into site-scale models and their abstractions for TSPA-License Application.

As part of the Phase 1A excavation activities at Busted Butte, four subparallel vertical faces 50 cm (20 in.), 90 cm (35 in.), 115 cm (45 in.), and 140 cm (55 in.) from the original left rib of the main adit have been exposed since termination of testing on January 12, 1999; more than 200 auger samples were taken on each vertical layer for analysis. The eight-month test consists of continuous single-point injections in four boreholes at 1 mL/h (Boreholes #2 and #4) and 10 mL/h (Boreholes #1 and #3). These injection rates are equivalent to infiltration rates of 30 mm/yr (1.2 in./yr) and 380 mm/yr (15 in./yr), respectively, and represent infiltration rates for the Yucca Mountain region from present day to wetter Pleistocene conditions. Due to the presence of fluorescein, tracer migration from the injection points appears as fluorescent areas around the boreholes in ultraviolet illumination. Based on the distribution and geometry of the fluorescent areas, the following observations can be made:

- Matrix flow is dominant in the vitric zone in the Calico Hills nonwelded hydrogeologic unit, even in the presence of fracture and/or fault zones.
- When fracture flow occurs, based on Phase 1B observations (overcores), it appears rate-limited by local matrix flow until localized fracture-matrix equilibrium is established.
- As predicted by Phase 1A stochastic modeling, capillary flow is important; however, within a lithologic sub-unit, it is substantially more homogeneous than expected.
- Interfaces between lithologic horizons tend to act as transient hydrologic barriers such that combined with matrix flow and in the presence of strong capillary forces, lateral flow can be substantial.

These results are to be confirmed by quantitative tracer analyses using auger samples collected from the excavation walls. At this time, however, one can hypothesize that in terms of radionuclide transport, the combination of strong matrix flow with the presence of 4±2 percent smectite throughout the vitric zone in the Calico Hills nonwelded hydrogeologic unit ($K_d \sim 1,000$) should result in substantial retardation in the unsaturated zone beneath Yucca Mountain.

3.4 SITE SATURATED ZONE FLOW AND TRANSPORT

Nye County Drilling Program—A total of eight of the 22 planned shallow and deep wells were installed under the Nye County Early Warning Drilling Program. In addition to providing lithologic and geologic logs from the drilled wells, the program consists of completing the following:

- Aquifer testing data of all wells
- Long-term (six months, 94.6 L/s [1,500 gal/min]) aquifer testing
- Testing of alluvial units to examine hydrologic properties [Note: The testing of alluvial units focused on hydrologic properties that included transmissivity, storativity, specific yield, horizontal and vertical hydraulic conductivity, and anisotropy.]
- Hydrochemical and isotopic analyses of water samples
- Redox and related measurements
- Eh and pH data.

This program will provide additional lithologic, hydraulic, and transport-parameter data needed for the saturated zone flow and transport model and identified by the different review processes.

Saturated Zone Flow and Transport Modeling—Progress continues in developing the new site-scale saturated zone flow and transport model [FEHMN, TBV-569], which is used for TSPA. A three-dimensional numerical transport methodology that incorporates dispersion, matrix diffusion, sorption, and colloid transport was developed and tested. The methodology allows for representation of quantitatively small dispersivity values (a few centimeters) and minimizes numerical dispersion. The methodology also allows for representation of small radionuclide sources at the water table. Progress continues in calibrating the flow component of the model. The calibration effort with the specified flux (from the regional model) and specified head is progressing. Head differences average between 10 to 20 m (33 to 66 ft). Particle pathways from the repository generally trend southeast to Fortymile Wash and follow its trace to the NRC-proposed 20 km (12.4 mi.) compliance boundary. The calibration process is starting from a relatively simple model and increasing the complexity during the calibration process. A geostatistical methodology to handle block cell heterogeneity was developed and is being implemented.

Efforts continue to link the regional and site-scale models. Lateral fluxes are extracted from the regional model [MODFLOW V2.3, TBV-569] and are used as boundary conditions to the site-scale model. Recharge to the site-scale model is obtained from the unsaturated zone model for areas where the two models overlap, from the Fortymile Wash recharge study, and from the regional model for the rest of the model domain.

Large Hydraulic Gradient—At a drilled depth of 864 m (2,834 ft) below land surface, USW WT-24 was still in the Calico Hills Formation, a confining unit overlying the lower volcanic aquifer. The maximum depth permitted for USW WT-24 is 884 m (2,900 ft) (YMP 1997, p. 4). A request has been made to complete USW WT-24 into the lower volcanic aquifer, believed to be deeper than 884 m (2,900 ft). Currently, drilling operations at USW WT-24 have been suspended. Field Work Package SB-97-005, R1 (YMP 1997, p. 20) stated that, for long-term monitoring of water levels in USW WT-24, monitoring tubes would be placed in the borehole; however, at this time, this activity has not been completed. Further characterization of the aquifer is planned, and the site-scale model is being used to test the

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perched-water table conceptual model scenario against the large hydraulic gradient scenario to see if the different conceptualization results in any difference in the flow-field configuration.

C-Well Testing—The tests at the C-well complex were completed in the Prow Pass Tuff, which is closer to the groundwater table than the Bullfrog and Tram Tuff aquifers studied in earlier tests. Preliminary results from the Prow Pass Tuff test indicate:

- Matrix diffusion is occurring similar to that seen in earlier tests.
- Flow rates and hydraulic conductivity are greatly reduced in this section, as compared to the sections previously studied.
- There is more lithium (a reactive tracer) sorption in the Prow Pass Tuff than laboratory tests would have predicted, suggesting that laboratory test results are conservative.
- The microsphere data (two sizes) are highly attenuated as compared to the Bullfrog Tuff results, indicating the Prow Pass Tuff is a tight formation with low hydraulic conductivity.

3.5 SEISMIC HAZARDS AND DESIGN

Tectonics Program—Work continued to understand crustal deformation in the vicinity of Yucca Mountain. YMP scientists reported results from a 1998 resurvey of a 13-station, 50-km (31-miles) aperture geodetic array centered on the site. These data, along with data from previous surveys in 1983, 1984, and 1993, indicate principal strain accumulation rates of $\epsilon_1 = 9 \pm 12$ nanostrain/yr N88°W $\pm 11^\circ$ and $\epsilon_2 = -17 \pm 12$ nanostrain/yr N02°E $\pm 11^\circ$ (extension reckoned positive) (Savage et al. 1998). This analysis shows a N65°W extension rate of 5 ± 12 nanostrain/yr, significantly less than the 50 ± 9 nanostrain/yr reported by Wernicke et al. (1998) for this area based on data from 1991 to 1997. When strain accumulation on the Death Valley-Furnace Creek and Hunter Mountain-Panamint Valley faults to the west are considered, the residual strain rate in the vicinity of Yucca Mountain is not significant at the 95 percent confidence level (Savage et al. 1998).

During the next reporting period, work will continue on using satellite radar interferometry to examine crustal deformation associated with the Little Skull Mountain earthquake, which occurred in June 1992. Results of this study will provide more confidence in how surface deformation associated with the earthquake is taken into account in analyzing crustal strain data. In addition, work will continue on development of seismic-design inputs. Completion of a topical report on this topic is expected in early Fiscal Year 2000.

Geotechnical Site Investigations—A draft report on preliminary geotechnical investigations for the Waste Handling Building summarizes initial information to be used for conceptual-level foundation design and for evaluation of earthquake-induced ground motions in the design of this safety-related structure (see Appendix B, work in progress 23). In addition to the review of existing YMP information, results of new investigations conducted between October 1998 and March 1999 are presented. These investigations consisted of the following activities: (1) drilling, logging, and sampling one new borehole (designated UE-25 RF#13); (2) in situ penetration tests; (3) laboratory geotechnical characterization and dynamic response tests; (4) downhole seismic logging by two methods (conventional and suspension); and (5) seismic-refraction surveys. The following recommendations are provided as initial conceptual level design input: (1) preliminary, generalized characterization of subsurface conditions and pertinent material properties; (2) preliminary estimate of foundation-design parameters; and (3) preliminary evaluation of alternative foundation systems for conceptual, structural-design considerations, including recommendation on general foundation type.

