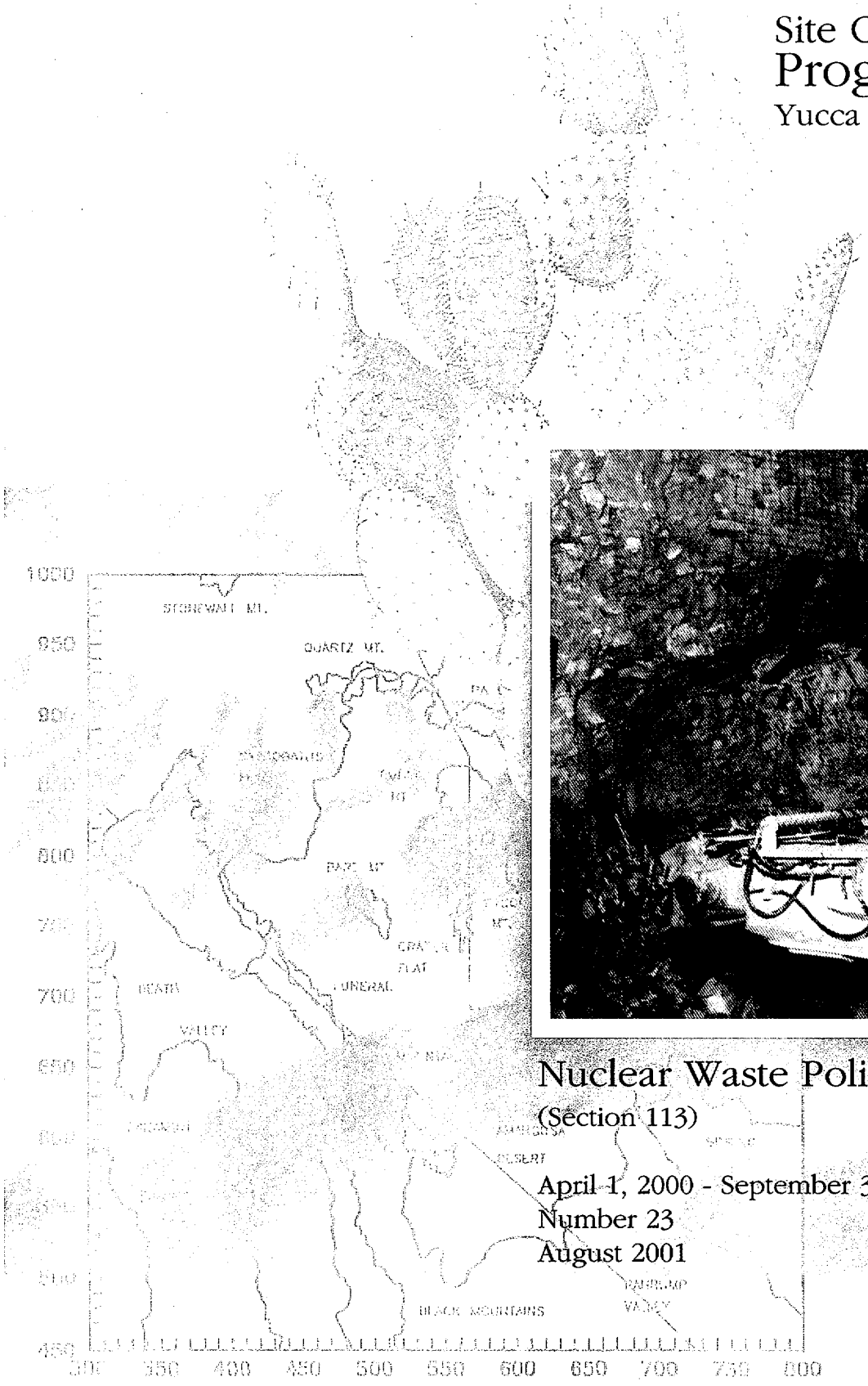
DOE/RW-0545

Site Characterization Progress Report

Yucca Mountain, Nevada



Nuclear Waste Policy Act

(Section 113)

April 1, 2000 - September 30, 2000

Number 23

August 2001

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

NOTE INSIDE FRONT COVER

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 to be produced. Title 10 of the Code of Federal Regulations, Part 60 (10 CFR 60.18(g)), 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 23rd 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 April 1, 2000, through September 30, 2000. 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. A glossary of Yucca Mountain Site Characterization Project-specific terms used in this report is given in Appendix C.

Documentation of Program Change, last published in April 2000 as Revision 02 (CRWMS M&O 2000a), updates site characterization activities in relation to the 1988 *Site Characterization Plan Yucca Mountain Site, Nevada Research and Development Area, Nevada* (DOE 1988). Beginning with the reporting period of April 1997 through September 1997, the *Documentation of Program Change* was removed as an appendix to the progress report and published separately as reference material on the Yucca Mountain Site Characterization Project's site characterization program. The U.S. Department of Energy plans to revise this document annually.

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ACRONYMS AND SYMBOLS

ACRONYMS

AMR	analysis and model report
CAR	corrective action request
CFR	Code of Federal Regulations
CRWMS	Civilian Radioactive Waste Management System
DBE	design basis event
DOE	U.S. Department of Energy
EBS	engineered barrier system
ECRB	Enhanced Characterization Repository Block
EIS	environmental impact statement
EPA	U.S. Environmental Protection Agency
ESF	Exploratory Studies Facility
EWDP	Early Warning Drilling Program
FEP	feature, event, and process
FR	Federal Register
FY	fiscal year
ICN	Interim Change Notice
ISM	Integrated Safety Management
IRSR	issue resolution status report
ISA	integrated safety analysis
KTI	key technical issue
LA	license application
M&O	Management and Operating Contractor
MGR	monitored geologic repository
NRC	U.S. Nuclear Regulatory Commission
NWPA	Nuclear Waste Policy Act of 1982
PMR	process model report
QA	quality assurance
SR	site recommendation
SRR	site recommendation report
SSC	structure, system, and component
SZ	saturated zone
TSLCC	total system life cycle cost
TSPA	total system performance assessment

UNLV	University of Nevada, Las Vegas
USGS	U.S. Geological Survey
UZ	unsaturated zone
YMP	Yucca Mountain Site Characterization Project

SYMBOLS

PTn	Paintbrush Tuff nonwelded hydrogeologic unit
TCw	Tiva Canyon welded
TSw	Topopah Spring welded lower lithophysal unit

SECTION 1 – EXECUTIVE SUMMARY

The 23rd semiannual report of the Yucca Mountain Site Characterization Project summarizes activities from April 1, 2000, through September 30, 2000. These activities are focused on evaluating the suitability of Yucca Mountain, Nevada, as a site for permanent geologic disposal of nuclear materials, as directed by the Nuclear Waste Policy Act of 1982, as amended (NWPA). Site characterization, and the semiannual reports describing it, will end when the Secretary of Energy decides whether to recommend the Yucca Mountain site for development of a geologic repository.

This progress report documents the Project activities that contributed to completing the near-term programmatic and statutory objectives. These objectives, which are to be completed in the next several years, include:

- Completing the environmental impact statement (EIS)
- Developing a possible U.S. Department of Energy (DOE) Secretarial site recommendation (SR) to the President
- Submitting a license application (LA) to the U.S. Nuclear Regulatory Commission (NRC) if the President recommends the site to Congress, and the President's recommendation is approved.

Science and engineering work is focused on developing the technical basis for a decision on SR. Project work is concentrated on three integrated activities: site characterization, design and construction, and repository performance. Accomplishments during this period and their relationship to near-term objectives are summarized briefly in following sections. The near-term objectives and the three integrated activities are presented in more detail in Sections 2-6.

1.1 PROGRESS TOWARD NEAR-TERM OBJECTIVES

The public comment period on the *Draft Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (DOE 1999) (draft EIS) ended in February 2000. Before the final EIS is issued, the technical analyses supporting the document will be updated, as appropriate, to reflect ongoing progress of site studies and resolve public comments received on the draft document.

Work also continued during this reporting period on those technical activities considered necessary to support a possible SR. This additional technical information will be considered in development of the site recommendation report (SRR), which will provide the technical basis for the Secretary's decision. The final EIS, which DOE will publish separately, will accompany the SRR.

While concentrating on the SR, the Project also continued to meet with the NRC. These interactions help to gain assurance that the technical work planned and completed to date is consistent with NRC expectations for submittal of a high-quality LA, if the Yucca Mountain site is designated by the President. Interactions with the NRC continued to focus on the nine NRC key technical issues (KTIs) and the associated NRC issue resolution status reports (IRSRs). The NRC identified the KTIs as the topics the NRC considers most important to postclosure performance of a potential repository at the Yucca Mountain site.

Revision 4 of the *Repository Safety Strategy: Plan to Prepare the Safety Case to Support Yucca Mountain Site Recommendation and Licensing Considerations* (CRWMS M&O 2000c) was issued as a Management and Operating Contractor (M&O) document in October 2000. This revision reflects project

developments and information learned since previous revisions, including the latest performance assessment results based on the design for SR. The principal factors, which determine whether the postclosure performance objective will be met, have been expanded to include igneous activity scenarios. This revision also includes a discussion of preclosure activities and strategies that had not been previously addressed. Revision 4 is based on the work supporting SR and workshops conducted from February through June 2000. The process model report (PMR) development process continued. Various analysis and model reports (AMRs) have been summarized in the nine PMRs, which are synthesis reports that reference supporting analyses and modeling documentation, documents developed outside the Project, and other key documents (e.g., topical reports and other PMRs). The PMRs bring together the technical basis information for various total system performance assessment (TSPA) process models. The detailed technical information is contained in the supporting AMRs.

It was verified in September 2000 that DOE had successfully implemented the Guiding Principles and Core Functions described in the Integrated Safety Management (ISM) description document.

The five crosscutting, programmatic, quality assurance (QA) deficiencies identified in 1998 as corrective action requests (CARs) have been resolved and closed. The original CARs documented deficiencies in data traceability, data qualification, procurements, software qualification, and modeling. An additional CAR issued to cite a lack of timely implementation of corrective action related to deficiencies in software qualification has also been closed.

1.2 SITE CHARACTERIZATION

Site-related work focused on completing PMRs and supporting AMRs for the SR and a potential LA. Revision 1 of the *Integrated Site Model Process Model Report* (CRWMS M&O 2000d) was prepared during the reporting period to address regulatory comments and reflect new information regarding the geologic framework model and rock properties. The *Yucca Mountain Site Description* was revised (CRMWS M&O 2000e) to include new site characterization results through about the end of 1999 and to summarize current understanding of the natural system at the site.

1.2.1 Geological Field Investigations

Work continued on the development of stratigraphic workbooks that summarize geophysical, stratigraphic, and lithologic information organized by individual borehole. These computer-automated workbooks provide contacts for rock units and discussion of source information integrated across the array of available boreholes. Photography and mapping of excavated openings continued in the Enhanced Characterization Repository Block (ECRB) Cross Drift, including the Crossover Alcove (Alcove #8) and Niche 5 (Figure 3-1). Technical review of Busted Butte mapping was completed, and those maps were submitted for QA review.

1.2.2 Exploratory Studies Facility Testing

The thermal tests validate the conceptual model of thermal-mechanical-hydrological-chemical processes and couplings between these processes, which are expected to result from the heat produced by decaying radioactive waste. In the drift-scale heater test, some of the drift wall temperatures exceeded 200°C during the reporting period. Heater power has been reduced incrementally to maintain wall temperatures at 200°C. Neutron logging, electrical resistivity tomography, ground-penetrating radar measurements, air permeability testing, and water and gas sampling and analyses continued in the drift-scale test to characterize the rock properties in the rock adjacent to the drift-scale test. Preliminary planning for the Cross Drift Thermal Test in the ECRB was completed.

Liquid-release tests are being conducted to determine parameters necessary to estimate seepage into drifts. Eleven liquid-release tests were completed on three test intervals positioned above Niche 4, located in an intensely fractured zone in the southern part of the Exploratory Studies Facility (ESF) Main Drift at Station 4788 (4,788 m from the North Portal) (Figure 3-1). Preliminary analyses indicate that the seepage threshold flux values at Niche 4 range from 3,060 mm to 5,740 mm/year, consistent with the seepage threshold values determined at Niche 2.

The tracer-infiltration experiments in Alcove #1 in the upper Tiva Canyon tuff continued. The seepage data and tracer breakthrough data were used to validate and refine unsaturated zone (UZ) flow and transport models. Matrix diffusion was shown to have a significant effect on transport in unsaturated fractured rock.

Examination and description of fluid inclusions in secondary mineralized calcite continued in parallel with the University of Nevada, Las Vegas (UNLV), thermochronology investigation. The purpose of the fluid-inclusion study is to determine the temperature and age of formation of minute pockets of fluids that were trapped during the deposition of calcite/opal coatings in fractures and cavities in the volcanic tuffs at Yucca Mountain.

Chlorine-36 content provides a basis to identify potential pathways for rapid groundwater flow to the potential repository horizon. A validation study of chlorine-36 results was initiated because of concerns about possible contamination, representativeness of samples, lack of bomb-pulse chlorine-36 in the southern part of the ESF, and difficulties with replicating earlier analyses. Data indicating the presence of bomb-pulse chlorine-36 in the ESF are important because, if validated, they suggest that surface water is reaching the ESF in 50 years or less. During the reporting period, the chlorine-36 validation study continued with evaluation of drill core from the Sundance fault anomaly in the ESF. Results of the chlorine-36 analyses for the Sundance anomaly do not agree with results previously reported. Experiments are underway to resolve the discrepancy between the two data sets. In addition, tritium analyses of water extracted from chlorine-36 validation cores are being performed. Tritium is also a "bomb-pulse" isotope and should be found wherever bomb-pulse chlorine-36 is found. To date, of approximately 38 analyses from the Sundance anomaly, only one exceeds the detection limit for tritium, which would be indicative of post-bomb percolation. The work is continuing, in an effort to resolve the possible influence of different sampling procedures in the different data sets.

1.2.3 Cross Drift Testing

One objective of the testing that comprises the ECRB is to collect information needed to estimate seepage. Niche 5 in the Topopah Spring lower lithophysal unit was excavated at a lower lithophysal site with high cavity density, located near the center of the potential repository block at a distance of 1,620 m from the Cross Drift entrance. Preliminary results from the ongoing tests reveal differences in permeability and capillary strength, which are important parameters for estimating percolation flux and seepage into drifts. The lithophysal cavities may contribute to the approximately two-orders-of-magnitude enhancement in air-permeability values compared to corresponding permeability values measured in niches in the Topopah Spring middle nonlithophysal unit in the ESF.

A fault was detected during excavation of Alcove #8, which is located directly above Niche 3 in the ESF Main Drift. The amount of offset is relatively minor compared to the offset of some other faults in the area. This location was selected for the first seepage test, because faulting is expected to alter the hydrologic parameters within and near the fault zone. Permeability is expected to increase and capillarity should decrease because of increased fracture apertures.

1.2.4 Unsaturated Zone Modeling

An effort is underway to incorporate more realistic processes and parameters into the UZ model so that future predictions of the behavior of the UZ natural barrier will be more realistic. Two important aspects of UZ model refinement are the parameter adjustments being made to (1) realistically assess the contribution of the UZ natural barrier to total performance and (2) determine the magnitude of lateral diversion of percolation occurring in the Paintbrush Tuff nonwelded hydrogeologic unit (PTn).

1.2.5 Busted Butte Test Facility

The UZ transport test is a field study of water and tracer transport in the unsaturated Calico Hills Formation at Busted Butte. Phase II testing initiated in July 1998 at Busted Butte has been extended through October 2000. Phase II is an expanded version of Phase I, scaled-up with respect to size and flow rates, and involves an augmented suite of reactive and nonreactive tracers. The experiment was extended in part because most of the reactive tracers did not break through into existing collection holes. Measurement of hydrologic properties on core samples from Busted Butte was completed.