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SECTION 4 -- DESIGN AND CONSTRUCTION

The YMP continued to develop and refine the documents that establish and form the repository design requirements and support the license application. This effort included:

- Completing 17 Compliance Program Guidance Packages (CRWMS M&O 1999b through 1999r) that served as regulatory input to both design and licensing documents in support of the license application. Of these packages, seven were engineering packages for input to the system description documents, and 10 were non-engineering topical packages for input to the *Technical Guidance Document for License Application Preparation* (YMP 1998a).
- Updating the *Mined Geologic Disposal System Requirements Document* (YMP 1998b) to capture recent changes in the *Civilian Radioactive Waste Management Systems Requirements Document* (DOE 1999b). Three changes were incorporated in this update. These changes were to: (1) add a description of the monitored geologic repository concept, which results in a repository that can be kept open for up to 300 years, (2) require the design to be capable of accommodating the current inventory projection of SNF and high-level waste, and (3) change the waste inventory to include immobilized plutonium and mixed-oxide SNF. The document has been renamed the *Monitored Geologic Repository - Requirements Document* (YMP 1999). The document was completed, approved, and submitted for incorporation into the DOE Level-II technical baseline.
- Completing several interface-control documents (CRWMS M&O 1998p through 1998r) to help control and integrate the physical, data and modeling, and functional interfaces of the system and project.
- Completing two analyses, the *Broad Based Risk Assessment for Surface Facilities* (CRWMS M&O 1999ab) and the *Evolution of the Monitored Geologic Repository Reference Design* (see Appendix B, work in progress 24), in support of criteria development and to support the draft EIS.

4.1 REPOSITORY

The YMP continued the study of design features and design alternatives that will be a basis for selecting the next-phase design for site recommendation and license application. Features are design enhancements that can be easily incorporated within multiple alternative designs; alternatives involve significant changes to the fundamental concepts on which the VA is based. A major part of the YMP's repository design effort was spent supporting the design features and design alternatives studies that will be a basis for selecting the license application reference design.

In subsurface design, laboratory testing of concrete drift liner in the VA reference design at elevated temperatures was completed. The test showed that concrete will retain adequate strength and stiffness for the anticipated range of repository temperatures and loads, including a thermal heating and cooling cycle (CRWMS M&O 1999ad, p. vii). This testing also revealed that the creep is greater than that predicted by the VA design model (CRWMS M&O 1999ad, p. vii). The results of this testing also indicated that the stress reduction resulting from creep will be greater than previously assumed in the VA design model.

Preliminary results of a key block analysis for rock surrounding the drifts determined the maximum probable key block size and the distribution, number, and location of key blocks as a function of drift orientation and four lithologic units (CRWMS M&O 1999u, Section 3). The lithologic units considered in the key block analysis are: (1) Ttpul, (2) Ttpmn, (3) Ttppl, and (4) Topopah Spring Tuff crystal-poor, lower nonlithophysal zone (Ttpln). The final results will provide a basis for choosing an

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emplacement drift orientation that minimizes the potential long-term (postclosure) key block size, which may enhance long-term drift stability.

Testing was begun on a ¼-scale model emplacement drift and waste package to determine the effectiveness of emplacement drift backfill on keeping infiltration from contacting the waste packages. Pilot Scale Test #1 was a Richards Barrier test where a fine layer of sand over a coarse layer was used as backfill. This model is performing as expected by diverting the water around the surrogate waste packages (see Appendix B, work in progress 2). Pilot Scale Test #2, using the same ¼-scale model, was used for a plain backfill test consisting of a single gradation backfill (coarse sand). The test resulted in infiltrated water being visible on the top of the surrogate waste package within three days and below the surrogate waste package within seven days (see Appendix B, work in progress 2). Planning is underway for Pilot Scale Test #3 that will use the same ¼-scale model, but will use a drip shield over the waste package instead of backfill to divert water from the waste package. This test will be run at a temperature that is similar to that calculated in the repository when water re-enters the emplacement drifts (see Appendix B, work in progress 2).

In repository surface design, the YMP completed one technical report (CRWMS M&O 1999ae) to support the EIS activities. The YMP completed or revised three technical reports (CRWMS M&O 1999af) (see Appendix B, works in progress 25 and 26) in support of the site recommendation and license application design. Additional analyses are ongoing that focus on the waste handling and waste treatment systems and facilities, and site-wide systems needed to support the site recommendation and license application. Two technical reports are being prepared that will support the LADS effort: one will evaluate impacts to the surface facilities for nine potential features, the other will evaluate the cash flow benefits of a modular-phased construction sequence for the repository.

In subsurface design, the EIS support document titled *Engineering File Subsurface Repository* (CRWMS M&O 1999ag) was revised to incorporate newer VA analyses and the REV 00 addenda requested by the EIS contractor. The purpose of the Engineering File is to supply descriptive information and environmental data to the EIS contractor in support of the contractor's preparation of the draft EIS.

4.2 WASTE PACKAGE

The YMP completed the *Disposal Criticality Analysis Methodology Topical Report* (CRWMS M&O 1998a). The topical report describes a postclosure criticality analysis. The analysis is intended to support risk-informed demonstrations that multiple natural and engineered barriers in the repository can protect the public health and safety against postclosure criticality. The NRC issued a letter accepting the topical report for review.

The YMP completed *Waste Package Final Update to EIS Engineering File* (CRWMS M&O 1999ai). This deliverable was an update of the engineering file that was prepared and submitted in Fiscal Year 1998 for the draft EIS. The major changes in the file update were to reflect the VA design and include plutonium in the base case. This impacted the number of waste package designs, the waste package materials, and the make-up and receipt of high-level waste.

The YMP completed several reports supporting the LADS alternative investigations. Reports supporting this effort included *Thermal Evaluation for Design Selection* (CRWMS M&O 1999aj), which consisted of calculations supporting both the additives and filler (additives and fillers are materials placed into a loaded waste package to fill void spaces, to provide absorption capacity for certain radionuclides, and moderator displacement for additional criticality control) design feature and the getter (fine-grained materials with high adsorption capacity for certain radionuclides that would be placed below the waste package) design feature. Documents *Thermal Evaluation of the Conceptual Consolidated Fuel Waste Package Loaded with PWR Fuel* (CRWMS M&O 1999ak), *Thermal Calculation of the Waste Package*

with *Drip Shield* (CRWMS M&O 1999al), and *Thermal Evaluation of Different Drift Diameter Sizes* (CRWMS M&O 1998s) provided thermal design information, and *Dose Calculation of Waste Package Containing Consolidated Spent Fuel Rods* (CRWMS M&O 1998t) supported rod-consolidation investigations.

The YMP completed the *Interface Control Document for the Waste Packages/Disposal Containers and the Surface Repository Facilities and Systems for Mechanical, Envelope and Functional Interfaces Between Surface Facilities Operations and Waste Package Operations* (CRWMS M&O 1998u). This document recorded agreements on controlled design parameters for the mechanical envelope and functional interfaces between the various waste packages and the systems, structures, and components of the surface repository facilities and systems. A calculation was completed to determine the effect of the source geometry model on the dose from pressurized-water reactor waste packages, *Calculation of the Effect of Source Geometry on the 21-PWR WP Dose Rates* (CRWMS M&O 1998v). For commercial SNF waste packages, fuel assemblies are modeled as a homogenized cylindrical source inside the inner barrier volume for radiation dose evaluation, an assumption that should yield conservative doses. This calculation assessed the validity of this assumption, and the results indicated that the homogenized source model leads to conservative dose results. This will provide significant savings of time performing future waste package shielding analyses for commercial SNF.

The YMP completed seven calculation documents (CRWMS M&O 1999am through 1999as) to evaluate the viability of disposing of the DOE-owned SNF inventory and for inclusion of this information in a license application.

Long-term corrosion testing of waste package candidate materials continued. Additional materials were added to the test matrix based on an evaluation of alternate waste package design and materials configurations. This work was done in support of the LADS alternatives evaluation. Also, a short-term test program that should be completed within a year was initiated to support the waste package material degradation model development effort. The short-term test program focuses on stress-corrosion cracking in Alloy 22 and titanium, hydrogen embrittlement in titanium, crevice corrosion in Alloy 22 and titanium, and galvanic effects among Alloy 22, titanium, and 316 stainless steel. Flow-through tests on high-burnup spent fuel and glass waste forms continued. The modeling of the effect of burnup on spent fuel dissolution is being updated, using newly acquired data at high and low burnups. Unsaturated drip tests on spent fuel, using Well J-13 water equilibrated with Topopah Spring Tuff (Well EJ-13 water), had undergone 6.5 years of reaction at 90°C (194°F) by the end of March 1999. Development continues on film-flow release-rate models for the spent fuel unsaturated drip-tests.

4.3 EXPLORATORY STUDIES FACILITY

During the reporting period, the YMP completed a further 103 m (338 ft) of excavation of the cross drift in the repository block. The DOE terminated excavation at this point and declared excavation of the cross drift complete. The DOE concluded that an alternative investigative approach has been developed that satisfactorily provides the means of obtaining the required scientific information. Therefore, further excavation at this time is deemed unnecessary (CRWMS M&O 1999at). The cross drift starts at a position 1,992 m (6,536 ft) from the beginning of the North Ramp and extends 2,681 m (8,796 ft) southwest across the repository block. Operation and maintenance are continuing at the site for support of ongoing testing.

The YMP completed the mineback (additional excavation of the rock in the experimental region to explore the results of the testing within the rock mass) and associated core drilling at Busted Butte to support testing activities. The mineback consisted of excavating an approximate 5 m-high by 3 m-wide by 2 m-deep (16 ft by 10 ft by 7 ft) area in the left rib of the Busted Butte tunnel in 0.5 m (1.6 ft)-depth increments.

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SECTION 5 – REPOSITORY PERFORMANCE

During this reporting period, the YMP accomplished several advances in the topics of preclosure radiological safety assessment, postclosure performance assessment, and performance confirmation.

5.1 PRECLOSURE RADIOLOGICAL SAFETY ASSESSMENT

Preclosure radiological safety input is required to support several ongoing YMP studies and documents. To provide that input, a revision of the document *Classification of the Preliminary MGDS Repository Design* (CRWMS M&O 1999w) was issued. This document provides input to the design bases for structures, systems, and components of the monitored geologic repository. The classification of items identifies the administrative, design, and operational features required to meet radiological safety (preclosure) or waste isolation (postclosure) functions.

Evaluations of candidate DBEs involving DOE SNF were performed and summarized in *DOE Spent Nuclear Fuel Design Basis Event Analysis Fiscal Year 1998* (CRWMS M&O 1999x) for the National Spent Nuclear Fuel Program. The scope of this effort consisted of identifying characteristics of the DOE SNF, establishing a preliminary list of candidate DBEs, determining isotopic inventory bounds, establishing preliminary grouping of DOE SNF, and performing a limited number of preliminary DBE analyses.

Three technical exchange meetings were held with the NRC to discuss preclosure radiological safety methods for identification of DBEs and radiological consequences resulting from those events. These discussions with NRC representatives also included proposed methods to implement the integrated safety analysis requirements of the proposed site-specific regulations (64 FR 8640 [1999]).

5.2 POSTCLOSURE PERFORMANCE ASSESSMENT

The focus of this reporting period has been on supporting repository design activities; the draft EIS; preparing, conducting, and documenting TSPA technical workshops; completing the TSPA-VA Technical Basis Documents (CRWMS M&O 1998b through 1998l); QA training, PVAR, and Corrective Action Report response; and work planning.

Total system analyses were performed for the LADS effort based on EDAs. New abstraction analyses were performed for a number of component models, including thermal hydrology and waste package degradation (see Appendix B, works in progress 27 through 54). The total system model provided "expected value" simulations for each EDA. This was used for sensitivity analyses of each EDA to provide a measure of the robustness of each. The performance assessments for the EDAs will factor strongly into the choice of a reference design for the site recommendation and design for the license application.

The total system analyses for the draft EIS used most aspects of the VA design and the TSPA-VA component models. In addition, the draft EIS performance assessment investigated three emplacement scenarios representing different waste package thermal-loading designs that were not analyzed in the TSPA-VA (see Appendix B, work in progress 55). The draft EIS performance assessment also calculated total, long-term, individual dose at 10,000 and 1,000,000 years to receptors for distances of 5 km (3 mi.), 30 km (19 mi.), and 80 km (50 mi.), in addition to the 20 km (12 mi.) distance used in the TSPA-VA. Insights were gained into several processes, including the observations that alluvial retardation and dilution are principal factors in reduction of total dose with distance from the repository.

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Progress toward corrective action report responses was made through the integrated Management Plan and Response to Corrective Action Requests, (CARs) LVMO-98-C-002, VAMO-98-C-005, LVMO-98-C-006, and LVMO-98-C-010 (CRWMS M&O 1999au).

Through attendance at QA training sessions, technical staff developed competence in using quality approaches required in a nuclear culture. These training sessions covered about 20 key QA procedures. Additional focus on QA issues was achieved through support of the PVAR effort. Resources were directed to improve QA and software configuration management of the total system code with the goal of ensuring traceability of the total system analyses.

Development was begun on a model tracking database that includes model descriptions and mapping of changes in models from one major assessment, such as the VA, to another, such as a site recommendation and license application.

Five technical workshops were held to evaluate important issues and aid in work planning. All workshops addressed issues identified in NRC IRSRs acceptance criteria, Performance Assessment Peer Review comments, and other technical reviews of TSPA. Progress made at the workshops included improvement of the couplings between the total system model and the component-model feeds. Documentation of the workshops will be completed for each component. The workshops and the major issues addressed in each were:

- Unsaturated-Zone Flow and Transport: climate and infiltration, unsaturated zone flow, seepage, and unsaturated zone transport
- Saturated Zone Flow and Transport and Biosphere: saturated zone flow, saturated zone transport, parameter uncertainty, biosphere, and interfaces with other TSPA components
- Thermal Hydrology and Coupled Processes: thermal hydrology, coupled processes, and thermal effects on flow and seepage
- Disruptive Events: igneous activity, seismic activity, and nuclear criticality
- Waste Form: waste-form degradation, cladding degradation, solubility, colloids, and secondary phases.

Development was started on work plans to describe tasks, resources, and documentation required to address important issues and feed the appropriate process model reports. See Section 2 for additional descriptions on process model reports. Development included writing planning details for a number of analyses and models for the natural systems.

Work was initiated to bring the waste package degradation analysis [WAPDEG CSCI: 30048 V3.09 TBV-568; MKHISTORY V1.0, CSCI: 30080 V1.0 TBV-568; Post 308, TBV-568] into full QA compliance. In the saturated zone component, progress was made in development of a new flow and transport model.

The *Final Report Total System Performance Assessment Peer Review Panel* (Budnitz et al. 1999) was issued. The report documented results of an independent peer review of the completed TSPA-VA, and included comments, concerns, conclusions, and recommendations that could be used to improve a TSPA to support a license application. It recommended that analyses of bounds and design changes be considered to address systems or events for which it is not feasible to produce realistic models supported by data, and recommended that the YMP begin future performance assessment efforts with a less complex

set of analyses. The report also recommended that more complex issues be evaluated through either sensitivity studies or evaluations of bounds.

5.3 PERFORMANCE CONFIRMATION

Performance confirmation activities are conducted to collect and analyze data to ensure conditions encountered and changes in those conditions are within the limits to be stated in the license. This program began during site characterization and will continue until permanent closure. The program evaluates whether natural systems and engineered systems and components are functioning as intended and anticipated.

This period, the YMP developed several evaluations of the impacts to performance confirmation for design features, design alternatives, and EDAs in support of the LADS effort (CRWMS M&O 1999av through 1999be). In support of performance confirmation baseline development, the *Full Periphery Geotechnical Mapping, Strike and Dip Data Entry Correction Analysis* (CRWMS M&O 1999bf) was completed. This report supplied validated fracture data for input required in evaluation of the fracture network as related to the formation of key blocks in the tunnel system at Yucca Mountain.