1.2.6 Nye County Drilling Program

Test results are being evaluated for estimates of transmissivity, hydraulic conductivity, and storativity. The results are also being evaluated for identifying potential hydraulic communication between the tested intervals in the alluvium and the tuff units. Much of the reporting period was spent preparing for and initiating Phase II operations. Significant effort was placed on test design and instrumentation of the Alluvium Testing Complex. Work continued to update stratigraphic interpretations from Nye County drilling and to evaluate the Nye County paleodischarge sites.

1.2.7 Saturated-Zone Flow and Transport Modeling

Improvements to the saturated zone (SZ) flow and transport modeling continued, with effort focused on the Expected Case model for SZ flow and transport. The work focused on reevaluating potentially conservative elements of the groundwater flow field and radionuclide transport parameters.

1.2.8 Seismic Hazards and Design

Geotechnical investigations were initiated to provide additional data supporting development of seismic design inputs and foundation recommendations for the Waste Handling Building. Work on the development of seismic design inputs was suspended pending completion of these investigations.

1.3 DESIGN AND EXPLORATORY STUDY FACILITIES CONSTRUCTION

Design work continued to focus on enhancing repository performance to support a possible SR. In addition, some LA-related work was performed to ensure timely availability of sufficient design development to support submittal of the LA, should the site be found suitable.

The design process has produced a robust design concept that offers operational flexibility by allowing adjustments to be made in the period of ventilation, the amount of fuel staging, and waste package spacing. Although the Project believes it has a reasonable basis for the long-term predictions of repository performance for the current above-boiling design, the performance is being evaluated for a number of lower-temperature operational modes that address the uncertainties related to the above-boiling design.

1.3.1 Repository

The Project continued to develop and refine the documents that establish and form the repository design requirements and support the LA. This effort included revision of 24 system description documents (see Section 4) that define design bases and criteria for many important structures, systems, and components (SSCs).

Design concepts that result in a below-boiling drift wall temperature were developed. Three operational variables were evaluated for their effects on operating the repository at below-boiling temperatures: waste package spacing within the emplacement drifts, surface staging of hot wastes to effectively increase their age, and increasing the duration of the forced ventilation period. Singly and in combination, these variables were demonstrated to allow operating the repository at below-boiling drift-wall temperatures. A design concept for a below-boiling point repository using natural ventilation that offsets the cost of a forced ventilated repository was also evaluated.

Testing was completed on a quarter-scale model emplacement drift and waste package that was used to determine the effectiveness of emplacement drift backfill and drip shield on preventing infiltration from contacting waste packages.

Testing began on a quarter-scale engineered barrier system (EBS) model ventilation test to predict the efficiency of the emplacement drift ventilation system in removing heat from the waste packages.

1.3.2 Waste Package

The Project completed the waste package degradation and the waste form degradation PMRs. These reports summarize all of the degradation processes for waste package materials and waste forms.

The Project met with the NRC to discuss five subissues related to the NRC KTI pertaining to container lifetime and source term. These subissues pertained to the performance of waste package and waste form materials. The remaining subissue on criticality will be the subject of a separate technical exchange meeting planned for October 2000.

The Project completed the closure weld development program. The program included the basic fabrication of the mock-up and welding of lids. The program also included the welding of Alloy 22, stainless steel 316 NG, and titanium samples.

1.3.3 Exploratory Studies Facility Construction and Operation

The Project is continuing testing that requires continued operation of the ESF and the Busted Butte Facility. Excavation of the Crossover Alcove #8 and Niche 5 in the Cross Drift were completed. These excavations will support testing related to the evaluation of flow and seepage processes in the rocks around the potential repository.

1.4 REPOSITORY PERFORMANCE

Repository performance assessment activities continued to focus on three topics: preclosure radiological safety assessment, postclosure performance assessment, and performance confirmation.

1.4.1 Preclosure Radiological Safety

The *Preliminary Preclosure Safety Assessment for Monitored Geologic Repository Site Recommendation* (CRWMS M&O 2000f) was issued to document the preliminary safety assessment of monitored geologic repository (MGR) operations during the preclosure period.

Revision 4 of the repository safety strategy (CRWMS M&O 2000c) was issued October 2000. Each of the elements of the repository safety case for the preclosure operational period is explained and the safety strategy is presented. These elements include an integrated safety analysis (ISA), margin and defense-in-depth, consequence analysis of beyond-design-basis events (DBEs), commercial nuclear industry precedent and experience, and license specifications and surveillances.

1.4.2 Postclosure Performance Assessment

Significant progress has been made in the area of postclosure performance assessment during this reporting period. The total system model for the Total System Performance Assessment for the Site Recommendation (TSPA-SR) (CRWMS M&O 2000g) was completed. The model uses GoldSim (Golder Associates 2000), a qualified version of the total system simulator (V6.04.007 STN: 100344-6.04.007-00). The base-case model includes two scenario classes: the nominal scenario class (which contains all included features, events, and processes [FEPs] except igneous activity) and the igneous activity scenario class.

Other activities in performance assessment include contributing the TSPA-SR results and analyses necessary for SR and Revision 4 of the repository safety strategy (CRWMS M&O 2000c), finalizing the TSPA FEPs database, and providing performance assessment input to the final EIS on numerous cases specific to the final EIS (e.g., alternative receptor distances and alternative waste inventories).

1.4.3 Performance Confirmation

The performance confirmation program includes activities conducted to collect and analyze data to ensure that conditions encountered, and changes in those conditions, are within the limits to be stated in the LA. The program, which began during site characterization and continues until permanent closure, will determine whether the natural systems, engineered systems, and system components function as intended and anticipated.

The *Performance Confirmation Plan* (CRWMS M&O 2000h) was updated. This revised plan provides a basis for out-year planning, support for the SRR and support for the total system life cycle cost estimate.

The *Monitored Geologic Repository Test & Evaluation Plan* (CRWMS M&O 2000i) was revised. This plan defines an integrated test program that identifies the tests necessary to satisfy regulatory requirements and successfully construct an MGR. Performance Confirmation is a subset of the Test and Evaluation Plan.

A total system life cycle cost estimate for all testing and performance confirmation activities was completed and submitted to the DOE for review (CRWMS M&O 2000j).

SECTION 2 – PROGRESS TOWARD NEAR-TERM OBJECTIVES

During this reporting period, Project activities continued to support major near-term objectives of the final EIS and SR prescribed in the NWPA. The public comment period on the draft EIS, Volumes I and II (DOE 1999), was completed in February 2000. Before the final EIS is issued, the technical analyses supporting the document will be updated, as appropriate, to reflect the ongoing progress of site studies and to resolve public comments received on the draft document. This activity will be integrated with Project work in site testing, design, performance assessment, and preparation of the SRR and the LA.

Work also continued during this reporting period on those technical activities considered necessary to support a possible SR . The NWPA specifies a process for the recommendation and approval of a site for development of a repository, and it requires that the Secretary of Energy provide a comprehensive statement of the basis for recommendation if the site is recommended. Before deciding whether to recommend to the President that the site be approved for development of a repository, the Secretary of Energy will consider the information presented in the SRR and the final EIS; comments received pursuant to Section 114 of the NWPA; preliminary comments on sufficiency from the NRC; and any other information deemed appropriate. Any recommendation and a comprehensive statement of the basis for the recommendation would then be submitted to the President, as required by the NWPA.

Revision 4 of the repository safety strategy (CRWMS M&O 2000c) was issued as an M&O document October 2000. This revision reflects project developments and information learned since previous revisions. It also includes a discussion of preclosure activities and strategies that were not addressed earlier. Revision 4 is based on the work supporting SR and workshops conducted from February through June 2000. This revision has few significant changes, reflecting convergence in the strategy.

The PMR development process continued. The various AMRs have been summarized in the nine PMRs, which are synthesis reports that reference supporting analyses and modeling documentation, documents developed outside the Project, and other key documents (e.g., topical reports and other PMRs). The PMRs bring together the technical basis information for the various TSPA process models. The detailed technical information is contained in the supporting AMRs.

Each PMR addresses the following aspects related to a model:

- Description of the model and submodels
- Abstraction of the model into TSPA
- Relevant data and data uncertainties
- Assumptions and bases
- Model results (outputs)
- Information on code verification and model validation
- Opposing views
- Information necessary to support regulatory evaluations.

The nine PMRs, which will be updated if significant new information becomes available, describe the following process models:

- Integrated Site Model
- Near-Field Environment
- Waste Package Degradation

- Waste Form Degradation
- UZ Flow And Transport
- Saturated Zone (SZ) Flow And Transport
- Engineered Barrier System
- Biosphere
- Disruptive Events.

2.1 ENVIRONMENTAL IMPACT STATEMENT

The NWPA (Section 114(f)(1)) requires that a final EIS serve as one of the supporting elements for a decision on the SR and that the EIS accompany any Secretarial recommendation to the President. The draft EIS completed in 1999 (DOE 1999) assesses the following:

- Impacts of constructing, operating, monitoring, and eventually closing a geologic repository at Yucca Mountain
- Potential long-term impacts of repository disposal
- Potential impacts of transporting the high-level radioactive waste and spent nuclear fuel nationally and in the State of Nevada
- Potential impacts of not proceeding with the proposed action (construction, operation, and eventual closure of a geologic repository at Yucca Mountain)
- Potential impact of constructing a rail line or intermodal transfer facility in Nevada.

A 199-day public comment period began in September 1999 with issuance of the draft EIS (DOE 1999). Twenty-one hearings were held in the local area and elsewhere around the country. The public comment period closed during this reporting period. DOE is reviewing comments received on the draft EIS. Before the final EIS is issued, the technical analyses supporting the EIS will be updated, as appropriate, to reflect the ongoing progress of the program. Changes also will be made, as appropriate, to respond to public, agency, and Native American tribal comments on the draft EIS (DOE 1999). A comment response document, responding to comments made during the draft EIS comment period, will accompany the final EIS. This activity will be integrated with Project work in site testing, design, performance assessment, and preparation of the SR and LA.

2.2 SITE RECOMMENDATION

The NWPA (42 U.S.C. 10134(a)(1)) requires the Secretary to hold public hearings near the Yucca Mountain site to inform residents of the area of such consideration and to receive their comments about the possible recommendation of the site. The key documents supporting a possible SR include the TSPA-SR technical report, the TSPA-SR model document, the *Yucca Mountain Site Description*, PMRs, AMRs, and the engineering system description documents. These documents will describe the current understanding of the likely performance of natural and engineered systems and will address uncertainties in available information and in analyses of system performance. A long-term monitoring program designed to address the remaining uncertainties also will be discussed.

The SRR will describe the final technical basis for the Secretary's decision. In addition to updated technical information, the SRR will contain the views and comments of the governor and legislature of any affected state and the governing body of any affected Indian tribe, and the response of the Secretary

to these views (NWPA, 42 U.S.C. 10134(a)(1)(F)). The SRR also will include other information that the Secretary considers appropriate (NWPA, 42 U.S.C. 10134(a)(1)(G)) and any impact report submitted under Section 116(c)(2)(B) by the State of Nevada (NWPA, 42 U.S.C. 10134(a)(1)(H)).

Preliminary NRC comments, concerning the extent to which the at-depth site characterization analysis and the waste form proposal for the site seem to be sufficient for inclusion in any LA (NWPA, 42 U.S.C. 10134 (a)(1)(E)) also will be included with the SRR. As required by the NWPA (42 U.S.C. 10134(a)(1)(D)), the final EIS, which DOE will publish separately, will be included with the SRR.

2.3 REGULATORY FRAMEWORK

The Energy Policy Act of 1992 signaled a broad shift from a generic to a site-specific regulatory framework for evaluation and decision-making for a repository at Yucca Mountain. Finalizing this regulatory framework is central to determining the suitability of the Yucca Mountain site for development as a repository that would protect public health and safety and the environment. The NRC proposed a site-specific regulation (10 CFR 63 [64 FR 8640]) on February 22, 1999, and DOE submitted comments on the proposal on June 30, 1999. The U.S. Environmental Protection Agency (EPA) proposed a site-specific regulation (40 CFR 197 [64 FR 46976]) on August 19, 1999, and DOE submitted comments on the proposal on November 26, 1999. The DOE comments emphasized that the technical aspects of the EPA rule should not only protect public health and safety and the environment, but also be a fair test of the safety of a repository and be demonstrable in a rigorous licensing proceeding.

The DOE issued a revised proposal to amend its site suitability guidelines for Yucca Mountain on November 30, 1999 (10 CFR 963 [64 FR 67054]). The proposed regulations would appear as a new 10 CFR 963. DOE modified its 1996 proposal to amend the guidelines in response to public comments and in light of Yucca Mountain site-specific regulations proposed by the NRC and EPA. The proposed guidelines require use of the latest analytical methods to support a site suitability determination. If suitable, this determination will accompany the other information required by the NWPA to be considered by the Secretary as a basis for an SR.

DOE held two public hearings in Nevada on the proposed suitability guidelines on February 2, 2000, in Pahrump; and on February 3, 2000, in Las Vegas. The public comment period was extended until March 20, 2000. A draft final rule was submitted for NRC concurrence on May 4, 2000.

2.3.1 Licensing

Although near-term work will continue to focus on supporting the Secretarial decision of whether to recommend the site, the DOE continues to interact with the NRC to ensure that the Yucca Mountain Site Characterization Project activities are consistent with NRC expectations for submittal of a high-quality repository LA, should the Yucca Mountain site be recommended. On February 22, 1999, the NRC published its proposed licensing criteria specific to Yucca Mountain. The proposed regulations, 10 CFR 63, Disposal of High-Level Radioactive Wastes in a Proposed Geologic Repository at Yucca Mountain, Nevada (64 FR 8640) would significantly change the NRC approach to evaluating repository performance. During this period, the NRC worked to finalize the proposed regulation, which had not been released at the end of this reporting period.

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 NRC would leave in place its existing generic regulations (10 CFR 60), and it would indicate that those regulations neither apply nor may be the subject of litigation in any NRC licensing proceedings for a repository at Yucca Mountain.

The NRC has identified 10 KTIs, topics that the NRC considers most important to evaluating performance of a repository at Yucca Mountain. DOE interactions with the NRC continue to focus on the KTIs and on the nine associated IRSRs that provide a framework for addressing the KTIs.

The DOE and NRC conducted public meetings on various important subjects including the approach to addressing open KTI issues, the level of design detail/ISA approach, TSPA methods and assumptions, UZ flow, igneous activity, and container life and source term. Three meetings were related to resolution of KTIs. These meetings provided appropriate forums for discussion of technical issues that will need to be resolved before licensing. In general, DOE and NRC participants assessed the meetings as beneficial. Substantial amounts of documentation were provided to the NRC in support of these and future meetings. This documentation included 7 PMRs and 120 AMRs. Each technical exchange meeting on the NRC KTIs has resulted in identifying those subissues that can be considered closed or identifying a set of agreement items necessary to conclude that a subissue can be considered "closed-pending" upon completion of those agreement items.

In addition to six technical exchanges, two quarterly QA/management meetings were conducted during this reporting period. 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 Project and to gain understanding of external issues and concerns.

In the prior period, a new revision to the DOE *Technical Guidance Document for License Application Preparation* (YMP 1999) was finalized. Revision 1 incorporated the requirements from proposed 10 CFR 63 (64 FR 8640) specifying format, content, and acceptance criteria for the LA. Additional work is contemplated to reconcile possible differences in the final regulations and the NRC Yucca Mountain review plan.

The DOE is taking an active role in implementing the Licensing Support Network Rule (10 CFR 2, Subpart J). The DOE comments regarding the NRC Proposed Rulemaking on 10 CFR 2, Subpart J, were provided to the NRC on October 6, 2000. In addition, DOE comments regarding the Licensing Support Network basic design standards, authority of the Administrator, and timing of participant compliance certifications (which had been developed over the summer) were provided to the NRC on that date. Work is now focusing on overall Project implementation strategy and plans for development of the electronic system and procedures to ensure compliance with the final rule.