Performance confirmation activities also supported development of criteria for the *Performance Confirmation Data Acquisition/Monitoring System Description Document* (see Appendix B, work in progress 56). An *Analysis of Clearance Envelopes for Emplacement Drift Operating Equipment and Space Requirements for Test Coupons Within the Emplacement Drift* (see Appendix B, work in progress 57) is in preparation. A revision of the *Performance Confirmation Plan* (CRWMS M&O 1997) is planned for July 30, 1999 based upon changes resulting from the LADS effort and a reassessment of parameters important to postclosure performance.

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SECTION 6 – EPILOGUE

Since the close of the reporting period, several important developments have occurred on the YMP. These developments included:

- LADS

The LADS project included developing and evaluating a diverse range of conceptual repository designs that work well in concert with the Yucca Mountain site and recommending an initial design concept for a potential site recommendation and license application (see Appendix B, work in progress 1).

The design selection process consisted of two phases.

- In Phase I, a series of basic design concepts (design alternatives) and components (design features) were analyzed for potential value as elements of a repository design. Using this information, a diverse set of EDAs was created.
- In Phase II, these EDAs were refined, screened for acceptable postclosure performance, and evaluated against a set of criteria addressing four broad aspects of the repository: licensing challenge; flexibility; construction, operations, and maintenance; and cost and schedule.

Based on this evaluation, the recommended repository concept can be characterized as a design with lower thermal impact than the VA reference design. This design used more extensive thermal management techniques than the VA design to limit the impacts of heat generated and released by the waste.

The recommended design differs from the VA design in a number of other important aspects.

- While both use a two-layer waste package, the recommended design places the corrosion-resistant material on the outside, rather than the inside, to provide long-term protection to the more corrosion-susceptible structural material.
- The recommended design also adds defense in depth by including a drip shield covered by backfill to protect the waste packages from dripping water while they are hot enough to be susceptible to localized corrosion.
- The recommended design provides the flexibility to change to a lower thermal goal with longer preclosure ventilation, or to a higher thermal goal by spacing the emplacement drifts closer together, should either change be found later to be appropriate.
- Finally, the recommended design uses steel structural materials in the drifts instead of the concrete evaluated in the VA design in order to avoid possible impacts of chemicals in the concrete on mobilization and movement of radionuclides.

The recommended design provides a good balance of the ability of lower temperature designs to reduce uncertainties about postclosure performance and the preclosure advantages that designs with greater thermal effects can offer with regard to construction and operations, flexibility, and cost.

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The design is being further refined to bring the recommended conceptual design to the level of detail needed for a possible site recommendation and license application (see Appendix B, work in progress 1). The DOE will not make a decision on the design until after June 1999. However, in view of the LADS results, the YMP is reviewing the principal factors that are part of the repository safety strategy (repository safety strategy development is discussed in Section 2). The principal factors found to be applicable to the selected design will be reflected in the strategy. In addition, planned work will focus on addressing applicable principal factors. Particular emphasis will be placed on addressing those factors for which uncertainties in repository characteristics and performance can be significantly reduced to support a site recommendation and license application.

- License Application Development

The YMP decided to redirect resources from completion of the working draft license application to addressing QA issues, supporting the focused effort discussed in Section 2. Draft text was completed for many sections of the working draft, but the document will not be compiled and reviewed for DOE approval. The draft text will serve as the basis for beginning development of a license application in October 1999.

- QA Issues

A performance-based QA audit of performance assessment work was conducted in May. The audit noted strong team integration, positive attitudes toward nuclear culture, and thorough understanding of roles and responsibilities at all levels in the performance assessment organization. In addition, five recommendations were made to improve processes, and one deficiency report was written on development of work direction.

- PVAR

Twenty-five PVAR procedures were approved and effective by the end of June 1999. Training on these procedures began in June and is ongoing.

- Proposed NRC Regulations

On June 30, 1999 the DOE provided comments to the NRC on the proposed regulations specific to Yucca Mountain. The comments supported the use of risk-informed, performance-based licensing criteria. They also stated that the proposed regulations are a major improvement in providing the DOE flexibility in satisfying the performance criteria and in allowing the NRC to focus on performance. The DOE recommended that the proposed human intrusion criterion focus on qualitative understanding of the resiliency of the repository and that requirements for performance confirmation be made consistent with the performance-based, overall approach of the proposed regulations.

SECTION 7 – REFERENCES

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7.2 CODES AND REGULATIONS

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APPENDIX A

**LIST OF COMPLETED YUCCA MOUNTAIN SITE CHARACTERIZATION PROJECT
DELIVERABLES**

October 1, 1998 to March 31, 1999

Document Control Number	Deliverable Number	Title and Revision
20047	BM1020M3	Submit Initial Fiscal Year (FY) 1999 Yucca Mountain Site Characterization Project (YMP) Plan Update to Yucca Mountain Site Characterization Office (YMSCO)
20293	BM1030M3	Submit Final Fiscal Year 1999 YMP Plan Update to YMSCO
20291	BM1040M3	Submit Fiscal Year 1999 Participant Planning Sheets to YMSCO
20296	BM1052M3	Submit Change Request to Baseline Fiscal Year 1999 YMP Plan Update
20032	BM146M3	Complete the Identification and Processing for All Records Directly Referenced in the Viability Assessment (VA)
20053	RP123M3	Safety Critical Data Communication System
2080	RP237M3	Waste Emplacement Design
20055	RP241M3	Waste Transporter Design
20087	RP243M3	Performance Confirmation Design
20061	RP479M3	Subsurface Integrated Control System
20063	RP740BM3	Carrier/Cask Handling System Design Analysis
20085	RP740CM3	Assembly Drying System Technical Report
20625	RP740DM3	Cask/Canister Cooldown System Technical Report
20062	RP74AM3	Waste Handling Equipment Development Test and Evaluation Study
20084	RP74BM3	Monitored Geologic Repository Operations Staffing Report
20355	RPA105M3	Repository Surface Design Draft Update to Environmental Impact Statement (EIS) Engineering File
20341	RPA302M3	Provide Updated Subsurface Draft Engineering File
20028	SC811M3	Enhanced Characterization of the Repository Block (ECRB) Niche 1 & 2 Design
20137	SCM120M3	Complete ECRB Cross Drift Excavation
20043	SE2920M3	Report on Intact and Degraded Criticality for Selected Plutonium Waste Forms in a Geologic Repository, Volume I MOX SNF, Volume II Immobilized in Ceramic
20139	SEA100M3	Complete U.S. Department of Energy (DOE) Criteria Acceptance Review
20391	SEA115M3	Monitored Geologic Repository Requirements Document
20346	SEA155M3	Mined Geologic Repository Draft Environmental Impact Statement Appendix I Evolution of the Monitored Geologic Repository Reference Design
2092	SEVA00M3	Civilian Radioactive Waste Management System (CRWMS) Program Implementation Options
2077	SL05X7B4	Submit Draft Repository Safety Strategy (formerly Waste Containment and Isolation Strategy), Revision 2
2076	SL05X7B7	CRWMS Management and Operating Contractor (M&O) Submit Repository Safety Strategy (formerly Waste Containment and Isolation Strategy) Revision 2 to YMSCO for Acceptance
20163	SL230AM3	Total System Performance Assessment-Viability Assessment (TSPA-VA) Analyses Technical Basis Document - Chapters 1 through 11, Revision 01
20122	SL29GM3	Quarterly Regulatory Interactions Summary Report Fourth Quarter - Fiscal Year 1998
20398	SL29HM3	Quarterly Interactions Summary Report First Quarter - Fiscal Year 1999
20397	SL29JM3	Semi-Annual Site Characterization Activities Open Item Status Report
20340	SL36X2M3	Technical Guidance Document for License Application Preparation
20241	SLPR19M3	Submit Progress Report (PR) 19 to YMSCO Assistant Managers for Review (Site Characterization Progress Report: Yucca Mountain, Nevada, Number 19)
20414	SLPRAMM3	Documentation of Program Change

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Document Control Number	Deliverable Number	Title and Revision
20410	SLPRBMM3	Site Characterization Progress Report: Yucca Mountain, Nevada April 1, 1998 to September 30, 1998, Number 19
2094	SLSR26M3	Comment Response on the Third Interim Report
20420	SLSR50M3	Annotated Outline of the Site Recommendation Report (Volume 1) and Site Recommendation Volume 2: 10 Code of Federal Regulations (CFR) 960 Compliance Evaluation
20334	SLTDAM3	1st Quarter Status of Data Submittals and Incorporations into the Technical Data Management System
20057	SLTDB2M3	Identification of VA Cited Data Incorporated in GENISES
20024	SP32D5M3	Evaluation of Flow and Transport Models of Yucca Mountain, Based on Chlorine-36 and Chloride Studies for Fiscal Year 1998
20018	SP3330M3	Drift Scale Test Progress Report Number 1
2074	SP39FBM3	Site Description Document
20060	SPAE04M3	AELT Final Report
2091	SPC26AM3	Paleoclimate Data Qualification Evaluation
2090	SPC26BM3	Paleohydrology Data Qualification Evaluation
20089	SPG28NM3	Probabilistic Seismic Hazard Analysis for Fault Displacement and Vibratory Ground Motion at Yucca Mountain, Nevada
20345	SPQ301M3	Environmental Baseline File for Geology/Hydrology
20502	SS128DM3	Nevada State Fire Marshal, Nevada Combined Agency HazMat Facility Report YMP
20501	SS128EM3	1998 Annual Report on Waste Generation and Pollution Prevention Progress as Required by DOE Order 5400.1
20198	SS128GM3	Air Quality Operating Permit Number AP9611-0573 Monitoring Period 29: July -September 1998
20495	SS128HM3	Ambient Air Monitoring Report Air Quality Operating Permit Number AP9611-0573 Monitoring Period 30: October - December 1998
20187	SS128KM3	Socioeconomic Monitoring Program Quarterly Employment Data Report
20321	SS128LM3	YMSCO Project Socioeconomic Monitoring Program Procurement Data Report April 1, 1998 to September 30, 1998
20462	SS128MM3	Socioeconomic Monitoring Program Quarterly Employment Data Report October 1998 through December 1998
20371	SS12AM3	Update Draft Environmental Baseline Files (Letter Report, LV.ESR.RLM.12/98-253)
20422	SS983AM3	Quarterly Underground Injection Control (UIC) Permit Report
20140	SS983M3	UIC Permit
20017	SSH13NM3	Draft Annual Report: Summary Monitoring through Calendar Year 1997
20157	SSH14HM3	Letter Report, 4th Quarter Fiscal Year 1998
20445	SSH14IM3	Letter Report, 1st Quarter Fiscal Year 1999
20259	SSJ193M3	Deliver Preliminary Draft EIS for the EIS Manager Review
2052	SSNE124M	Complete TSPA Analyses for National Environmental Policy Act (NEPA)
20086	WP051M3	Waste Package Phase II Closure Methods Report
20342	WP05AM3	Waste Package Draft Updates to EIS Engineering Files

APPENDIX B

**LIST OF FUTURE YUCCA MOUNTAIN SITE CHARACTERIZATION PROJECT
DELIVERABLES**

PROGRESS REPORT #20

Work in Progress Number	Document or Deliverable ID Number	Proposed Title	Expected Completion Date
Work in Progress PR 20 Listings			
1	B00000000-01717-4600-00123	License Application Design Selection Report, Rev. 01	5/28/99
2	B00000000-01717-5700-00001	Engineered Barrier System-Pilot Scale Testing Preliminary Results Through 1/3/99	—
3	B00000000-01717-5700-00031	Annotated Outline of the Site Recommendation Report, Volume 2: 10 CFR 960 Compliance Evaluation	—
4	B00000000-01717-4601-00002	Management Plan for the Development of the Yucca Mountain Site Recommendation Report	—
5	SP9904M3	Large Block Test Final Report – Revised, results incorporated in Near-Field Environment Process Model Report (Carried forward from PR 19, listed as work in progress 5.)	3/3/00
6	Number TBD	Unsaturated Zone Flow and Transport Model. Rev. 0 (Carried forward from PR 19, listed as work in progress 8.)	4/28/00
7	SPV248M3	Report: Saturated Zone Flow & Transport Model for Site Recommendation/License Application – Revised, Saturated Zone Process Model Report (Carried forward from PR 19, listed as work in progress 12.)	1/28/00
8	SS19DM3	Distribute Draft EIS (Carried forward from PR 19, listed as work in progress 13.)	7/30/99
9	SL916M3	Draft EIS – (PRIVILEGED RECORD) (Carried forward from PR 19, listed as work in progress 19.)	3/15/99
10	SLSTRBM3	Submit Seismic Topical Report (STR) III for QAP 6.2/YAP-30.12 Reviews (Carried forward from PR 19, listed as work in progress 15.)	11/8/99
11	B00000000-01717-1705-00003	Monitored Geologic Repository Project Description Document	—
12	SEA282M3	Performance Confirmation Plan, Revision 1 (Carried forward from PR 19, listed as work in progress 14.)	7/30/99
13	SL915M3	TSPA-Site Recommendation/License Application Methods and Assumptions Document (Carried forward from PR 19, listed as work in progress 17.)	6/30/99
14	SP32P4M3	Report: ISM3.1; Addendum to ISM3.0 Report (Carried forward from PR 19, listed as work in progress 2.)	12/13/99
15	SPG42GM3	Geology of the Enhanced Characterization of the Repository Block Drift (Carried forward from PR 19, listed as work in progress 3.)	8/16/99
16	SPG258M3	Preliminary Geologic Map for Saturated Zone Site Area (Carried forward from PR 19, listed as work in progress 4.)	5/28/99

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Work in Progress Number	Document or Deliverable ID Number	Proposed Title	Expected Completion Date
17	Number TBD	Data Submittal to Technical Database for Nye County	9/30/00
18	SPG452M3	Geometry and Characteristics of Fault Zones at Yucca Mountain	9/30/99
19	SP387CM4	Analysis and Model Report for Natural Resources	9/30/99
20	Number TBD	Seismicity for Fiscal Year 1999	9/30/99
21	BAB000000-01717-5700-00005	Single Heater Test Final Report	9/30/99
22	SPH372M4	Cross-drift Moisture Monitoring Data Package to RPC/TDB	9/30/99
23	BCB000000-01717-5705-00016	Preliminary Geotechnical Investigation for Waste Handling Building, Yucca Mountain Site Characterization Project, REV 00	—
24	B00000000-01717-5700-00025	Evolution of the Monitored Geologic Repository Reference Design	—
25	BCBD00000-01717-5705-00002	Cask/Canister Cooldown System Technical Report	—
26	BCBD00000-01717-5705-00007	Waste Handling Equipment Development Test and Evaluation Study	9/30/99
27	B00000000-01717-0210-00064	Thermal-Hydrology Modeling of a Modified Waste Emplacement Mode Concept: Borehole Emplacement	9/30/99
28	B00000000-01717-0210-00054	Thermal-Hydrology Modeling of the Blending of Waste Alternative Designs	9/30/99
29	B00000000-01717-0210-00055	Thermal-Hydrology Modeling of the Niche Pattern Modified Waste Emplacement Mode Alternative Design	9/30/99
30	B00000000-01717-0210-00056	Thermal-Hydrology Modeling of the Pre-Closure Ventilation Alternative Designs	9/30/99
31	B00000000-01717-0210-00057	Thermal-Hydrology Modeling of the Post-Closure Ventilation Alternative Designs	9/30/99
32	B00000000-01717-0210-00058	RIP Input Tables from WAPDEG for LA Design Selection: Continuous Post-Closure Ventilation Design - Closed "Bowtie" Layout	9/30/99
33	B00000000-01717-0210-00065	RIP Input Tables from WAPDEG for LA Design Selection: Continuous Post-Closure Ventilation Design - Open Loop	9/30/99
34	B00000000-01717-0210-00077	RIP Input Tables from WAPDEG for LA Design Selection: Modified Waste Emplacement Mode Design - Horizontal Borehole	9/30/99