2.4 REPOSITORY SAFETY STRATEGY

A key issue for the SR and NRC licensing decisions for a high-level waste repository at Yucca Mountain is the ability of the site to protect the public from any undue risk during operations and after permanent closure. The DOE is preparing preclosure and postclosure safety cases for the potential repository system. The repository safety strategy (CRWMS M&O 2000c) has been updated since the previous progress report. This update, Revision 4, was issued as an M&O document in October 2000, and provides information on the status of activities performed to support the defensibility and credibility of the safety cases. It also identifies a strategy for preparing an LA if Yucca Mountain is designated by the President.

2.4.1 Preclosure Safety Strategy

In Revision 4 of the repository safety strategy (CRWMS M&O 2000c), the following five elements of the repository safety case for the preclosure operational period are explained and the safety strategy is presented:

- ISA
- Margin and defense-in-depth
- Consequence analysis of beyond-DBEs
- Commercial Nuclear Industry precedent and experience
- License specifications and surveillances.

The central preclosure safety strategy is to design, construct, and operate SSCs that are important to safety to survive credible internal events, external events, and natural phenomena in such a manner that the design basis event dose limits are not exceeded. The safety strategy will be to design and operate SSCs important to safety to prevent adverse events and conditions, if practical, while at the same time applying mitigation measures, if required, to ensure compliance with the dose limits. The strategy for the preclosure operational period maximizes the use of proven commercial nuclear industry technology and concepts for safely handling radioactive wastes, and it takes advantage of commercial power industry licensing precedents. Proposed 10 CFR 63 (64 FR 8640) requires that compliance with the NRC repository preclosure performance objectives for the Yucca Mountain repository be demonstrated by means of an ISA. The purpose of the ISA is to ensure that all relevant hazards have been evaluated and that preventive and/or mitigative features are included in the repository design such that the proposed 10 CFR 63 limits on radiation exposures are not exceeded. The ISA provides a framework for risk-informed, performance-based decision making that is applied to identification of SSCs important to safety, measures for providing defense-in-depth, license specifications, and surveillance intervals. Preliminary analyses based on the design of the repository surface and underground facilities show large margins between expected performance and the regulatory limits.

2.4.2 Postclosure Safety Strategy

Revision 4 of the repository safety strategy (CRWMS M&O 2000c) contains few significant changes from the postclosure safety strategy discussed in Revision 3, suggesting convergence in the strategy. Revision 4 addresses postclosure performance of the repository system, the principal factors of postclosure safety, the postclosure safety case for SR considerations, and the plans to complete the postclosure safety case for a potential LA.

Postclosure Performance

Revision 4 of the repository safety strategy (CRWMS M&O 2000c) emphasizes the attributes of the postclosure system that would determine its capability to isolate waste. Yucca Mountain provides physically and chemically stable rock well below the surface. Consequently, current analyses indicate that waste can be emplaced deep underground and isolated from the surface. In the environments underground, temperature, humidity, and chemistry change slowly and current calculations indicate waste packages and drip shields maintain their integrity for tens of thousands of years. The waste packages alone are predicted to prevent any release of radionuclides for more than 10,000 years. The drip shield and drift invert provide additional barriers to limit release of radionuclides even if waste packages were to fail prematurely.

A repository system at the Yucca Mountain site, however, would provide more than stable environments for the engineered barriers. It would include multiple natural and engineered barriers that could provide safety margin and defense-in-depth. The site is arid, and analyses indicate the combination of processes at the surface and characteristics of the mountain limit the amount of seepage that can enter the emplacement drifts. Chemical conditions limit the concentrations of radionuclides in the water, and analyses indicate that the combination of low seepage and these concentration limits constrains the amount of radionuclides that can be released from the engineered barriers, even if they are breached.

The repository system also includes barriers to radionuclide migration away from the repository. The UZ at this site is sufficiently thick that waste can be emplaced more than 200 m below the surface and more than 100 m above the water table. In addition, the site is located more than 20 km from populated areas. Most radionuclides are immobile in the rock at Yucca Mountain and cannot migrate through this rock to populated areas. Current analyses indicate that the combination of the limited ability of radionuclides to be mobilized in the EBS and the delay of radionuclides that travel away from the system limits the possible mean annual dose to levels not significantly greater than those from natural background radiation. Thus, the multiple natural and engineered barriers would provide defense-in-depth, and they combine to restrict mean annual dose below the radiological exposure limit for more than 80,000 years.

Yucca Mountain is geologically stable and has changed little in the last several million years. The probability of events that could disrupt the repository is low. The probability of igneous activity in the next 10,000 years is less than one chance in 1,000 and analyses of this activity show that the mean annual dose arising from such an event is low. Analyses to assess the robustness of the system with respect to inadvertent human intrusion show that the quantity of radionuclides that could be mobilized would be small and that the amounts that could reach populated areas are even smaller.

Principal Factors of the Current Postclosure Safety Case

The principal factors, those factors that determine whether the postclosure performance objective would be met, are shown in Table 2-1. These principal factors are expressed in the context of waste isolation attributes of a potential repository system at Yucca Mountain.

Current Postclosure Safety Case

The postclosure safety case for the SR considerations continues to focus on the following elements:

- Performance assessment
- Safety margin and defense-in-depth
- Explicit consideration of potentially disruptive processes and events
- Insights from natural analogs
- Performance confirmation.

Performance assessment provides quantitative estimates of expected annual dose for comparison with the radiological exposure limit of the postclosure performance objective. The combination of principal factors described above results in mean annual doses that are calculated to meet the radiological exposure limit of the postclosure performance objective. In addition, analyses of the potentially disruptive events show that mean annual doses would be less than 1 percent of the limit. These analyses indicate the combination of all principal factors results in sufficient isolation of the waste; the postclosure performance objective is expected to be met by a wide margin.

Table 2-1. Principal Factors of the Postclosure Safety Case

Waste Isolation Attributes	Principal Factors
Limited water entering emplacement drifts	Seepage into emplacement drifts
Long-lived waste package and drip shield	Performance of the drip shield/drift invert system
	Performance of the waste package
Limited release of radionuclides from the engineered barriers	Radionuclide concentration limits in water
Delay and dilution of radionuclide concentrations provided by the natural barriers	Radionuclide delay through the UZ
	Radionuclide delay through the SZ
Low mean annual dose even considering potentially disruptive events	Probability of igneous activity
	Repository response to igneous (damage to waste packages and drip shields)
	Additional factors that also apply to the nominal scenario Seepage into emplacement drifts • Radionuclide concentration limits in water • Radionuclide delay through the UZ • Radionuclide delay through the SZ

Safety margin means the system would be designed to perform better than regulatory requirements. The greater the safety margin, the greater the confidence those requirements will be met. Defense-in-depth means utilization of multiple natural and engineered barriers to ensure that system performance does not rely unduly on any single barrier. The current analyses indicate substantial safety margin and adequate defense-in-depth.

Explicit consideration of potentially disruptive processes and events means that these processes and events will be addressed quantitatively and qualitatively. Potentially disruptive processes or events with a probability of occurrence in the next 10,000 years of at least one chance in 10,000 are incorporated in the quantitative performance assessment. The current analyses show the risk associated with potential igneous activity and inadvertent human intrusion is well below the proposed radiological exposure limit. The analyses also show that the probability for significant effects from other potentially disruptive processes or events is less than one chance in 10,000 in 10,000 years.

Insights from natural analogs refer to data from other sites that bear on long-term performance of a repository system at the Yucca Mountain site. In particular, the postclosure safety case includes information that can be obtained from natural analogs and used to evaluate long-term (e.g., millennia) or large-scale (e.g., kilometers) behavior that is not possible to replicate in laboratory and field studies. The current postclosure safety case documents 19 natural analogs of processes important to the postclosure performance of a repository at Yucca Mountain.

Performance confirmation is the program of testing and analyses that began during site characterization and would extend until permanent closure of the repository. This program will determine the degree to which the measurements (and the associated analyses) confirm estimates of system and barrier performance. A preliminary performance confirmation plan has been developed, but the final plan must wait for finalization of the regulations defining the regulatory requirements for performance confirmation.

On September 20, 2000, near the end of the reporting period, the Nuclear Waste Technical Review Board issued a letter to the Director of the DOE Office of Civilian Radioactive Waste Management (Cohon 2000) recommending additional technical work to improve the existing technical basis for a possible SR decision. The Project is developing an augmented plan to include additional activities.

Completing the Postclosure Safety Case for Site Recommendation and Licensing Considerations

The postclosure safety case is nearly complete. A few issues remain but they are understood and the general approach to address them has been identified. The work needed to address these remaining issues is shown in Table 2-2.

Table 2-2. Work Needed to Address Remaining Issues in the Postclosure Safety Case

Element of Postclosure Safety Case	Issues Remaining in the Postclosure Safety Case	Work Needed to Address Remaining Issues
Performance Assessment	Management of uncertainties	Complete the review of treatment of uncertainty and conservatism in TSPA models
	Reliance on waste package performance	Conduct additional testing and analysis of waste package degradation
	Repository-generated heat and coupled effects	Assess coupled effects Refine models and conduct performance assessment to assess both above-boiling and lower-temperature repository designs
Safety Margin and Defense-in-Depth	Role of natural barriers Reliance on waste package performance	Evaluate potential for drip shield/drift invert system to provide increased defense-in-depth Evaluate other process models to determine potential for increased margin and defense-in-depth • Seepage • Emplacement drift environments • In-package transport and transport away from waste package • Drift shadow • Unsaturated and saturated zone transport
Potentially Disruptive Events	Potential for igneous activity at Yucca Mountain	Provide conditional results for igneous activity groundwater release scenario
Natural Analogues	Management of uncertainties	Evaluate value of studies of natural analogues after license application
Performance Confirmation	Performance confirmation program	Complete Performance Confirmation Plan for a License Application

2.5 INTEGRATED SAFETY MANAGEMENT

An ISM Verification Team conducted the external DOE assessment in two phases. The first phase, which began in July 2000, concluded with approval of the ISM description document. The second phase of the verification was successfully completed in September 2000. The ISM Verification Team concluded that the DOE had successfully implemented ISM consistent with the Core Functions and Guiding Principles in the ISM description document. This enabled the DOE Office of Civilian Radioactive Waste Management to successfully meet the DOE Secretarial mandate that all DOE facilities complete ISM verification before September 30, 2000.

2.6 QUALITY ASSURANCE

The five crosscutting programmatic QA deficiencies identified in 1998 CARs have been resolved and closed. In addition, a CAR issued to cite a lack of timely implementation of corrective action related to deficiencies in software qualification has been closed.

The original CARs documented deficiencies in data traceability, data qualification, procurements, software qualification, and modeling. With the resolution of these programmatic QA issues, the substantial project resources diverted to that effort have now been redirected toward completion of the SRR and its supporting documents. Although minor QA deficiencies continue to be reported in the software and model validation areas, these conditions are expected to be identified by a rigorous QA audit and surveillance program during the ongoing refinement of corrective action implementation and are not expected to impact program progress.

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SECTION 3 – SITE CHARACTERIZATION

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

3.1 GEOLOGIC INVESTIGATIONS

3.1.1 Integrated Site Model

Preparation of Revision 1 of the Integrated Site Model PMR was initiated to address regulatory comments about Revision 0 Interim Change Notice (ICN) 1 (CRWMS M&O 2000d) and to reflect new information from the revised Geologic Framework Model AMR (CRWMS M&O 2000k) and Rock Properties AMR (CRWMS M&O 2000l). Four data qualification reports (CRWMS M&O 2000m–2000p), developed in support of this PMR, have been completed. The plan to qualify the mineralogical data (CRWMS M&O 2000q) was completed and implementation began during the reporting period.

3.1.2 Site Description

A revision of the *Yucca Mountain Site Description* was completed (CRWMS M&O 2000e). The revision includes new site characterization results until the end of 1999. The revision summarizes current understanding of the natural system at the site. It also provides information on the geography and demography of the site, nearby facilities that may be relevant to safety analyses, and integrated effects of thermal loading on the natural system that provides added confidence to understanding of site processes. The document was reorganized to improve the presentation of information. Information on disruptive tectonic events was highlighted independently of the section on the geologic framework. In addition, a section on natural analogs was added. The information in the *Yucca Mountain Site Description* forms the basis for many of the descriptions of site characteristics in Volume 2 of *the Site Recommendation Consideration Report* (CRWMS M&O 2000b).

3.1.3 Natural Analogs

A literature survey of natural analogs with potential applicability to natural and engineered barrier systems of the potential Yucca Mountain repository was prepared as Section 13 of Revision 1 of the *Yucca Mountain Site Description* (CRWMS M&O 2000e). The topics reviewed included engineered barrier materials, seepage, flow, and radionuclide transport in unsaturated and saturated media, and waste form analogs.

A report (Stuckless 2000) that describes some archaeological analogs for assessing the long-term performance of a mined geologic repository for high-level radioactive waste was published. The report indicates that evidence collected from archaeological analogs—including Paleolithic to Neolithic paintings and biological remains preserved in caves and rock shelters and artifacts and paintings preserved in manmade underground openings—shows that flow around openings in the UZ is a long-term feature and one that can be observed in a variety of climates. The evidence indicates that periodic seepage into the underground openings was minimal and not sufficient to destroy the artifacts. Further interpretations indicate that in the UZ, the mere presence of an opening creates a capillary barrier to seepage into the opening. The presence of such a capillary barrier could be important in limiting seepage into the potential repository and to postclosure performance. Results of natural analog studies will be reported in updated AMRs.

Work in natural analogs continued with the following activities:

- Studies at Peña Blanca, where water samples were analyzed for uranium-series and stable isotopes. Results will be used to test models of radionuclide transport in the UZ at Yucca Mountain.

- A study of paleohydrothermal reactions at Paiute Ridge, Nevada Test Site, for confidence-building in models of thermal-hydrological-chemical reactions, with petrographic studies of mineral alteration begun in this reporting period.

- A study of permeability changes induced by thermal-hydrologic-chemical alteration in selected portions of tuff cores from the Yellowstone geothermal field that have temperature and pressure histories similar to those anticipated in the current design for a Yucca Mountain repository. Resulting data will be used in models of thermal-hydrological-chemical reactions to compare to outcome of predictions from ESF heater tests.

- Modeling studies of radionuclide transport at the Radioactive Waste Management Complex of the Idaho National Engineering and Environmental Laboratory as an anthropogenic analog of transport in the UZ and SZ at Yucca Mountain.

3.1.4 Geologic Field Investigations

Work continued on the development of stratigraphic workbooks that summarize geophysical, stratigraphic, and lithologic information organized by individual borehole. These computer-automated workbooks provide contacts for rock units and discussion of source information integrated across the array of available boreholes. To date, 42 workbooks have been completed and submitted to the Project Technical Data Management System:

- Four a-series holes (a#1, a#4, a#5, and a#6)
- UE-25 b#1 and UE-25 p#1
- Four geologic holes (G-1, G-2, G-3, and G-4)
- Two volcanic/hydrologic holes (VH-1 and VH-2)
- Three hydrologic holes (H-3, H-5, and H-6)
- Five water-table holes (WT-7, WT-11, WT#14, WT#17, and WT-24)
- Three unsaturated-zone holes (UZ-1, UZ-6, UZ-14)
- Four north-ramp geologic holes (NRG#1, NRG#3, NRG-6, and NRG-7a)
- Three systematic-drilling holes (SD-6, SD-9, and SD-12)
- Twelve neutron holes.

NOTE: Sixteen of the compilations were submitted to the Technical Data Management System before this reporting period, and the remaining 26 will be available by the time Progress Report 23 is issued.

The workbooks are able to be archived and a convenient and accessible means of preserving detailed lithostratigraphic data and interpretations in consistent, "user-friendly" media, so that future analysts will not have to recreate the data-reduction work of the original investigators.