Work in Progress Number	Document or Deliverable ID Number	Proposed Title	Expected Completion Date
35	B0000000-01717-0210-00076	RIP Input Tables from WAPDEG for LA Design Selection: Modified Waste Emplacement Mode Design - Vertical Borehole	9/30/99
36	B0000000-01717-0210-00044	RIP Input Tables from WAPDEG for LA Design Selection: Modified Waste Emplacement Mode Design - Alcove	9/30/99
37	B0000000-01717-0210-00037	RIP Input Tables from WAPDEG for LA Design Selection: Drip Shield and Quartz Backfill	9/30/99
38	B0000000-01717-0210-00040	RIP Input Tables from WAPDEG for LA Design Selection: 50 Year Pre-Emplacement Aging	9/30/99
39	B0000000-01717-0210-00042	RIP Input Tables from WAPDEG for LA Design Selection: Blending of Waste	9/30/99
40	B0000000-01717-0210-00045	RIP Input Tables from WAPDEG for LA Design Selection: Continuous Pre-Closure Ventilation	9/30/99
41	B0000000-01717-0210-00038	RIP Input Tables from WAPDEG for LA Design Selection: Line Loading	9/30/99
42	B0000000-01717-0210-00049	RIP Input Tables from WAPDEG for LA Design Selection: Waste Package CRMs	9/30/99
43	B0000000-01717-0210-00059	RIP Input Tables from WAPDEG for LA Design Selection: Waste Package CRMs -- 2 cm Alloy 22	9/30/99
44	B0000000-01717-0210-00039	RIP Input Tables from WAPDEG for LA Design Selection: Richard's Barrier	9/30/99
45	B0000000-01717-0210-00047	RIP Input Tables from WAPDEG for LA Design Selection: Canistered Assemblies	9/30/99
46	B0000000-01717-0210-00060	RIP Input Tables from WAPDEG for LA Design Selection: Alluvium Surface Modification	9/30/99
47	B0000000-01717-0210-00061	RIP Input Tables from WAPDEG for LA Design Selection: Repository Horizon Elevation -- 2-Level AML 50% and Near Maximum	9/30/99
48	B0000000-01717-0210-00062	RIP Input Tables from WAPDEG for LA Design Selection: Higher thermal Loading	9/30/99
49	B0000000-01717-0210-00069	RIP Input Tables from WAPDEG for LA Design Selection: Enhanced Design Alternative I	9/30/99
50	B0000000-01717-0210-00070	RIP Input Tables from WAPDEG for LA Design Selection: Enhanced Design Alternative II	9/30/99

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Work in Progress Number	Document or Deliverable ID Number	Proposed Title	Expected Completion Date
51	B00000000-01717-0210-00071	RIP Input Tables from WAPDEG for LA Design Selection: Enhanced Design Alternative IIIa	9/30/99
52	B00000000-01717-0210-00078	RIP Input Tables from WAPDEG for LA Design Selection: Enhanced Design Alternative IIIb	9/30/99
53	B00000000-01717-0210-00072	RIP Input Tables from WAPDEG for LA Design Selection: Enhanced Design Alternative IV	9/30/99
54	B00000000-01717-0210-00073	RIP Input Tables from WAPDEG for LA Design Selection: Enhanced Design Alternative V	9/30/99
55	B00000000-01717-5705-00128	Environmental Impact Statement Performance Assessment	6/30/99
56	BCB000000-01717-1705-00034	Performance Confirmation Data Acquisition/Monitoring System Description Document	—
57	BCA000000-01717-5705-00007	Analysis of Clearance Envelopes for Emplacement Drift Operating Equipment and Space Requirements for Test Coupons within the Emplacement Drift	—
Work in Progress PR 19 Listings^a			
1	SLPRAMM3	Documentation of Program Change to YMSCO AMS for Review - Final	2/2/99 FINAL
2 ^b	SP32P4M3	Report: ISM3.1; Addendum to ISM3.0 Report	5/28/99 Revised 12/13/99
3 ^b	SPG42GM3	Geology of the Enhanced Characterization of the Repository Block Drift	3/31/99 Revised 8/16/99
4 ^b	SPG258M3	Preliminary Geologic Map for Saturated Zone Site Area	3/5/99 Revised 5/28/99
5 ^b	SP9904M3	Large Block Test Final Report – Revised, results incorporated in Near-Field Environment Process Model Report	8/12/99 Revised 3/3/00

^a The following entries are included in Progress Report 20 to track them through final disposition.

^b Item carried forward to Progress Report 20.

Work in Progress Number	Document or Deliverable ID Number	Proposed Title	Expected Completion Date
6	SP4CK1M4	Laboratory Experiments of Coupled Thermal-Hydrological Processed – Revised, Fracture Matrix Flow Experiments Results	9/30/98 FINAL
7	SPU85M4	Submit License Application Testing Status Report	9/30/98 FINAL
8 ^b	SP3538M3	Unsaturated Zone Flow and Transport Model for Site Recommendation – Revised, Unsaturated Zone Process Model Report	1/18/00
9	SP32E1M3 New number TBD	Report: Prow Pass Reactive Tracer Test - Revised as Flow Calibrations AP-3.10Q	4/1/99 Revised 8/2/99
10	SP32E7M4 New number TBD	Report: Prow Pass Reactive Tracer Test - Revised as Flow Calibrations AP-3.10Q	2/12/99 Revised 8/2/99
11	SPU17M4 Deleted	Submit Report on Eh and Ph Measurements WT-24 and SD-6/Flow Calibrations AP-3.10Q - Deleted	9/30/98 Deleted
12 ^b	SPV248M3	Report: Saturated Zone Flow & Transport Model for Site Recommendation/License Application – Revised, Saturated Zone Process Model Report	1/28/00
13 ^b	SS19DM3	Distribute Draft EIS	7/30/99
14 ^b	SEA282M3	Performance Confirmation Plan, Revision 1	7/30/99
15 ^b	SLSTRBM3	Submit Seismic Topical Report (STR) III for QAP 6.2/YAP-30.12 Reviews	9/30/99 Revised 11/8/99
16	M2MQ	License Application Design Selection Report	5/28/99
17 ^b	SL915M3	TSPA-Site Recommendation/License Application Methods and Assumptions Document	6/30/99
18	SLSR5M3	Performance Assessment Peer Review Panel	5/28/99
19 ^b	SL916M3	Draft EIS – (PRIVILEGED RECORD)	2/26/99 Revised 3/15/99 FINAL
20	SEAA21M3	Criticality Analysis of Pu Waste Forms in a Geologic Repository	9/30/99
21	SEA1A9M3	Design Basis Events Analysis of Immobilized Pu Waste Form	9/30/99

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APPENDIX C

**STATUS OF MILESTONE REPORTS REFERENCED
IN PREVIOUS PROGRESS REPORTS**

PROGRESS REPORT #20

Introduction

This appendix lists YMP documents referenced in previous progress reports (Progress Reports 17 to date) as Level 4 milestone reports and indicates a current status (i.e., a final, published reference; publication pending; or no change). This list will be updated in each progress report; documents will be carried forward until final disposition.

These documents are developed for the YMP primarily by the national laboratories and U.S. Geological Survey. The versions originally presented as Level 4 milestone reports for use by the YMP may differ from the final published documents. This appendix provides readers the opportunity to obtain final, published technical documents when available.

As referenced in:	Current Status
Progress Report 17	
Buscheck, T.A.; Shaffer, R.J.; Lee, K.H.; and Nitao, J.J. 1997. <i>Analysis of Thermal-Hydrological Behavior During the Heating Phase of the Single-Heater Test at Yucca Mountain</i> . Milestone Report. Supplement to SP9266M4, LLYMP9708069, August 12, 1997. Livermore, California: Lawrence Livermore National Laboratory. MOL.19980109.0241	No change
Buscheck, T.A.; Shaffer, R.J.; and Nitao, J.J. in prep. <i>Pretest Thermal-Hydrological Analysis of the Drift Scale Test at Yucca Mountain</i> . YMP FY 97. Level 4 Deliverable SP 9321M4. Livermore, California: Lawrence Livermore National Laboratory.	No change
Bussod, G.Y.; Robinson, B.A.; Vaniman, D.T.; Broxton, D.E.; and Viswanathan, H.S. in prep. 1997. UZ Transport Test Plan, Rev. 1. Yucca Mountain Project Milestone SP341SM4. Los Alamos, New Mexico: Los Alamos National Laboratory.	No change
Cohen, A.J.B.; Oldenburg, C.M.; and Simmons, A.M. 1997. <i>S⁴Z: Sub-Site Scale Saturated Zone Model for Yucca Mountain</i> . Milestone Report SP25UM4, 91p. MOL.19971204.0732	No change
Conca, J.L.; Robinson, B.A.; Triay, I.R.; Bussod, G.Y. 1997. Direct Characterization of Transport Parameters in Near-Field and Engineered Backfill/Invert Materials. Yucca Mountain Project Milestone SP341NM4. Los Alamos, New Mexico: Los Alamos National Laboratory.	No change

PROGRESS REPORT #20

As referenced in:	Current Status
Progress Report 17	
<p>CRWMS M&O 1997cn. <i>Summary of Seismic Source Characterization Feedback Workshop (#5)</i>. Salt Lake City, Utah. April 14-16, 1997. Prepared for the U.S. Geological Survey to satisfy Yucca Mountain Project Milestone SPG28NM4. EXR.19971007.0080</p>	<p>CRWMS M&O 1997cn-1997cr fed into:</p>
<p>CRWMS M&O 1997co. <i>Summary of Feedback on Ground Motion Interpretations Workshop on Ground Motion Characterization at Yucca Mountain</i>. Salt Lake City, Utah. April 16, 17 and 18, 1997. Prepared for the U.S. Geological Survey to satisfy Yucca Mountain Project Milestone SPG28DM4. EXR.19971007.0080</p>	<p>CRWMS M&O 1998. <i>Probabilistic Seismic Hazard Analysis for Fault Displacement and Vibratory Ground Motion at Yucca Mountain, Nevada, Final Report</i> (3 Volumes). Wong, I.G. and Stepp, J.C., Report Coordinators. Milestone Report SP32IM3 prepared for the U.S. Geological Survey. Oakland, California: CRWMS M&O. MOL.19980619.0640. Final.</p>
<p>CRWMS M&O 1997cp. <i>Summary of Seismic Source Characterization Fault Displacement Workshop</i>. Salt Lake City, Utah. June 3, 1997. Prepared for the U.S. Geological Survey. MOL.19980302.0362</p>	
<p>CRWMS M&O 1997cq. <i>Seismic Source and Fault Displacement Characterization Project</i>. Prepared for the U.S. Geological Survey to satisfy Yucca Mountain Project Milestone SPG28OM4.</p>	
<p>CRWMS M&O 1997cr. <i>Ground Motion Characterization at Yucca Mountain, Nevada</i>. Prepared for the U.S. Geological Survey to satisfy Yucca Mountain Project Milestone SPG28EM4.</p>	
<p>Czarnecki, J.B.; Faunt, C.C.; Gable, C.W.; and Zyvoloski, G.A. in prep. <i>Hydrogeology and Preliminary Calibration of a Preliminary Three-Dimensional Finite-Element Ground-Water Flow Model of the Site Saturated Zone, Yucca Mountain, Nevada</i>. Milestone Report SP23NM3, DTN: GS970808312333.002. Submitted for release as a U.S. Geological Survey Administrative Report. Denver, Colorado: U.S. Geological Survey.</p>	<p>Czarnecki, J.B.; Faunt, C.C.; Gable, C.W.; and Zyvoloski, G.A. 1997. <i>Hydrogeology and Preliminary Calibration of a Preliminary Three-Dimensional Finite-Element Ground-Water Flow Model of the Site Saturated Zone, Yucca Mountain, Nevada</i>. Milestone Report SP23NM3, DTN: GS970808312333.002. U.S. Geological Survey Administrative Report. Denver, Colorado: U.S. Geological Survey. MOL.19980204.0519. [No additional publication planned.] Final.</p>
<p>D'Agnese, F.A.; O'Brien, G.M.; Faunt, C.C.; and San Juan, C.A. in prep. <i>Simulated Effects of Climate Change on the Death Valley Regional Ground-Water Flow System, Nevada and California</i>. Milestone Report SP23OM3, DTN: GS970708312144.003. Submitted for publication as a U.S. Geological Survey Water-Resources Investigations Report. Denver, Colorado: U.S. Geological Survey.</p>	<p>D'Agnese, F.A.; O'Brien, G.M.; Faunt, C.C.; and San Juan, C.A. 1999. <i>Simulated Effects of Climate Change on the Death Valley Regional Ground-Water Flow System, Nevada and California</i>. Milestone Report SP23OM3, DTN: GS970708312144.003. MOL.19980130.0211. U.S. Geological Survey Water-Resources Investigations Report 98-4041. Denver, Colorado: U.S. Geological Survey. TIC: TBD. Final.</p>
<p>Eatman, G.L.Q.; Singleton, W.L.; Moyer, T.C.; Barr, D.L.; Albin, A.L.; Lung, R.C.; and Beason, S.C. in prep. <i>Geology of the South Ramp - Station 55+00 to 78+77, Exploratory Studies Facility, Yucca Mountain Project, Yucca Mountain, Nevada</i>. Milestone Report SPG42CM3, DTN: GS970808314224.016. Unpublished. Denver, Colorado: U.S. Bureau of Reclamation and U.S. Geological Survey.</p>	<p>Eatman, G.L.W.; Singleton, W.L.; Moyer, T.C.; Barr, D.L.; Albin, A.L.; Lung, R.C.; and Beason, S.C. 1997. <i>Geology of the South Ramp - Station 55+00 to 78+77, Exploratory Studies Facility, Yucca Mountain Project, Yucca Mountain, Nevada</i>. Milestone Report SPG42CM3, DTN: GS970808314224.016. Unpublished. Denver, Colorado: U.S. Bureau of Reclamation and U.S. Geological Survey. MOL.19980127.0396. [No additional publication planned.] Final.</p>

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As referenced in:	Current Status
Progress Report 17	
<p>Efurd, D.W.; Runde, W.; Tait, C.D.; Banar, J.C.; Reonsch, F.R.; Palmer, P.D.; and Clark, D.L. 1996. <i>Measured Solubilities And Speciation Of Neptunium And Plutonium In J#13 Ground Water</i>. Yucca Mountain Project Milestone 3411. Los Alamos, New Mexico: Los Alamos National Laboratory.</p>	No change
<p>Efurd, D.W.; Runde, W.; Janecky, D.J.; and Tait, C.D. 1997. <i>Delivery Solubility Models And Experiments</i>. Yucca Mountain Project Milestone SP341FM4. Los Alamos, New Mexico: Los Alamos National Laboratory.</p>	No change
<p>Fabryka-Martin J.T.; Flint, A.L.; Sweetkind, D.S.; Wolfsberg, A.V.; Levy, S.S.; Roach, J.; and Wolfsberg, L.E. in prep. <i>Evaluation of Flow and Transport Models of Yucca Mountain, based on Chlorine-36 Studies for FY97</i>. Milestone Report SP2224M3. Los Alamos, New Mexico: Los Alamos National Laboratory.</p>	No change
<p>Feighner, M.A.; Daley, T.M.; Gritto, R.; and Majer, E.L. in prep. Report on CDP Reflection Image and Subsurface Structure Along Lines B and C: US-16 VSP. Milestone Report SP3B2BM4. September 30, 1997.</p>	No change
<p>Flint, L.E. in prep. <i>Characterization of Hydrogeologic Units Using Matrix Properties, Yucca Mountain, Nevada</i>. WRIR-97-4243. Water Resources Investigations Report. Unpublished Milestone Report 3GUP603M, DTN: GS960908312231.004. Denver, Colorado: U.S. Geological Survey.</p>	<p>Flint, L.E., 1998. <i>Characterization of Hydrogeologic Units Using Matrix Properties, Yucca Mountain, Nevada</i>. WRIR-97-4243. Water Resources Investigations Report. Denver, Colorado: U.S. Geological Survey. TIC 236515. Final.</p>
<p>Flint, A.L.; Hevesi, J.A.; and Flint, L.E. in prep. <i>Conceptual and Numerical Model of Infiltration for the Yucca Mountain Area, Nevada</i>. Milestone Report 3GUI623M, DTN: GS960908312211.003. Submitted for publication as a Water-Resources Investigations Report. Denver, Colorado: U.S. Geological Survey.</p>	<p>Flint, A.L.; Hevesi, J.A.; and Flint, L.E. 1996. <i>Conceptual and Numerical Model of Infiltration for the Yucca Mountain Area, Nevada</i>. Milestone Report 3GUI623M, DTN: GS960908312211.003. Submitted for publication as a Water-Resources Investigations Report. Denver, Colorado: U.S. Geological Survey. MOL.19970409.0087. [Milestone report still being processed for publication as USGS WRIR.]</p>
<p>Forester, R.M.; Bradbury, J.P.; Carter, C.; Elvidge, A.; Hemphill, M.; Lundstrom, S.C.; Mahan, S.A.; Marshall, B.D.; Neymark, L.A.; Paces, J.B.; Sharpe, S.; Whelan, J.F.; and Wigand, P. in prep. <i>Synthesis of Quaternary Response of the Yucca Mountain Unsaturated and Saturated Zone Hydrology to Climate Change</i>. Milestone Report 3GCA102M. Submitted for publication as an Open-File Report. Denver, Colorado: U.S. Geological Survey. MOL.19970211.0026. 229822</p>	<p>Forester, R.M.; Bradbury, J.P.; Carter, C.; Elvidge, A.; Hemphill, M.; Lundstrom, S.C.; Mahan, S.A.; Marshall, B.D.; Neymark, L.A.; Paces, J.B.; Sharpe, S.; Whelan, J.F.; and Wigand, P. 1999. <i>The Climatic and Hydrologic History of Southern Nevada During the Late Quaternary (formerly: Synthesis of Quaternary Response of the Yucca Mountain Unsaturated and Saturated Zone Hydrology to Climate Change, Milestone Report 3GCA102M, MOL.19970211.0026. 229822)</i>. Open-File Report 98-635. Denver, Colorado: U.S. Geological Survey. TIC: TBD. Final.</p>
<p>Francis, N.D.; Sobolik, S.R.; Ho, C.K.; Eaton, R.R.; and Preece, D. 1997. <i>Pre-Experiment Thermal-Hydrological-Mechanical Analyses for the ESF Heated Drift Test</i>. SLTR97-0002. YMP FY97 Level 4 Deliverable SP9323M4. Albuquerque, New Mexico: Sandia National Laboratories. MOL.19980128.0366</p>	No change