Field mapping of excavated openings in the ECRB Cross Drift, including the Crossover Alcove (Alcove #8) and Niche #5 (Figure 3-1), has been completed. Structural mapping of Alcove #8 is needed to support the drift-seepage tests to be conducted between Alcove #8 and Niche #3 in the ESF Main Drift

below (see Section 3.3.2). Structural mapping of Niche #5 is needed to support the drift-seepage tests to be conducted in the Topopah Spring welded (TSw) lower lithophysal unit. The TSw lower lithophysal unit had not been tested previously, because it was not penetrated by an ESF excavation until the Cross Drift was excavated. The bulk of the repository drifts would be located in the TSw lower lithophysal unit. Mapping data will be technically reviewed before submittal to the Project database.

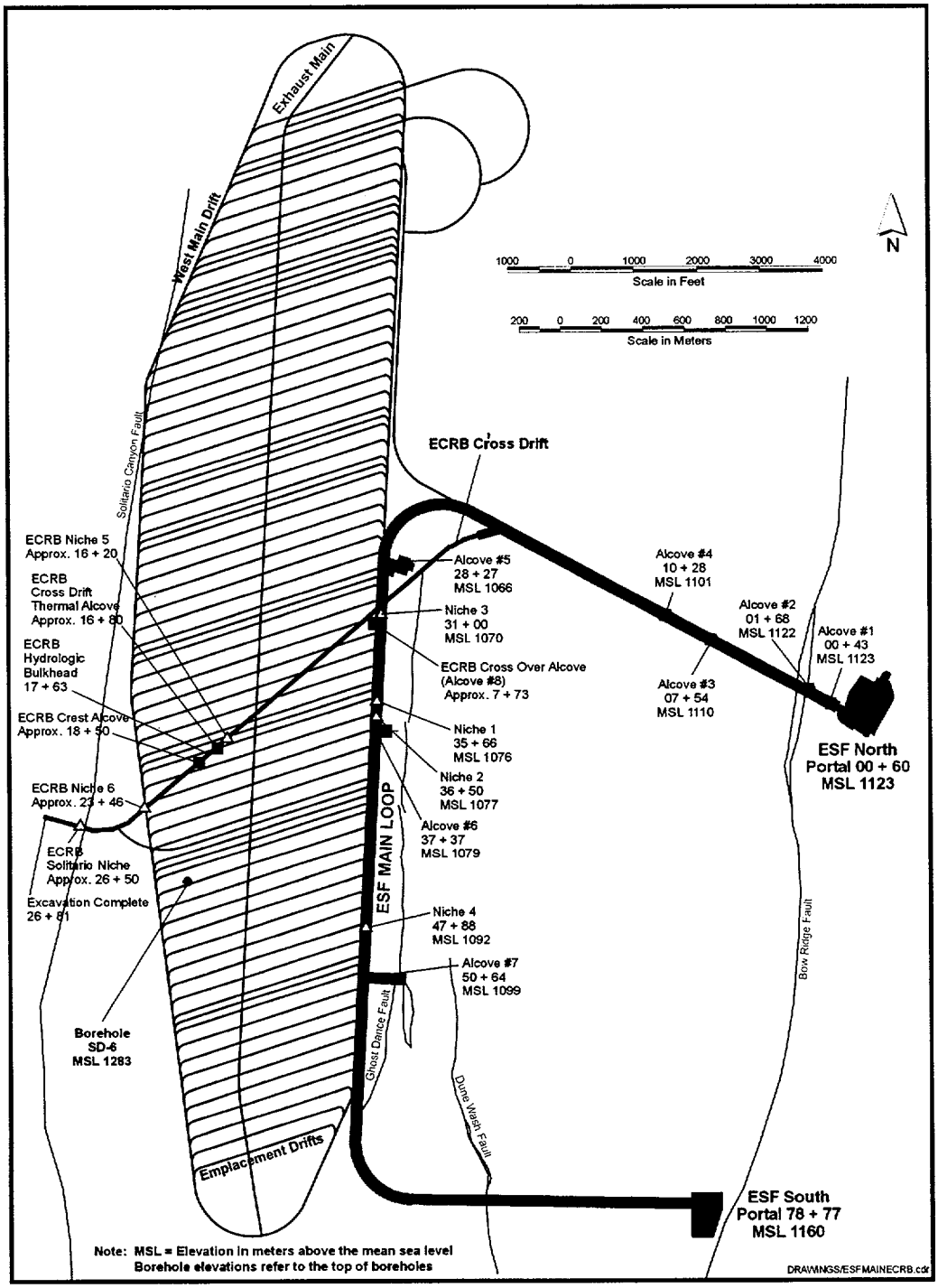

Figure 3-1. Exploratory Studies Facility, Showing Main Loop and Enhanced Characterization of the Repository Block Cross Drift

Technical review of Busted Butte mapping was completed and those maps were submitted for QA review. Additional effort went to support AMR and PMR issues, including data-management work on review and verification of data packages in preparation for submittal to the Project database. These data packages included rock-mechanics data from the North Ramp and the Main Drift, as well as on the small-scale fracture data and detailed line-survey data from the ECRB Cross Drift. The rock-mechanics data for the North Ramp and the Main Drift support repository design and the UZ PMR, and the small-scale fracture data and detailed line-survey data support development of drift-seepage models.

In support of the waste-handling-building design effort, the underground mapping team developed a template for borehole logs and compiled data from borehole RF-13 into that new format. The new format records the seismic velocities right on the borehole log. Staff began compilation of data and construction of surface profiles in order to generate generalized geologic cross sections. Development of plan-view borehole and trench-location maps continued. In addition, multiple sand-cone density tests were conducted in test pits, as were ring-density tests. Field logging of four boreholes was completed and logging continued in two boreholes. The holes were drilled to provide additional supporting data for development of seismic design inputs and foundation recommendations for the Waste Handling Building. (see Section 3.6.3). The drilling revealed that the nonwelded tuffs at the north end of the ESF North Portal pad are much thicker (~300 feet) than expected (~100 feet).

3.2 ALTERED-ZONE AND NEAR-FIELD ENVIRONMENT

3.2.1 Near-Field Environment

The *Near Field Environment Process Model Report* Revision 00 ICN 01 (CRWMS M&O 2000r) was completed. A second ICN of the PMR is in preparation to incorporate review comments. The four supporting AMRs (*Thermal Tests Thermal-Hydrological Analysis/Model Report* [CRWMS M&O 2000s], *Drift-Scale Coupled Processes (DST and THC Seepage) Models* [CRWMS M&O 2000t], *Abstraction of Drift-Scale Coupled Processes* [CRWMS M&O 2000u], *and Features, Events, and Processes in Thermal Hydrology and Coupled Processes* [CRWMS M&O 2000v], and a calculation report, *Calculation of Permeability Change Due to Coupled Thermal-Hydrological-Mechanical Effects* (CRWMS M&O 2000w), also were completed. Revisions and/or ICNs are being developed to incorporate new or recently qualified data and modeling results and to address review comments on the earlier revisions.

3.2.2 Thermal Tests

Large-scale, field thermal tests are integral parts of the program to characterize Yucca Mountain. The thermal tests validate the conceptual model of thermal, mechanical, hydrological, and chemical processes and couplings between these processes, which are expected to result from the heat produced by decaying radioactive waste.

At the time when the Drift Scale Test was planned, the repository design called for temperatures at the drift wall to not exceed 200°C, and the test continues to observe that limit. During the reporting period, temperature readings from some of the sensors on the drift wall in the Drift Scale Test exceeded 200°C. Therefore, heater power was reduced on May 4, 2000, and August 15, 2000, in addition to the reduction implemented on March 2, 2000, to maintain wall temperatures at 200°C. The reduction brought the total heater power down to approximately 85 percent of that at the start of heating on December 3, 1997. The drift wall temperatures continue to be monitored closely.

Thermohydrological simulations of the Single Heater Test, the Drift Scale Test, and the Large Block Test employing the dual permeability, active fracture model were completed for *the Thermal Tests*

Thermal-Hydrological Analyses/Model Report (CRWMS M&O 2000s). This AMR was completed in April 2000. Neutron logging, electrical resistivity tomography and ground penetrating radar measurements, air-permeability testing, and water and gas sampling and analyses continued in the Drift Scale Test. Recent measurements and collected data were presented and discussed in the thermal test workshop in Livermore, California, in May 2000.

Preliminary planning for the Cross Drift thermal test in the ECRB was completed, and the results were documented in the *Cross Drift Thermal Test Planning Report* (Younker 2000) completed in August 2000. This report describes the objectives of the test, location (see Figure 3-1, ECRB Cross Drift Thermal Alcove at Station 16 + 80) and layout of the test, test configuration, positions of the heater and instrument holes, measurements to be made, and the schedule outlining the duration of the test and associated activities. Thermal testing will support validation of the conceptual model of thermal-mechanical-hydrological-chemical processes and the coupling of these processes expected to result from the decay heat produced by the radioactive waste.

3.3 SITE UNSATURATED ZONE FLOW AND TRANSPORT

3.3.1 Exploratory Studies Facility Alcove and Niche Studies

Liquid-release tests are being conducted to determine parameters needed to estimate seepage into drifts. Eleven liquid-release tests were completed on three test intervals positioned above Niche 4, located in an intensely fractured zone in the southern part of the ESF Main Drift at Station 4788 (4788 m from the North Portal) (Figure 3-1). The tests were conducted with the bulkhead door at the entrance to the niche closed and sealed. The air space within the niche was artificially humidified to minimize the effects of evaporation resulting from tunnel ventilation. The Niche 4 seepage tests were conducted for periods ranging from 1 to 24 days, with each test stopped when the seepage rate into the niche stabilized. The volume of water released (i.e., what the fracture accepts) in the seepage threshold tests at Niche 4 ranged from 9 L to 40 L, which is significantly greater than the 1-L liquid-release volume determined in the Niche 2 tests (reported in Progress Report #22 [DOE 2000b]). By releasing a greater volume of water over a longer period, these tests are less affected by transient conditions. The preliminary analyses indicate that the seepage threshold flux values at Niche 4 range from 3,100 to 5,700 mm/year. Although the water-application phase of the infiltration experiment in the ESF Upper Tiva Canyon Alcove (Alcove #1; Figure 3-1) ended on June 20, water continued to seep into the alcove until July 6, 2000. During the second phase of the experiment, 170,780 gal (646,404 L) of water were applied to the surface above the alcove. At the conclusion of the experiment, 30,909 gal (116,991 L) of water had been collected as seepage into the alcove. Test results indicate that water apparently has been displaced from the fractures and the matrix of the rock, as evidenced by lower concentrations of the tracer in the water collected near the conclusion of the test. The test results indicate that some of the tracer has entered the matrix of the welded tuff, thus delaying the arrival and reducing the concentration of tracer because of matrix diffusion. All of the calibrated equipment used in these tests has been submitted for closing calibrations. A draft outline for the interpretive report describing the Alcove #1 infiltration experiments has been prepared. The seepage and the tracer-breakthrough data are being used to validate and refine unsaturated-zone flow and transport models (CRWMS M&O 2000y, Section 3.11.11.1).

Examination and description of fluid inclusions in secondary mineralized calcite continued in parallel with UNLV thermochronology investigation. The purpose of the fluid-inclusion study is to determine the temperature and age of formation of minute pockets of fluids that were trapped during the deposition of calcite/opal coatings in fractures and cavities in the volcanic tuffs at Yucca Mountain. Essentially, the examination of fluid inclusions determines the temperature at which the calcite was formed, while the ratio of certain uranium isotopes to lead isotopes in opal, which was formed at the same time as the calcite, determines the age of the sample. Opal is used because it contains more uranium than calcite.

To date, 10 samples of the opal that is intercalated with calcite in silica-calcite veinlets in the various subunits of the TCw and TSw exposed in ESF North Ramp and Main Drift have been analyzed by thermal ionization mass spectroscopy. The youngest uranium-lead age is about 1.9 million years old, and the remaining nine range in age from 3.6 million to 9 million years. Information about the ages of formation of the silica-calcite veinlets and their fluid inclusions is essential for understanding their significance with regard to the thermal history of the unsaturated-zone rock mass at Yucca Mountain. The current data indicate that the samples containing the two-phase fluid inclusions are at least several million years old and exhibit no hydrologic implications that would adversely impact the suitability of the site. To date, of the 91 samples examined, 38 contain two-phase (gas and liquid) fluid inclusions potentially suitable for temperature measurements. Project scientists have determined formation temperatures for 16 fluid-inclusion assemblages that consist of 1,401 individual inclusions. Project scientists met June 19–21, 2000, with counterparts from UNLV and the State of Nevada to exchange data and interpretations on their respective fluid inclusion studies. There was general agreement between the Project and UNLV that fluid inclusions exist in the early calcite and that those inclusions formed at temperatures ranging from slightly below 40°C to perhaps 90°C. These temperatures, if valid, are higher than would be expected for secondary mineralization resulting from downward percolation of water from the surface, given that the present-day mean temperature at the potential repository level is about 26° C. However, there is considerable uncertainty associated with the technique used to determine fluid-inclusion formation temperatures and, therefore, these preliminary data should be considered with caution.

Chlorine-36 content provides a basis to identify potential pathways for rapid groundwater flow to the potential repository horizon. A validation study of chlorine-36 results was initiated because of concerns about possible contamination, representativeness of samples, lack of bomb-pulse chlorine-36 in the southern part of the ESF beyond station 45+00, and difficulties with replicating earlier analyses. Results of chlorine-36 investigations to date are summarized in Section 6.6.3 of CRWMS M&O 2000z. Data indicating the presence of bomb-pulse chlorine-36 in the ESF are important because, if validated, they suggest that surface water will reach the ESF in 50 years or less. The validation study consists of resampling and analysis of rocks from the ESF for bomb-pulse isotopes (chlorine-36, technetium-99, and tritium) in Drillhole Wash and Sundance fault zones, where bomb-pulse chlorine-36 had been detected previously.

During the reporting period, the chlorine-36 validation study continued with evaluation of drill core from the Sundance fault anomaly in the ESF. Results of the chlorine-36 analyses for the Sundance anomaly, which were presented at the Nuclear Waste Technical Review Board meeting in Pahrump, Nevada, on May 1, 2000, do not agree with results previously reported. At the urging of the Board, experiments were designed to resolve the discrepancy between the two data sets. Experiment designers concluded that preparation of a homogeneous tuff sample, from which representative splits could be distributed to Lawrence Livermore National Laboratory and Los Alamos National Laboratory for leaching experiments, would be a logical first step in trying to resolve differences between the two data sets. This "standard sample" (material excavated from ECRB Niche #5 in the lower lithophysal unit of the Topopah Spring Tuff) is reference material that can be used to develop an accepted leaching protocol that will allow extraction of the meteoric component of chlorine-36 while minimizing leaching of the rock component. Splits from the standard sample were distributed in July 2000 and are being used by both laboratories to investigate the effect of chloride-extraction techniques on measured chlorine-36 concentrations. Such experiments will involve systematic studies of dependencies on leaching techniques, leaching times, further crushing of the samples, and other possible variables. The results of those studies are relevant to the differences seen in the validation study. Those data also may provide important constraints on the nature of processes affecting the exchange of recharge water with preexisting pore water in the rock. In addition, tritium analyses of water extracted from chlorine-36 validation cores are being performed. Both tritium and chlorine-36 are "bomb-pulse" isotopes; therefore, tritium should be found wherever

bomb-pulse chlorine-36 is found. Thus, the chlorine-36 peer review panel (Cornett et al. 1998, pp. x-xi and 58) recommended that tritium analysis be included in the validation study. To date, of approximately 38 analyses from the Sundance anomaly, only one exceeds the detection limit for tritium, which would be indicative of post-bomb percolation. This work is continuing.