PROGRESS REPORT #20

As referenced in:	Current Status
Progress Report 17	
French, D.E., in prep. Draft Report, "Assessment of Hydrocarbon Resources of the Yucca Mountain vicinity, Nye County, Nevada." Unpublished independent consultant's report prepared for Civilian Radioactive Waste Management System Management and Operating Contractor, Billings, Montana. Level 4 Deliverable #SPTAM4.	No change
Glassley, W.E. 1997. <i>Thermo-Chemical Analysis of the Drift Scale Heater Test : Mineralogical and Geochemical Characteristics</i> . YMP FY97 Level 4 Deliverable SP 9320M4. Livermore, California: Lawrence Livermore National Laboratory. MOL.19980105.0566	No change
Glassley, W.E. and DeLoach, L. 1997. <i>Second Quarter Results of Chemical Measurements in the Single Heater Test</i> . Milestone report for CRWMS M&O, DOE. SP9240M4. Livermore, California: Lawrence Livermore National Laboratory. MOL.19971218.0917	No change
Huang, J. in prep. <i>Thermal Embrittlement of Carbon Steels in Canistered Waste Disposal Containers</i> . September 1997. WP60508 Milestone report for CRWMS M&O, DOE. Livermore, California: Lawrence Livermore National Laboratory.	No change
McCright, D. 1997a. <i>Material Thermal Stability</i> . WP26904 Milestone Report. July 1997. Livermore, California: Lawrence Livermore National Laboratory. MOL.19980107.0363	No change
Meijer, A. 1994. <i>Ground Water Composition Parameters Most Critical To The Sorption Behavior Of Radionuclides Of Interest To The Yucca Mountain Project</i> . YMSCP Milestone Report 4032. Los Alamos, New Mexico: Los Alamos National Laboratory. MOL.19950630.0308	No change
Meijer, A. 1996. <i>Conceptual Model of Ground Water Chemistry</i> . Yucca Mountain Project Milestone Report 3098. Los Alamos, New Mexico: Los Alamos National Laboratory.	No change
Nitao, J.J. 1997. <i>Preliminary Bounds for the Drift-Scale Distribution of Percolation and Seepage at the Repository Level under Pre-Emplacement Conditions</i> . Letter report to DOE. LLYMP 9703034. Livermore, California: Lawrence Livermore National Laboratory. 234515	No change
Paces, J.B.; Forrester, R.M.; Whelan, J.F.; Mahan, S.A.; Bradbury, J.P.; Quade, J.; Neymark, L.A.; and Kwak, L. 1996. <i>A Synthesis of Ground-Water Discharge Deposits Near Yucca Mountain</i> . USGS Milestone Report 3GQH671M to DOE-YMSCO. 75 p. Denver, Colorado: U.S. Geological Survey. MOL.19970205.0007. 234044	No change
Paces, J.B.; Marshall, B.D.; Whelan, J.F.; and Neymark, L.A. 1997a. <i>Progress Report on Unsaturated Zone Stable and Radiogenic Isotope Studies</i> , Milestone Report SPC23FM4. Denver, Colorado: U.S. Geological Survey.	No change

PROGRESS REPORT #20

As referenced in:	Current Status
Progress Report 17	
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APPENDIX D

GLOSSARY

GLOSSARY

Many of the definitions in the glossary are YMP-specific.

Air-Permeability Test	Measurement of the degree to which a given material or substance will permit the passage of air.
Alcove	One of several underground excavations made from the main drift or ramps of the ESF as sites for in situ testing of ambient rock characteristics or thermal perturbations of those characteristics.
Altered Zone	Generally, the altered zone is considered to be the regions surrounding the waste emplacement areas that allow temperatures sufficiently high to prevent liquid water from existing in pores and fractures.
Aquifer	A water-bearing layer of permeable rock that is capable of yielding groundwater to supply wells and springs.
Barrier Assessment	The evaluation of the likely effectiveness of various engineered and natural components of the repository system to slow the transport of radionuclides from the waste.
Cross Drift	The west-southwest trending excavation extending from near the base of the north ramp of the ESF through the main trace of the Solitario Canyon fault.
Design Alternative	A design that involves significant changes to the fundamental concepts on which the VA design is based.
Design Feature	Enhancements to design that can be easily incorporated within multiple alternative designs.
Drift	From mining terminology, a horizontal underground passage. The nearly horizontal underground passageways from the ramp(s) to the alcoves and rooms. Includes excavations for emplacement of waste (emplacement drifts) and repository access (access mains).
Drip Shield	A sheet of impermeable material placed above the waste package to prevent seepage water from directly contacting the waste packages.
Enhanced Design Alternative	Combinations of one or more Design Alternatives and Design Features that fit logical principles derived from the objectives for repository design.
Fault Zone	A generally broad area composed of many small, closely spaced rock fractures, which show evidence of movement, or such an area composed of breccia or fault gouge.

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Fluid-Inclusion	A tiny fluid- or gas-filled cavity in a mineral deposit, typically 1 to 100 micrometers in diameter, formed by the entrapment of a fluid, typically that from which the mineral crystallized.
Geologic Framework Model	The geometric representation of selected rock units and structures around the site. The Geologic Framework Model includes the stratigraphic units between the ground surface and the Tertiary-Paleozoic contact, the potentiometric surface (water table), and depictions of major structural features.
Integrated Site Model 3.1 (ISM)	The geometric representation of selected rock units and structures provided by the Geologic Framework Model plus a set of rock properties and mineralogy models and data sets.
Near-Field Environment	The zone of environmental conditions that directly impacts the waste package container materials and the waste form.
Niche	A relatively shallow excavation in the side of the ESF or cross drift where scientific experiments are conducted.
Quality Assurance	All those planned and systematic actions necessary to provide adequate confidence that the geologic repository and its subsystems or components will perform satisfactorily in service.
Saturated Zone	The subsurface zone below the water table in which all interstices are filled with water at a pressure greater than the pressure of the atmosphere.
Unsaturated Zone	The area below the ground surface and above the water table in which the interstices are filled with water at a pressure less than the pressure of the atmosphere, and air at atmospheric pressure.
Vitric	Describing any glassy, pyroclastic material containing at least 75 percent glass.
Waste Form	A generic term that refers to radioactive materials and any encapsulating or stabilizing matrix.