3.3.2 Enhanced Characterization of the Repository Block

One objective of the testing that comprises the Enhanced Characterization of the Repository Block is to collect information needed to estimate seepage. The hydrological studies, hydrological studies with air-injection, and liquid-release tests were extended from four niches along the Main Drift of the ESF to a new niche in the Cross Drift, thus extending from the middle nonlithophysal tuff unit to seepage studies in the lower lithophysal tuff unit. Information about seepage into the lower lithophysal unit is important, because most of the emplacement drifts will be in that unit. Niche 5 (Figure 3-1) was excavated at a lower lithophysal site with high cavity density, located near the center of the potential repository block at a distance of 1,620 m from the Cross Drift entrance. Preliminary results from the on-going tests reveal differences in permeability and capillary strength, which are important parameters for estimating percolation flux and seepage into drifts planned in these potential repository units. The lithophysal cavities may contribute to the approximately two-orders-of-magnitude enhancement in air-permeability values compared to the nonlithophysal niche sites. A nearly symmetric tracer plume shape observed at the new niche indicates that the capillary strength could be an order of magnitude higher in the lower lithophysal unit than in the middle nonlithophysal unit. In addition, the field-measured plume configurations were compared with preliminary modeled distributions. Preliminary assessments of hydrogeological characteristics indicate that the seepage threshold values may be higher in the lower lithophysal unit than in the middle nonlithophysal unit. This difference could result from diversion around the niche associated with higher permeability and retention of water above the niche caused by stronger capillarity. These preliminary assessments will be evaluated by seepage tests to be conducted at the niche sites.

A new systematic hydrological characterization study was initiated in May 2000 to complement the site-specific seepage threshold tests at Niche 5 in the lower lithophysal tuff unit. First seepage data in the lower lithophysal tuff have been collected for inputs to the drift-scale model calibration and verification. The systematic hydrological characterization uses slanted boreholes drilled into the crown of the Cross Drift at an interval of one borehole every 30 m. At selected locations, additional nearly vertical boreholes and horizontal boreholes are drilled. The boreholes are used for the determination of spatial heterogeneity of seepage potential and to measure effective porosity.

The other new excavation at the ECRB Cross Drift is Alcove #8, which is located directly above Niche 3 in the ESF Main Drift. The approximately 20-m thick test block between Alcove #8 and Niche 3 includes the tilted contact between upper lithophysal tuff unit and the middle nonlithophysal unit. A fault was detected during Alcove #8 excavation. The fault, at the rear of Alcove 8, has strike/dip measurements of 6/83 with 0.23m of reverse offset and 0.75m of left lateral offset. The amount of offset is relatively minor compared to the offset of some other faults in the area. This location was selected for the first seepage test, because faulting is expected to alter the hydrologic parameters within and near the fault zone. Permeability is expected to increase, and capillarity is expected to decrease because of increased fracture apertures. Pretest model predictions using site-scale and drift scale parameters were performed and tracer test sequences were designed to determine the effects of matrix diffusion on transport and to determine related hydraulic parameter values. The lateral spreading associated with the contact is predicted to contribute to the spreading of the seepage plume before it enters Niche 3. Sensitivity studies indicate that the wetting front arrival time is most sensitive to fault permeability.

Planning, procurement, equipment testing, and quality assurance work continued for the infiltration experiment that will evaluate seepage from the ECRB Crossover Alcove (Alcove #8; Figure 3-1) into Niche 3. The small-plot infiltration apparatus (a 30-cm-diameter infiltrometer ring) was tested and then placed in Alcove #8 where water applications began on August 9, 2000, with a testing phase that does not use tracers. Niche 3 was instrumented with wetting front detectors in boreholes and automated seepage collection system in the niche and main drift space. Data from the small-plot test will be used for detailed planning for the large-plot test, which will cover an area of 12 m^2. Preparations continued for the large-plot tests including construction of the large-plot box and installation of camera equipment. Laboratory column tests are in progress to determine maximum concentrations appropriate for the Alcove #8 infiltration tests and to estimate breakthrough curves for each tracer. Because of construction delays and interference with the schedule for the current seepage experiment, tracer tests in the Crossover Alcove have been delayed. See Section 3.3.1 for additional information on the ESF and niche studies, and Sections 3.1.3 and 3.1.4 for more information about seepage tests.

Work on fracture-mineral studies continued during the period. Additional subsamples of opal from outermost layers of mineral coatings from the ECRB Cross Drift were prepared for uranium-series dating. Calculated initial 234U/238U activity ratios from subsamples with ages younger than 100,000 years are being used to model the evolution of $^{234}U/^{238}U$ ratios in fracture water that percolates downward through the welded units of the Topopah Spring Tuff. Subsamples of calcite also were collected across individual mineral coatings for chemical analyses. Variations in trace-element abundances are being analyzed to identify systematic changes in the composition of fracture water through time at Yucca Mountain. Once these relationships are developed, chemical microstratigraphy can be used as a proxy for age where dateable material (e.g., opal or chalcedony) is absent. As reported in Section 3.3.1, the fracture-mineral studies are important, because they yield estimates of long-term percolation flux based on the ages and growth rates of secondary minerals precipitated in the UZ.

3.3.3 Unsaturated Zone Modeling

The UZ Flow and Transport Model PMR Revision 00 ICN 02 (CRWMS M&O 2000y) is supported by approximately 24 AMRs, all of which have been accepted. The AMR updates are USGS 2000a and 2000b and as CRWMS M&O 2000t, 2000z, and 2000aa–2000at. Four of these AMRs are being revised to include field data obtained since the first generation of each was completed. The UZ PMR is being similarly revised.

The UZ modeling study continues to incorporate site characterization data for input to the TSPA model. In addition, the level of conservatism embodied in the parameters and processes incorporated in the UZ model documented in the UZ PMR (CRWMS M&O 2000y) was evaluated. In many cases, it was found that assumptions and parameter values were overly conservative. This resulted in an overly conservative assessment of the ability of the UZ natural barrier to reduce radionuclide concentration and delay breakthroughs at the water table. This overly conservative model did not allow for a realistic assessment of the contribution of the UZ natural barrier to total performance. Consequently, an effort is underway to incorporate more realistic processes and parameters into the UZ model so that future predictions of the behavior of the UZ natural barrier will be more realistic. Thus far, adjustments have been made to the UZ model with respect to the following aspects of flow and transport in the UZ:

- Flow in the vitric Calico Hills nonwelded unit
- Perched water models and lateral diversion
- Hydrologic properties of faults in the Calico Hills nonwelded unit
- Transport computational methods
- Flow paths determined from geochemical data.

Results of simulations using less conservative representation of these aspects of flow and transport indicate longer breakthrough times at the water table. More realistic parameters and processes also will be incorporated for the following aspects of flow and transport:

- Spatial distribution of infiltration and seepage
- Effects of drift degradation on drift seepage
- Effects of flow focusing on drift seepage
- Effects of episodic flow on drift seepage
- Gridding methods for the dual-permeability model.

A new AMR is in preparation to document the findings of the realistic case for input to the next revision of the UZ PMR. This new AMR will be completed April 1, 2001.

During the reporting period, the UZ modeling was extended from 10,000 years to 1 million years, based on new inputs of the climate model. The extension of climate prediction to 1 million years was done to encompass a full-glacial climate (which did not occur during the first 10,000 years) as specified by the EPA (40 CFR 197 [64 FR 46976]). Four additional flow fields have been added to incorporate full-glacial climates. The TSPA-SR will be updated with the new UZ flow and transport field inputs to include the peak dose period.

A refined model for the PTn was completed during the reporting period. This model incorporates capillary barrier effects in the PTn. Capillary barriers could develop at the upper and/or lower PTn contacts or within the PTn unit, depending on the contrast in hydraulic properties of fractures and matrix as well as moisture conditions between adjacent layers or subunits. If capillary barriers form along the PTn, significant lateral flow could occur, diverting water to faults or to some distance down dip. In this model, the PTn is represented by (1) six homogeneous hydrogeologic layers, (2) layer interfaces that are represented as piece-wise linear contacts whose continuity is interrupted by a few major faults, and (3) vertical columns of grid blocks having finite width (1-10 m). Sensitivity analyses indicate that several thousand years are needed for 50 percent of the groundwater to travel through the PTn. Capillary barriers within the PTn unit are mainly controlled by contrasts in matrix hydraulic parameters, while fracture properties have a less significant impact on moisture flow. Average net infiltration rates, not detailed spatial distributions, have a larger impact on flow patterns through the PTn. Both numerical and analytical models show that capillary-barrier effects are strongly correlated with surface infiltration rates, with lower infiltration leading to larger lateral flow. As net infiltration rates increase, the system gets wetter and capillary barriers become weaker as a result.

Numerical grid resolution is important for capturing the effects of thin layers on the formation of strong capillary barriers. For large-scale modeling, limitations on vertical grid spacing are more important than on horizontal spacing. No more than 5 m of vertical grid spacing should be used for the upper portion of the PTn unit. In addition, strong capillary barrier effects may exist with the PTn under transient, pulsed infiltration, and the PTn is very effective in damping transient infiltration pulses spatially and temporally in the unfaulted zones. The refined model for the PTn shows that percolation is laterally diverted from the west to the east in a new two-dimensional, cross-sectional model. The lateral diversion will redistribute the percolation and is expected to reduce the net flux through the potential repository horizon.

During the reporting period, the mountain-scale thermal-hydrological model was refined for areas near the drifts to address the dry-out effects above and around the potential emplacement drifts. A model incorporating heterogeneous fracture permeability was compared to a homogeneous model to reaffirm that the channeling associated with rock heterogeneity does not penetrate the dry-out zone. Condensates, like natural seepage, are diverted away from the potential emplacement drifts so that no seepage occurs

during the thermal period, which is expected to result in improved postclosure performance. This study is continuing.

3.3.4 Field-Scale Unsaturated Zone Transport Test at Busted Butte

The UZ transport test is a field study of water and tracer transport in the unsaturated Calico Hills Formation at Busted Butte, 8 km southeast of Yucca Mountain (Figure 3-2). The site for the test was selected to be analogous to the rock underlying the potential repository. In the UZ transport test, water containing tracers has been injected in boreholes, and geophysical techniques and analysis of samples are being used to detect the injected water and tracers. Results of this experiment are being used to test models. Phase II of the UZ transport test at Busted Butte Test Facility, originally scheduled for injection termination on January 31, 2000, was extended through October 31, 2000. During this injection period, 17,686 sample pads were collected at regular intervals, including sample pads from the three instrumented core holes that were drilled last spring. These pads will be analyzed (extraction is complete for 4,188 of the pads) for detection of tracer breakthrough at that level of the test block.

Between February 29—March 16, 2000, cores and rock samples were collected from three new holes. These cores, as well as older cores, were used to identify and examine faults that crossed the test block and were intersected by the cores. The new holes were instrumented so that flow and transport data could be obtained. The rock samples from these new cores were analyzed for both nonreactive and reactive metals as a means to understand the movement, or lack of movement, of metals through the test block. Non-reactive tracer breakthrough has occurred in 11 of 15 boreholes, and lithium breakthrough has occurred in 9 of 15 boreholes.

Modeling of Phase II is occurring in parallel with data collection. The preliminary simulation results show good qualitative agreement with breakthrough data. The model grids have been enhanced to include two faults, more accurate layering, and more accurate boreholes. The statistics of hydrogeologic properties has also been improved.

The design for three overcores (larger-diameter core drilling to recover the rock immediately surrounding the injection boreholes) and two mini-mine backs (removal by hand, for analysis, of rocks near the injection boreholes), one on the injection face and one on the collection face, will be completed by October 31, 2000. The schedule is to cease injection of Phase II by November 1, 2000, and proceed to the post-test characterization phase. The overcoring and two mine backs will be completed by late spring. Rock samples will be acquired from the overcoring and from various faces of each of the mine backs. A full suite of chemical analyses will be run on these samples.

Chemical data and analytical results will be submitted to databases throughout the year, as they become available.

3.4 SITE SATURATED ZONE FLOW AND TRANSPORT

SZ field investigations and modeling work continued in the last period, generating results that are described in the following sections.

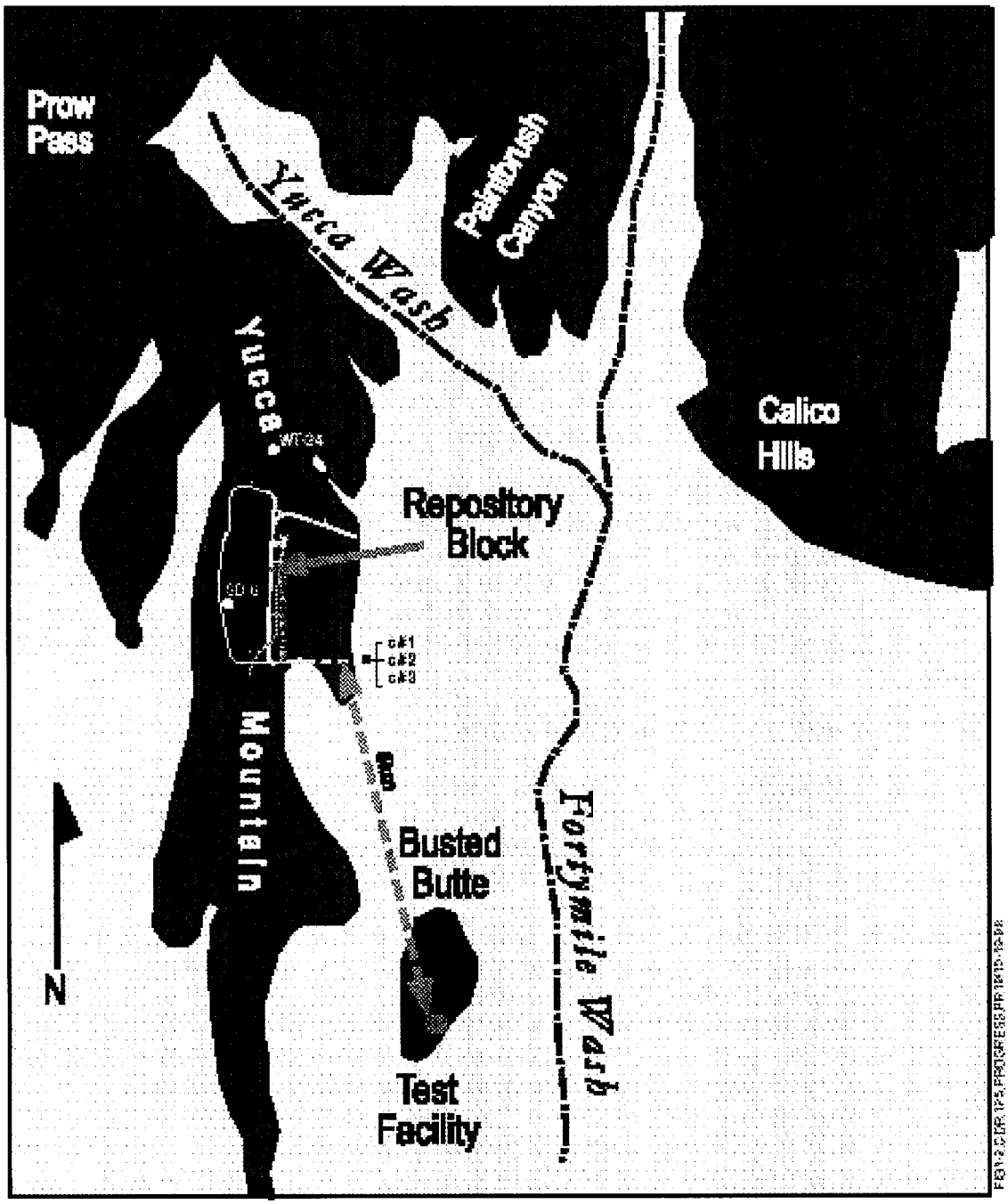

Figure 3-2. Location of Test Facilities, Yucca Mountain, Nevada

3.4.1 Nye County Early Warning Drilling Program and Alluvial Testing Complex Program

Well EWDP-19-D/D1 was installed based on an extensive review of lithologic and geophysical data by Project and Nye County staff. Nye County performed a 48-hour pumping test to assist in the design of the hydraulic test. Following EWDP-19D/D1, borehole EWDP-2DB was drilled to a depth of 3,075 ft. This hole reached the Paleozoic carbonate aquifer beneath the alluvium at a depth of approximately 2,685 ft. Biannual water level measurements and water quality sampling were completed in May at all Nye County Phase I and Phase II EWDP wells. Updated stratigraphic interpretations by Project staff

were developed by integrating information from drilling by Nye County. Development of geophysical interpretations continued using geophysical logs provided by Nye County. Borehole gravity meter surveys were conducted at EWDP-19D/D1.

Single-well hydraulic testing began in well NC-EDWP-19-D/D1 in June 2000. One 14-day hydraulic test was completed in the saturated alluvium at NC-EWDP-19-D/D1 under open-hole conditions. Two seven-day isolated-interval tests were also completed for the two lower screens in the alluvium at that well. The test-derived conductivity values are about one-tenth of than those estimated in the previous site-scale SZ flow model. Test results are being evaluated for estimates of transmissivity, hydraulic conductivity, and storativity. The results are also being evaluated for identifying potential hydraulic communication between the tested intervals in the alluvium and the tuff units.

Efforts continued in test design and selection of equipment and instrumentation for the tracer tests at the Alluvial Testing Complex. A draft, pretest predictions milestone report was prepared to assist in the selection of test well locations and pumping/injection rates.

Single-well, isolated-interval hydraulic testing will proceed, followed by tracer testing in the first part of fiscal year (FY) 2001. Nye County plans to drill eight boreholes in FY 2001, including four for use in the cross-hole Alluvial Testing Complex testing (i.e., one injection well I1 and three monitoring wells M1, M2, and M3). Environmental permit applications are being prepared so that cross-hole hydraulic and tracer testing can start in FY 2001. A special volume of the Journal of Environmental and Engineering Geosciences is being prepared to summarize the results of the EWDP and Alluvial Testing Complex investigations.

3.4.2 Saturated-Zone Flow and Transport Modeling

The SZ Flow and Transport PMR REV 00 (CRWMS M&O 2000au) was completed and delivered to the DOE in April 2000. The ICN 01 (CRWMS M&O 2000av) was prepared in response to DOE comments and delivered to the DOE in August 2000. All supporting SZ AMRs (CRWMS M&O 2000am, 1999b, 2000aw–2000be, and USGS 2000c and 2000d) were completed and accepted by DOE.

Improvements to the SZ flow and transport modeling continued, with effort focused on the Expected Case model for SZ flow and transport. The work focused on reevaluating potentially conservative elements of the groundwater flow field and radionuclide transport parameters. Transport parameters relevant to the expected case model and groundwater travel time in the SZ that are being reevaluated include effective diffusion coefficient, fracture porosity, location of the tuff/alluvium contact at the water table, and effective porosity in the alluvium. The average groundwater specific discharge, especially as inferred for the alluvium, is being reevaluated relative to recently completed open-hole hydraulic testing in well EWDP-19D/D1 at the Alluvial Testing Complex. The southern boundary of the SZ site-scale model is being examined to estimate the predevelopment groundwater head in that region of the model domain. Results of the Expected Case will be reported in an AMR that will be drafted by December 14, 2000, and finalized by April 2001.

In addition, an alternate approach to simulating the high hydraulic gradient north of Yucca Mountain without the artificial east-west barrier was investigated. Finally, model setup was completed for calibrating the site-scale SZ flow model against thermal data in FY 2001. Results of both the hydraulic gradient and thermal new model setup will be incorporated in the next ICN of the site-scale SZ flow model report.

Two AMRs in support of the SZ site-scale flow and transport model were developed and submitted during the reporting period. The hydrogeologic framework model AMR (USGS 2000c), completed in

July, documents the three-dimensional geometric framework for constructing the site-scale SZ model that will be used to evaluate potential radionuclide transport through the SZ from beneath the potential repository to down-gradient compliance points. Similarly, the water-level data analysis AMR (USGS 2000d), which was completed in August, documents an analysis of water-level data performed to provide the SZ model with the configuration of the potentiometric surface and target water-level data for model calibration.

Numerous efforts in Death Valley regional flow-system modeling continued, with focus on database issues, refinement of the hydrogeologic framework model, and work on the hydrogeologic framework AMR. Changes to the database structure were made to handle more efficiently the different data types appearing in the database. Enhancements also were made to the various software packages used to automate data-code conversion during data retrieval from the database for input to the flow model. The enhancements resulted in improved performance such that overnight runs of the model now are possible. The visualization capabilities of the flow model also were improved. For example, an ArcView project was created to visualize flux data from the flow model, facilitating examination of the output information for flux between layers, recharge, flux in and out at constant heads, and general-head boundaries. Various efforts continued for documentation and qualification of hydrogeologic-framework-model output and comparison to input data points. Compilation of software documentation for ARC/INFO continued; additional software-related work involved documentation of the Environmental Resource Management Application ("ERMA") Site Geologist (USGS 2000e) and Petrosys (USGS 2000f) codes.

The regional hydrogeologic framework model is being updated to reflect correction of discrepancies discovered during flow modeling. Because flow modeling indicated that identification of zones within the undifferentiated volcanic unit would aid calibration, hydrogeologic justification for the zonation was investigated. It was concluded that the volcanic unit really consists of two volcanic centers with different types of volcanism and, consequently, differing hydraulic properties. Therefore, the volcanic unit was divided into northern and southern parts, representing the Southwest Nevada Volcanic Field (in the northern part) and the Greenfield Volcanic Field (in the southern part). Differentiation of the two units currently is being accomplished within the flow model. In addition, the uppermost surface of the hydrogeologic framework model was updated with the smoothed potentiometric surface, rather than the land surface previously used, to facilitate model calibration. Steady-state calibration of the regional flow model continued during the reporting period, with emphasis on review of water-level observations with high model residuals.

3.4.3 Other SZ Field Investigations

A report (Graves 2000) that describes groundwater levels in the Yucca Mountain area during 1997-98 was published. The report indicates that water levels may have been affected by as much as 0.3 m by long-term pumping at the C-hole complex between May 1996 and November 1997 (Graves 2000, pp. 1 and 19). Preliminary indications are that these data will have few, if any, impacts on TSPA results. However, these data could be useful for model calibration.

Continuous-recording, water level measurement equipment was installed, calibrated, and made operational in hydrologic borehole USW H-4 in August 2000 to monitor the response of SZ water levels to earthquakes. Borehole USW H-4, which had been instrumented for this purpose during 1985-95 (Graves et al. 1997, Appendix B), was chosen because of its proximity to the footprint of the potential repository.

3.5 DISRUPTIVE EVENTS

Initial versions of the Disruptive Events PMR (CRWMS M&O 2000bf) and seven supporting AMRs (CRWMS M&O 2000bg–2000bm) were approved in April. The completion of one AMR was delayed until June. The ICN 01 to the PMR (CRWMS M&O 2000bn) was completed in July to address DOE comments. Another update (ICN 02) is underway to report on new analysis associated with repository design changes (no backfill).

Several informational exchanges with Project stakeholders, including the NRC staff, MGR Consulting Board, and Nuclear Waste Technical Review Board occurred during the last half of FY 2000. These meetings focused primarily on igneous issues; however, a technical exchange with the NRC involving seismic issues is planned for October.

3.6 SEISMIC HAZARDS AND DESIGN

3.6.1 Seismic Hazards

An updated version of inputs and results for the *Probabilistic Seismic Hazard Analyses for Fault Displacement and Vibratory Ground Motion at Yucca Mountain, Nevada* (Wong and Stepp 1998) was submitted to the Technical Data Management System. These data were provided to the NRC to facilitate their review of the probabilistic seismic hazard analyses.

3.6.2 Development of Seismic Design Inputs

Work on the development of seismic design inputs was suspended pending completion of geotechnical site investigations that will provide an enhanced set of site-specific data to use as inputs to the analysis. Preliminary seismic design inputs (response spectra, time histories, and strain-compatible soil properties) based on available data were submitted to the Technical Data Management System). These data support a preliminary soil-structure interaction analysis conducted for the Waste Handling Building and other design analyses.

3.6.3 Geotechnical Site Investigations

Geotechnical investigations were initiated to provide additional data supporting development of seismic design inputs and foundation recommendations for the Waste Handling Building. The investigations include drilling boreholes, excavating test pits, geological and geophysical logging of boreholes, spectral analysis of surface wave surveys, and testing of soil and rock sample properties. Geotechnical investigations are expected to be completed in the first quarter of FY 2001. Preclosure seismic design inputs will be developed using the results of the geotechnical investigations.

SECTION 4 – DESIGN AND CONSTRUCTION

During this reporting period, the Project continued to develop repository design requirements, evolve the surface and subsurface repository design, evolve the waste package design, and continue construction of sites for testing activities in the ESF. Advances in these areas are described in the following sections.

4.1 DESIGN REQUIREMENTS

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

- Revision to 24 system description documents (CRWMS M&O 2000bo–2000cl)
- Revision to the *Monitored Geologic Repository Project Description Document* (CRWMS M&O 2000cm)
- Revision to *Reference Design Description for a Geologic Repository* (DOE 2000a).

4.2 REPOSITORY

The Project continues to study and advance the design of the repository to support the SR. Concepts for the design of the overall ventilation system are described in *Overall Subsurface Ventilation System* (CRWMS M&O 2000co) and Emplacement Ventilation System (CRWMS M&O 2000cp). The project completed the Ground Control for Emplacement Drifts for SR (CRWMS M&O 2000cq). This document was developed to demonstrate that steel sets, with or without fully grouted rockbolts, would provide adequate ground support in emplacement drifts. Steel sets and rockbolts of carbon steel should perform effectively through the preclosure period.

The Project completed *Design of a Cooler, Naturally Ventilated Yucca Mountain Repository: Feasibility and Impacts* (see enclosure to Wilkins 2000). The report provides a design concept for a below boiling point repository using natural ventilation that offsets the cost of a forced ventilated repository.

The Project completed the *Longevity of Emplacement Drift Ground Support Materials* (CRWMS M&O 2000cr). This report concluded that grout should be effective through the preclosure period; however, testing will be required to establish the proper mix.

The Project completed the *Bottom/Side Lift Gantry Conceptual Design* (CRWMS M&O 2000cs). The design confirmed the suitability of a new type of gantry for handling the waste packages and emplacement pallets in and near the emplacement drifts. Concepts for remote monitoring and control, and for remote handling techniques during waste handling, were developed in *Instrumentation and Controls for Waste Emplacement* (CRWMS M&O 2000ct). The Project completed revisions to the *Subsurface Transporter Safety Systems Analysis* (CRWMS M&O 2000cu). The results of the analysis concluded that currently available technology could be incorporated into the electronic controls and mechanical systems of the transporter to ensure that this event (runaway transporter) can be regarded as a beyond DBE.

Concepts for designing a repository that can be operated with below-boiling emplacement drift wall temperatures were developed in *Operating a Below-Boiling Repository: Demonstration of Concept* (CRWMS M&O 2000cv). Three operational variables were evaluated for their effects on operating the repository at below-boiling temperatures: waste package spacing within the emplacement drifts, surface staging of hot wastes to effectively increase their age, and increasing the duration of the forced ventilation

period. Singly and in combination, these variables were demonstrated to allow operating the repository at below-boiling drift-wall temperatures.

Testing was completed on a quarter-scale model emplacement drift and waste package that was used to determine the effectiveness of emplacement drift backfill and drip shield on preventing percolation from contacting waste packages. Test results in *Engineered Barrier System–Pilot Scale Testing Initial Results Through 2/28/99* (CRWMS M&O 2000cw) indicated that a two-material backfill diverted approximately 97 percent of the water from the waste packages; single-material backfill was ineffective in diverting water from the waste packages. As documented *in Engineered Barrier System-Pilot Test #3, Heated Drip Shield Test Results* (CRWMS M&O 2000cx), elevated temperature tests using drip shields, with and without overlying backfill, kept the dripping water (including condensate) from the waste packages. However, it was noted that water seeped through the joint between drip shield segments. Testing began on a quarter-scale EBS model ventilation test to predict the efficiency of the emplacement drift ventilation system to remove heat from the waste packages. Testing was restarted on the coupled column test (thermal, chemical, and hydrologic coupling) to assess the effect of refluxing hot water on the chemical changes in crushed welded tuff in the invert. Pilot-scale test #5, the ponding or evaporation test, is on hold pending budget allocation. Testing has started in the ECRB to determine the drainage capacity of the emplacement drifts.

In repository surface design, the Project completed *Engineering Files for Site Recommendation* (CRWMS M&O 2000cy), *WHB/WTB Space Program Analysis for Site Recommendation* (CRWMS M&O 2000cz), and *Repository Surface Design Engineering Files Report Supplement* (CRWMS M&O 2000da) in support of the Yucca Mountain SRR and the final EIS.

4.3 WASTE PACKAGE

The Project completed the *Waste Form Degradation Process Model Report* (CRWMS M&O 2000db) and the *Waste Package Degradation Process Model Report* (CRWMS M&O 2000dc). These reports incorporated responses to comments by the DOE on the original REV 00 documents (CRWMS M&O 2000dd and 2000de).

The NRC issued the "Safety Evaluation Report for Disposal Criticality Analysis Methodology Topical Report, Revision 0" (Reamer 2000) for the *Disposal Criticality Analysis Methodology Topical Report* (YMP 1998). The safety evaluation report demonstrated the NRC acceptance of several key items of the criticality methodology, including acceptance of the overall risk-informed approach for disposal criticality analysis. Open items of the safety evaluation report are addressed in the updated *Disposal Criticality Analysis Methodology Topical Report* (YMP 2000).

The Project met with the NRC to discuss five subissues related to the NRC KTI on container lifetime and source term. These subissues pertained to the performance of waste package and waste form materials. The meeting resulted in the NRC designation of all five subissues as "closed-pending." One remaining subissue on criticality will be the subject of a separate technical exchange meeting planned for October 2000.

The Project completed the following seven calculation documents to support the waste package and repository design process:

- *Thermal Evaluation for the Naval SNF Waste Package* (CRWMS M&O 2000df)
- *Drift Scale Thermal Analysis* (CRWMS M&O 2000dg)

- *Two-Dimensional Repository Thermal Design Calculations* (CRWMS M&O 2000dh)
- *Comparison of Cladding Creep Rupture Models* (CRWMS M&O 2000di)
- *Rock Fall on Drip Shield* (CRWMS M&O 2000dj)
- *Puncture Drop of 44-BWR Waste Package* (CRWMS M&O 2000dk)
- *Structural Calculations for the Drop of a Loaded Emplacement Pallet on Unyielding Surface* (CRWMS M&O 2000dl).

The Project completed an AMR, *Preclosure Design Basis Events Related to Waste Packages* (CRWMS M&O 2000dm), to support an AMR being prepared for repository DBEs.

The Project completed the *Waste Package Design Methodology Report* (CRWMS M&O 2000dn). This report summarizes the design methodology to be used to satisfy system design description requirements for LA.

The Project completed the *Waste Package Design Sensitivity Report* (CRWMS M&O 2000do). This report describes the waste package design attributes that will be fully developed to demonstrate compliance to the system design description requirements for LA.

The Project completed the *Design Analysis for UCF Waste Packages* (CRWMS M&O 2000dp), *Design Analysis for the Defense High-Level Waste Disposal Container* (CRWMS M&O 2000dq), *Design Analysis for the Naval SNF Waste Package* (CRWMS M&O 2000dr), and *Design Analysis for the Ex-Container Components* (CRWMS M&O 2000ds). These analyses provide representative applications of the waste package design methodology and a report on the ancillary components within the EBS.

The Project completed *Water Pooling-Evaporation in a Waste Package* (CRWMS M&O 2000dt). The calculation provides data that indicated evaporation of water from the waste package (driven by residual heat) are sufficient to prevent pooling of water in a breached waste package. Prevention of pooling ensures that there will be no criticality, and in general suggests a minimization of radionuclide release.

The Project completed the closure weld development program, which included the basic fabrication of the mock-up and welding of lids. The program also included the welding of Alloy 22, Stainless Steel 316 NG, and titanium samples.

The Project completed the *Waste Package FY-00 Closure Methods Report* (CRWMS M&O 2000du). This report details the closure weld and nondestructive examination program for FY 2000.

The Project completed the *Waste Package Operations Fabrication Process Report* (CRWMS M&O 2000dv). This report details changes in the design and lessons learned from the FY 2000 closure weld program.

The Project completed the *Evaluation of Codisposal Viability for U-Zr/U-Mo Alloy (Enrico Fermi) DOE-Owned Fuel* (CRWMS M&O 2000dw) and *Evaluation of Codisposal Viability for Th/U Oxide (Shippingport LWBR) DOE-Owned Fuel* (CRWMS M&O 2000dx). These reports support the demonstration that DOE spent nuclear fuel can be viably disposed of in the proposed geologic repository. Five of the nine groups of DOE spent nuclear fuel have been evaluated.

The Project completed the *Probability of External Criticality of Plutonium Disposition Waste Forms* (CRWMS M&O 2000dy), *Far-Field Accumulation of Fissile Material from Waste Packages Containing Plutonium Disposition Waste Forms* (CRWMS M&O 2000dz), and *In-Drift Accumulation of Fissile Material from Waste Packages Containing Plutonium Disposition Waste Forms* (CRWMS M&O 2000ea) calculations. These calculations demonstrate the viability of disposal of plutonium disposition waste forms.

4.4 EXPLORATORY STUDIES FACILITY

The Project is continuing testing activities that require continued operation and maintenance of the ESF and Busted Butte. Excavation of the Cross Over Alcove (Alcove #8 located at Cross Drift Station 7+98 (798 m [2,618 ft])) and Niche #5 (located at Cross Drift Station 16+20 (1,620 m [5,315 ft])) were completed. The Project completed the designs for Niche #6, the Crest Alcove (Alcove #9), and the Thermal Test (ECRB Cross Drift Thermal Alcove).

SECTION 5 – REPOSITORY PERFORMANCE

During this reporting period, the Yucca Mountain Project made several advances in the areas of preclosure radiological safety assessment, postclosure performance assessment, and performance confirmation. Advances in these topics are described in the following sections.

5.1 PRECLOSURE RADIOLOGICAL SAFETY ASSESSMENT

Several documents were issued to support a possible site recommendation, including the *Preliminary Preclosure Safety Assessment for Monitored Geologic Repository Site Recommendation* (CRWMS M&O 2000f), as well as revisions to the *Design Basis Event Frequency and Dose Calculation for Site Recommendation* (CRWMS M&O 2000ec) and *Repository Safety Strategy: Plan to Prepare the Safety Case to Support Yucca Mountain Site Recommendation and Licensing Considerations* (CRWMS M&O 2000c) documents.

The purpose of the preliminary preclosure safety assessment is to document the preliminary safety assessment of MGR operations during the preclosure period. This safety assessment includes the identification of facility hazards and their potential for initiating events, identification of MGR DBEs, evaluation of DBE occurrence frequencies and consequences, and the identification of those SSCs important to safety. SSCs important to safety are those engineered features of the MGR operations area that function to (1) provide reasonable assurance that high-level waste can be received, handled, packaged, stored, emplaced, and retrieved without exceeding regulatory limits or (2) prevent or mitigate DBEs that could result in doses equaling or exceeding regulatory limits. The preliminary preclosure safety assessment also provides MGR strategies for criticality safety, radiation protection, and fire protection, and it provides a description of the provisions for the control and management of low-level radioactive waste.

Descriptions of the MGR site characteristics and facility design are provided to support the identification of hazards and the evaluation of DBEs. The calculation of event frequencies and offsite doses for identified MGR DBEs was revised and reported in the DBE frequency and dose calculation report (CRWMS M&O 2000ec). This calculation also supports a possible site recommendation. The safety case for the MGR to demonstrate the robustness of a potential repository system at Yucca Mountain was revised during this performance period, and it is presented in the repository safety strategy document (CRWMS M&O 2000c). Another DBE-related analysis that was issued during this performance period is *Leakpath Factors for Radionuclide Releases from Breached Confinement Barriers* (CRWMS M&O 2000ed). This is a scoping analysis to determine the feasibility of taking credit for the retention of radioactive material during a confinement breach event. In addition, preclosure safety work has been completed in support of a waste acceptance system requirements document, the design of the DOE spent nuclear fuel canister, transportation studies, and the MGR SSC components performance allocation study. Work in progress includes a beyond-DBE study for DOE spent nuclear fuel and immobilized plutonium waste forms. Work in progress also includes a canister transfer system event tree calculation. These analyses will be used to support future preclosure safety assessments, including those performed to support LA activities. Results of these analyses may be used to determine or modify the QA classification level of repository SSCs.

A meeting was held with the NRC in May 2000 to discuss preclosure operations design and the concept of the integrated safety analysis.

5.2 POSTCLOSURE PERFORMANCE ASSESSMENT

5.2.1 Performance Assessment

During this reporting period, progress was made in postclosure performance assessment of the potential Yucca Mountain repository. The total system model for the *Total System Performance Assessment for the Site Recommendation* (TSPA-SR) (CRWMS M&O 2000g) was completed and is being documented in (CRWMS M&O 2000ee). The model uses GoldSim (Golder Associates 2000), a qualified version of the total system simulator (V6.04.007 STN: 10344-6.04.007-00). The model integrates multiple SR component models, such as WAPDEG (CRWMS M&O 1999d) (V4.0 STN: 10000-4.0-00), which models waste package degradation; ASHPLUME (CRWMS M&O 2000eg) (V1.4LV STN: 10022-1.4LV-00), which models direct release of radionuclides for the eruptive release scenario; and FEHM (LANL 1999) (V2.0 STN: 10031-2.0-00), which models transport through the UZ, and uses the technical basis from the AMRs. The base case model includes two scenario classes: the nominal scenario class, which contains all included FEPs except igneous activity, and the igneous activity scenario class.

The TSPA-SR (CRWMS M&O 2000g) was completed during this reporting period. This document provides a description of the TSPA-SR model, model results, and multiple sensitivity analyses. The document is complete with numerous graphics that depict the overall TSPA process as well as the conceptual underpinning for the models.

Other performance assessment activities include contributing results and analyses of the TSPA-SR to a possible site recommendation and Revision 4 of the repository safety strategy (CRWMS M&O 2000c), finalizing the TSPA FEPs database, and providing performance assessment input (e.g., alternative receptor distances and alternative waste inventories) to the final EIS. In support of these documents and other SR activities, numerous probabilistic, multiple-realization simulations were conducted using the TSPA-SR total system model, Revision 00 (CRWMS M&O 2000ee). These simulations support the repository safety strategy and compliance regulations as outlined in proposed 10 CFR 63 [64 FR 8640] and 40 CFR 197 [64 FR 46976]. The simulations include 58 multiple-realization simulations for the nominal scenario class (including the base-case, parameter sensitivity, and barrier importance analyses), 32 simulations for the igneous scenario class (including base-case and sensitivity analyses for the eruptive release and intrusive groundwater-release scenarios), 4 simulations for the human intrusion scenario class, 16 barrier-neutralization simulations, 12 juvenile waste-package failure simulations, and 2 alternative design simulations. All of the TSPA-SR Revision 00 total system simulations were catalogued and stored in the Project Technical Data Management System. In preparation for Revision 01 of the TSPA-SR and for the final EIS, work has begun on improving some of the TSPA-SR Revision 00 component models using new testing and analyses. This will require changes to the total system model in the first quarter of FY 2001.

5.2.2 Near Field Environment

Two AMRs were completed and approved during the second half of FY 2000: *Abstraction of NFE Drift Thermodynamic Environment and Percolation Flux* (CRWMS M&O 2000ef) and *Abstraction of Drift-Scale Coupled Processes* (CRWMS M&O 2000u). AMR revisions to address the no-backfill design change were developed during the reporting period. Presentations were made to the NRC at the technical exchange meeting in June, and the thermal-hydrologic models were presented to the Nuclear Waste Technical Review Board in July. Other activities included contributing to the *Near Field Environment Process Model Report* (CRWMS M&O 2000r) and working to integrate AMR products with the TSPA model.

5.2.3 Engineered Barrier System

Eleven AMRs and one calculation report were completed during the second half of FY 2000: *EBS FEPs/Degradation Modes Abstraction* (CRWMS M&O 2000eh), *EBS Radionuclide Transport Abstraction* (CRWMS M&O 2000ei), *In Drift Microbial Communities* (CRWMS M&O 2000ej), *Seepage/Backfill Interactions* (CRWMS M&O 2000ek), *In-Drift Gas Flux and Composition* (CRWMS M&O 2000el), *In Drift Corrosion Products* (CRWMS M&O 1999c), *In-Drift Colloids and Concentration* (CRWMS M&O 2000em), *Seepage/Cement Interactions* (CRWMS M&O 2000en), *Seepage/Invert Interactions* (CRWMS M&O 2000eo), *In-Drift Precipitates/Salts Analysis* (CRWMS M&O 2000ep), *Physical and Chemical Environmental Abstraction Model* (CRWMS M&O 2000eq), and *Precipitates/Salts Model Results for THC Abstraction* (CRWMS M&O 2000er).

The *EBS FEPs/Degradation Modes Abstraction* (CRWMS M&O 2000eh) provides screening summaries for EBS FEPs and identifies FEPs for treatment. The *EBS Radionuclide Transport Abstraction* (CRWMS M&O 2000ei) defines and quantifies transport paths in the EBS for evaluating EBS performance. The *Physical and Chemical Environmental Abstraction Model* (CRWMS M&O 2000eq) identifies locations along the transport paths where chemical environments affect EBS performance, and it defines the system of interrelated processes that influence those environments. The remaining nine documents describe and quantify the processes for consideration in evaluating performance of the EBS. That system of abstractions and models was documented in the TSPA-SR text within the context of related TSPA activities, such as drift degradation and thermal hydrologic environments. A review of the system and context was presented to the NRC at the technical exchange on the TSPA for Yucca Mountain.

5.2.4 Unsaturated Zone Flow and Transport

Two AMRs were completed and approved during the second half of FY 2000: *Analysis of Infiltration Uncertainty* (CRWMS M&O 2000al) and *Particle Tracking Model and Abstraction of Transport Processes* (CRWMS M&O 2000ag). Other activities included presentations to the NRC at a technical exchange and working to integrate AMR products with the TSPA model.

5.2.5 Saturated Zone Flow and Transport

Four AMRs were completed and approved during the second half of FY 2000: *Uncertainty Distribution for Stochastic Parameters* (CRWMS M&O 2000bb), *Input and Results of the Base Case Saturated Zone Flow and Transport Model for TSPA* (CRWMS M&O 2000bc), *Features, Events, and Processes in SZ Flow and Transport* (CRWMS M&O 2000bd), and *Saturated Zone Colloid-Facilitated Transport* (CRWMS M&O 2000ay). The *Saturated Zone Flow and Transport Process Model Report* (SZ PMR) (CRWMS M&O 2000au) was audited. Other activities included contributing to the SZ PMR and working to integrate AMR products with the TSPA model.

5.2.6 Biosphere

Work was initiated to update three of the four performance-assessment AMRs that support the *Biosphere Process Model Report* (CRWMS M&O 2000es). The updates will provide TSPA input that accommodates a revision of the habits and characteristics of the critical group and the mandated requirement to address future climate change in the biosphere modeling effort. The affected AMRs are *Evaluate Soil/Radionuclide Removal by Erosion and Leaching* (CRWMS M&O 2000et), *Distribution Fitting to the Stochastic BDCF Data* (CRWMS M&O 2000eu), and *Abstraction of BDCF Distributions for Irrigation Periods* (CRWMS M&O 2000ev).

5.2.7 Disruptive Events

The TSPA FEPs database was delivered to the DOE; however, acceptance is conditional on completing work in four areas by December 15, 2000. This work involves QA issues regarding database software, completion of screening arguments for criticality FEPs, updating the FEPs AMRs for the no-backfill design, and addressing comments on FEPs AMRs raised by the DOE legal review. Only the first issue (software QA) is within the scope of the FEPs database. Work is on schedule for resolving the DOE concerns.

The *Igneous Consequence Modeling for the TSPA-SR* (CRWMS M&O 2000ex) report was completed. Results of this report were incorporated into the TSPA-SR (CRWMS M&O 2000g) and continuing work to support a possible site recommendation. The results were presented to the NRC in a technical exchange meeting August 29-31, 2000. Performance assessment modeling and participation in the technical exchange were major factors in reaching a resolution of closed-pending on all but one of the acceptance criteria from the igneous activity IRSR (NRC 1999). Work remaining to close all igneous issues with the NRC includes final documentation of performance assessment modeling and disruptive events AMRs. The performance assessment disruptive events team also provided support in preparation of the *Disruptive Events Process Model Report* (CRWMS M&O 2000bf) and in participation in an NRC technical exchange on structural deformation and seismicity.

Two other disruptive events AMRs and one calculation were completed during the report period. Revisions to the three AMRs and the calculation are in progress and scheduled for completion in November 2000. The three AMRs and the calculation are *Disruptive Events FEPs* (CRWMS M&O 2000bj), *Dike Propagation Near Drifts* (CRWMS M&O 2000bi), *Igneous Consequence Modeling for the TSPA-SR* (CRWMS M&O 2000ex), and *Number of Waste Packages Hit by Igneous Intrusion* (CRWMS M&O 2000ew), respectively.

5.3 PERFORMANCE CONFIRMATION

The performance confirmation program includes activities conducted to collect and analyze data to ensure that conditions encountered, and changes in those conditions, are within the limits to be stated in the license. The program, which began during site characterization and continues until permanent closure, will determine whether the natural systems, engineered systems, and system components function as intended and anticipated.

The *Performance Confirmation Plan* (CRWMS M&O 2000h) was updated and approved. The updated plan incorporates several clarifications and revised requirements based on a review by the DOE. This revised plan provides a basis for out-year planning, support for the SRR, and support for the total system life-cycle cost (TSLCC) estimate.

The *Monitored Geologic Repository Test & Evaluation Plan* (CRWMS M&O 2000i) was revised, completed on schedule, and submitted to the DOE for review. This plan defines an integrated test program that identifies the tests necessary to satisfy regulatory requirements and successfully construct an MGR. The plan describes each of the program phases, test categories, and implementation logic; and it provides a top-level description of the resultant test concepts. The program also provides a context for performance confirmation activities (part of the test program), a basis for out-year planning, and support for the SRR.

A TSLCC estimate was completed for all testing and performance confirmation activities. As part of this effort, testing and monitoring activities for the program were identified, scoped, and estimated. Cost and resource level estimates were computed for each year, with a comparison of current activities to the

viability assessment cost estimate. Backup materials (estimate sheets, schedules, and scope descriptions) were provided and incorporated into the schedule as part of the TSLCC. The resulting deliverable, *FY2000 Monitored Geologic Repository Total System Life Cycle Cost Report* (CRWMS M&O 2000j), was completed and submitted to the DOE for review.

A presentation on performance confirmation was made July 26, 2000, to the Advisory Committee on Nuclear Waste in Washington, D.C., which summarized the status of the program and the outlook for the future.

A technical exchange meeting on performance confirmation with the NRC was planned for June 29, 2000. The exchange was to have provided comments on the revised performance confirmation approach and implementation to assist in the preparation of the LA; however, NRC postponed the meeting, which has not yet been rescheduled.

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SECTION 6 – EPILOGUE

Since the close of the reporting period, several important technical developments have occurred on the Project, including design and construction:

- The Project assembled a consensus position to respond to a number of issues identified by the Nuclear Waste Technical Review Board with regard to uncertainties, coupled processes, and lower temperature designs. Additional testing, modeling, and alternative design approaches are under consideration to increase confidence in the understanding of fundamental natural processes and the predictions for long term performance.

- The report *Natural Ventilation Study: Demonstration of Concept* (CRWMS M&O 2000x) was completed and issued in late November 2000. This report indicated that the concept of natural ventilation would work within the repository subsurface facility and remove enough waste package decay heat to maintain the postclosure waste package surface temperature, on average, less than 85°C (a conservative temperature for the Alloy 22 window of corrosion susceptibility).

- The *Department of Energy Spent Nuclear Fuel Canister, Transportation, and Monitored Geologic Repository Systems, Structures, and Components Performance Allocation Study* (CRWMS M&O 2000cn) was completed the first week of December 2000. This report determined that it was possible to design the surface facility canister handling line equipment so that drops and breaches of the DOE spent nuclear fuel canisters were incredible events. Design requirements were provided to ensure that the drop and breach of the DOE spent nuclear fuel canisters would not occur.

- Revision 4, ICN 1 of the *Repository Safety Strategy: Plan to Prepare the Safety Case to Support Yucca Mountain Site Recommendation and Licensing Considerations* (CRWMS M&O 2000b) was issued November 2000. This revision enhanced integration of the strategy documentation and improved conformance with referenced reports and regulations.

- The contents and title of the *Site Recommendation Consideration Report*, as described in previous progress reports, were reevaluated, and DOE made the decision to issue it as the *Yucca Mountain Science and Engineering Report* (DOE 2001a) which was released in May 2001. In conjunction with the release of this report, the Department announced the commencement of the public comment period on the possible recommendation of the site by the Secretary.

- The *Supplement to the Draft Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (DOE 2001b) was released for public comment in May 2001. This supplement updates repository design information presented in the draft EIS. The supplement addresses the latest repository design and operating modes as contained in the *Yucca Mountain Science and Engineering Report* (DOE 2001a), and evaluates potential environmental impacts that could occur based on the design and operating modes.

- On June 5, 2001, the EPA adopted the final rule that establishes site-specific radiation protection standards for Yucca Mountain.

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APPENDIX A

COMPLETED YUCCA MOUNTAIN SITE CHARACTERIZATION PROJECT DELIVERABLES

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COMPLETED YUCCA MOUNTAIN SITE CHARACTERIZATION PROJECT DELIVERABLES

Table A-1. Completed Yucca Mountain Site Characterization Project Deliverables (April 1 to September 30, 2000)

Document Control Number	Deliverable Number	Title and Revision
25113	SCC1640M3	Complete Subsurface Comm System As-Builts/Letter LV.TFDS.LRM.03/00-017 w/Enclosure
24559	SPG720M3	Strain Accumulation at Yucca Mountain, Nevada, 1983-1998
25253	SCC300M3	Complete Crossover Alcove
24169	SEDA09M3	Update QL1 SDDs – Letter Report
25203	SLT00AM3	Quarterly TDMS Processing Report
22742	SLR412M3	Notify SR V1S3 - Waste Form & Packaging Posted
25549	SEDA08M3	Update QL-2 SDDs – Letter Report
25328	SLR414M3	Postclosure Safety Case Evaluation Posted
23626	RPB516M3	Backfill Emplacement Analysis
25329	SLR423M3	Notify SRCR Waste Form And EBS Degradation, Flow & Transport, And Biosphere Postclosure Suitability Criteria Posted
24976	SCC230M3	Handicap Emergency Management Procedure
25381	SL20KM3	Quarterly Interactions Summary Second Quarter – Fiscal Year 2000
24317	RPB566M3	Instrumentation and Controls for Waste Emplacement
25431	SLR425M3	Suitability Determination Posted
25515	SLR422M3	Notify SRCR Site/SZ/DE Postclosure Suitability Criteria (Volume 2, Section 3.4) Posted
25514	SLR421M3	Notify SRCR Postclosure Suitability Determination Posted (Volume 2, Sections 3.0, 3.1, 3.2, and 3.3)
25513	SLR415M3	Notify Postclosure Safety Assessment Approach/FEPs Posted (Site Recommendation Consideration Report, Volume 1, Section 4(B))
25468	SLR411M3	Repository Description Posted
25432	SLR413M3	Preclosure Safety Case Description Posted
25430	SLR424M3	Flow/F&T and NFE Postclosure Suitability Criteria Evaluation Posted
24033	SCC1630M3	Complete Subsurface Compressed Air System As-Built
22852	SEDAX2M3	Performance Confirmation Plan, Rev. 1
24345	RPB526M3	Overall Subsurface Ventilation System
25234	SEDA03M3	PDD Design Description Update – Letter Report
25742	SCC1046M3	Complete Consolidation FY00
24988	RPB146M3	Repository Surface Design Engineering Files Report Supplement
23131	WPO5GM3	Design Analysis for the Ex-Container Components
25631	SCC120M3	Complete Construction of ECRB Niche 5
24179	WP05FM3	Design Analysis for UCF Waste Packages
23885	SLPMRM3	Biosphere Process Model Report

Table A-1. Completed Yucca Mountain Site Characterization Project Deliverables (April 1 to September 30, 2000) (Continued)

Document Control Number	Deliverable Number	Title and Revision
23483	RPB112M3	Preliminary Dynamic Soil-Structure-Interaction Analysis for the Waste Handling Building
24756	RPB536M3	Longevity of Emplacement Drift Ground Support Materials, Rev. 1
22618	RPBZ72M3	Engineering File for Site Recommendation (EFSR)
25718	RPB104M3	WHB/WTB Space Program Analysis for Site Recommendation (RPB 104M3)
23634	RPB538M3	Update to the Engineering File Subsurface Repository
25218	SCC1620M3	Complete ESF Q Ground Support System As-Built/Complete Accurate Technical Baseline – ESF "Q" Ground Support Letter LV.TFDS.LRM.03/00-018
25748	SLPR22M3	Progress Report 22 YMSCO AM Concurrence Draft
25725	SSSP02M3	M&O Reports Readiness for Phase II Verification
25699	SCC1610M3	Complete ESF Power System As-Builts Letter, LV.TFDS.LRM.05/00-032
25612	SCC1600M3	Complete Subsurface Lighting System As-Built
25719	SCC270M3	Site Development Plan
23871	SLFROLM3	Waste Package Degradation Model Report
23915	SLT7012M3	Disruptive Events Process Model Report
26010	BMF003M3	Initial FY01 YMP Plan Update to YMSCO Deliverable No: BMF003M3
26035	SLT00BM3	Third Quarter Status of Data Submittals and Incorporation into the Technical Data Management System
26051	SSH012M3	Occupational Training Needs Assessment
26052	SSH011M3	Annual Training Plan
26081	SSG01M3	CRWMS M&O Annual Training Plan Document FY01
26000	SSG00M3	Training Plan Document FY01
26237	SEDA0AM3	Update SDDs for Performance Allocation – Letter Report
25269	SSSP01M3	Civilian Radioactive Waste Management System Management & Operating Contractor Integrated Safety Management Description Document
26243	SLCTS2M3	CTS Semi-Annual Progress Report
23979	SLP593M3	Unsaturated Zone Flow and Transport Model Process Model Report
23855	SLPMRWM3	Waste Form Degradation Process Model Report
23405	SLEB145M3	Engineered Barrier System (EBS) Degradation, Flow, and Transport Process Model Report (PMR)
25674	SCC130M3	Cross Drift Solitario Canyon Fault Alcove #11 Plan Sections
26251	SCC140M3	Complete Design of the ECRB Niche 6 Letter LV.TFDS.LRM.07/00-049
26017	SLR427M3	Notify TSPA Sensitivity Studies/Multiple Barrier Analysis Posted
26016	SLR416M3	Notify VIS4(C) Sensitivity Studies/Multiple Barrier Analyses Posted
26296	BMK02M3	IT Investment Portfolio for FY 2001
26240	SL20LM3	Quarterly Interactions Summary Third Quarter – Fiscal Year 2000
24967	SEDA11M3	Preliminary Preclosure Safety Assessment for Monitored Geologic Repository Site Recommendation
26224	SLPRFMM3	Progress Report 22 HQ Concurrence Draft
25812	SCC100M3	Cross Drift Crest Alcove #9 Excavation Layout Plan and Sections

Table A-1. Completed Yucca Mountain Site Characterization Project Deliverables (April 1 to September 30, 2000) (Continued)

Document Control Number	Deliverable Number	Title and Revision
26620	SCC1055M3	Complete Excess Property Program FY00
26585	SCC220M3	Complete FY00 Noise Abatements
26619	SCC260M3	Interface Control Document for Support Operations to Perform Assessment Operations: Functional and Organizational Interfaces Between the M&O Support Operations and the M&O Performance Assessment
25939	SL981M3	The Development of Information Catalogued in Rev 00 of the YMP FEP Database

AM Assistant Manager

CRWMS Civilian Radioactive Waste Management System
CTS Commitment Tracking System

DE disruptive events

EBS engineered barrier system
ECRB enhanced characterization of the repository block
EFSR engineering file for site recommendation
ESF exploratory studies facility

FEP feature, event, or process
FY fiscal year

HQ U.S. Department of Energy Headquarters

IT information technology

M&O management and operating contractor

NFE near field environment

PDD project description document
PMR process model report

QL quality level

SDD system description document
SR site recommendation
SRCR site recommendation consideration report
SZ saturated zone

TDMS technical data management system
TSPA total system performance assessment

UCF uncanistered fuel

WHB waste handling building
WTB waste transportation building

YMP Yucca Mountain Project
YMSCO Yucca Mountain Site Characterization Office

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APPENDIX B

FUTURE YUCCA MOUNTAIN SITE CHARACTERIZATION PROJECT DELIVERABLES AND STATUS OF WORKS IN PROGRESS

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APPENDIX B

FUTURE YUCCA MOUNTAIN SITE CHARACTERIZATION PROJECT DELIVERABLES AND STATUS OF WORKS IN PROGRESS

B-1. Status of Works in Progress from Previous Progress Reports

Work in Progress Number	Document or Deliverable ID Number	Proposed Title	Expected Completion Date
PR22 Listings			
2	TDR-CRW-GS-000001	Yucca Mountain Site Description, Revision 1	07/14/00 Actual
3	ANL-NBS-HS-000017	Analysis of Geochemical Data for the Unsaturated Zone	07/26/00 Actual
PR21 Listings			
2	YMP/90-55Q	MGR Q-List, Rev. 06	04/27/00 Actual
4	SEDA09M3	Update QL-1 SDDs – Letter Report	04/14/00 Actual
5	SEDA03M3	PDD Design Description Update – Letter Report	06/13/00 Actual
8	UCRL-ID-133846	Fracture Characterization of the Large-Block Test, Fran Ridge, Yucca Mountain, Nevada	05/01/99 Actual
9	BBD000000-01717-5700-00001	Engineered Barrier System–Pilot Scale Testing Initial Results Through 2/28/99	03/06/00 Actual
PR 20 Listings			
6	SLP593M3	Unsaturated Zone Flow and Transport Model. Rev. 0	08/10/00 Actual
10	SLSTRBM3	Submit Seismic Topical Report (STR) III for QAP 6.2/YAP-30.12 Reviews	11/08/99 Revised 09/05/00 Deferred
17	N/A	Data Submittal to Technical Baseline for Nye County	continuous process
19	ANL-NBS-GS-000001	Analysis and Model Report for Natural Resources	09/30/00 Revised 12/12/00 Actual
20	Number TBD	Seismicity in the Vicinity of Yucca Mountain, Nevada, for the Period October 1, 1997, to September 30, 1999	09/30/00 Revised 03/31/01

NOTE: MGR = monitored geologic repository; PDD = project description document; SDD = system description document

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APPENDIX C

GLOSSARY

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GLOSSARY

NOTE: Many of the following definitions are Yucca Mountain Site Characterization Project-specific.

Glossary Item	Definition or Explanation
Alcove	Underground excavations made to the sides of drifts or ramps of the Exploratory Studies Facility (ESF) or Cross Drift and used as sites for in situ testing of ambient rock characteristics or thermal perturbations of those characteristics.
Analysis and Model Report	A report that documents the technical underpinnings used to defend the applicability of the model for its intended purpose of evaluating the postclosure performance of the potential Yucca Mountain Repository System.
Aquifer	A water-bearing layer of permeable rock that is capable of yielding groundwater to supply wells and springs.
Backfill	Material placed in the emplacement drifts to refill the drift after waste packages are placed in the drift and prior to closing the repository.
Borehole	A hole bored or drilled to investigate subsurface features.
Characterization	A study done to investigate (i.e., to determine the character or quality) and describe an item or process.
Colloid	A substance consisting of particles, dispersed throughout another substance, that are too small for resolution with an ordinary light microscope but are incapable of passing through a semipermeable membrane.
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 important changes to the fundamental concepts on which the viability assessment (VA) design was based.
Design Feature	Enhancements to design that can be easily incorporated within multiple alternative designs.
Drift	Mining terminology for a horizontal underground passage.
Drip Shield	A sheet of impermeable material placed above a waste package to prevent seepage water from dripping onto the waste package.
Emplacement Area	That part of the geologic repository in which radioactive waste would be placed.
Engineered Barrier System	Those engineered features of the geologic repository that contribute to containing radioactive wastes and preventing or delaying them from escaping the geologic repository. Engineered barriers are items such as waste packages and drip shields.

Glossary Item	Definition or Explanation
Fault Zone	An area composed of many small, closely spaced rock fractures that show evidence of movement, or such an area composed of breccia or fault gouge.
Geologic Repository	A facility designed for underground disposal of spent nuclear fuel and high-level radioactive waste.
Model	A depiction of a system, phenomenon, or process including any hypotheses required to describe the system or explain the phenomenon or process. The depictions may be conceptual or numerical.
Natural Barrier System	Those natural features of the geologic repository that contribute to containing radioactive wastes and preventing or delaying them from leaving the geologic repository. Natural barriers are items such as the rocks above and below the emplacement area.
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 a drift where scientific experiments can be conducted.
Perched Water	Small bodies of water held above the water table and supported by a relatively impermeable layer of rock.
Performance Confirmation	Assessment activities to confirm that the repository is performing as expected.
Permeability	Measurement of the degree to which a given material or substance will permit the passage of air or water.
Postclosure	The time after the repository is closed (contrast with preclosure).
Preclosure	The time before the repository is closed (contrast with postclosure).
Process Model Report	A report that documents a synthesis of the necessary and sufficient technical information that the Project will be relying upon to support its site suitability evaluation and the licensing safety case pertaining to a particular process model.
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.
Recharge	Water that flows into an aquifer and replaces, or recharges, water that is lost from the aquifer by pumping or natural discharge.
Repository Block	The geologic structure (i.e., block of rock) inside of which the emplacement area would be constructed.
Repository Horizon	The stratigraphic horizon in which the potential repository might be constructed.

Glossary Item	Definition or Explanation
Saturated Zone	The subsurface zone below the water table in which all void space is filled with water at a pressure greater than the pressure of the atmosphere.
Sensitivity Studies	Studies of models to determine the magnitude of differences in the results of the models that result from changes to the input values. These studies determine how sensitive the results of the model are to changes in the inputs and permit researchers to determine the input factors that most affect the results.
Unsaturated Zone	The volume of earth below the ground surface, and above the water table, in which the void space contains water at less than atmospheric pressure and air at atmospheric pressure.
Vitric	Any pyroclastic material containing at least 75 percent glass.
Waste Form	A generic term that refers to radioactive materials and any encapsulating or stabilizing matrix.
Waste Package	An engineered containment vessel, made of corrosion-resistant materials, in which radioactive material can be stored.
Water Table	The top of the saturated zone below which the rocks are saturated with water, and above which the rocks are not saturated (i.e., the interface between the saturated and unsaturated zones).

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