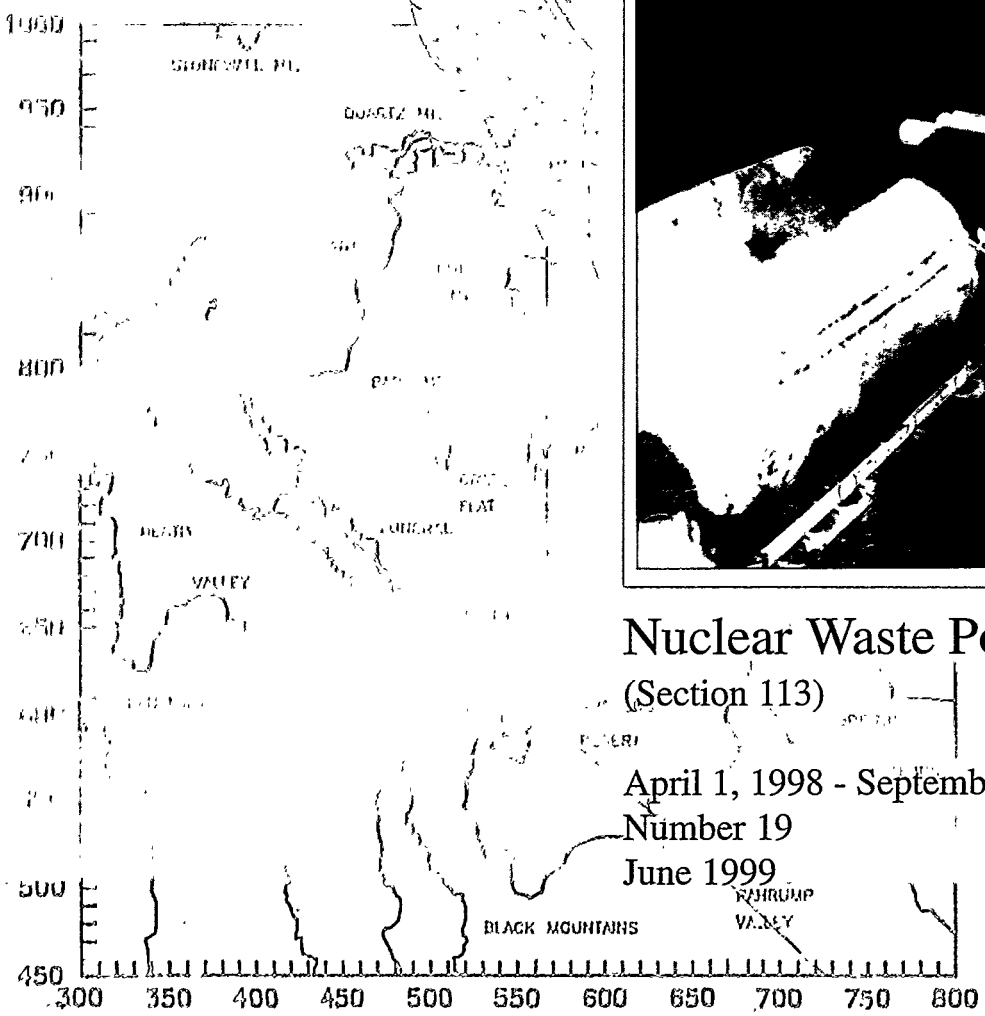
DOE/RW-0512

Site Characterization Progress Report

Yucca Mountain, Nevada



Nuclear Waste Policy Act

(Section 113)

April 1, 1998 - September 30, 1998

Number 19

June 1999

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

PROGRESS REPORT #19

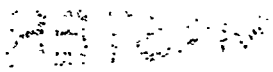
The Nuclear Waste Policy Act of 1982, as amended (NWPA) established the U.S. Department of Energy (DOE) Office of Civilian Radioactive Waste Management (OCRWM). The NWPA directs OCRWM to dispose of the nation's high-level radioactive waste and spent nuclear fuel in a geologic repository, and prescribes other related activities. The NWPA, as codified in U.S.C. 10133 (b)(3) requires a semiannual report on site characterization progress. 10 CFR 60.18(g) requires the report to:

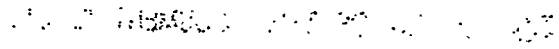
- Describe the progress of site characterization activities and information developed to date
- Identify decision points reached and schedule modifications
- Describe waste form and waste package research and development
- Identify new issues and plans to resolve these issues
- Discuss any planned studies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

This is the nineteenth semiannual progress report issued by the DOE. Like Progress Report 18 (DOE 1998a), this report departs from the highly detailed technical progress reports of the past, in that it 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 DOE's schedule. Greater detail is documented in the cited references and in deliverables listed in Appendix A to this report. Readers may request specific DOE-approved program documents that are listed in Section 6, References, and Appendix A by contacting the OCRWM Information Line at 1-800-225-6972.

This document provides a discussion of recently completed and ongoing activities conducted on the Project during the six-month reporting period. 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 noted in the text as work in progress.

Documentation of Program Change, last published in 1998 as Revision 00 (CRWMS M&O 1998a), provides an update to changes to and status of site characterization activities in relation to the 1988 Site Characterization Plan (DOE 1988). *Documentation of Program Change* (CRWMS M&O 1998a) was previously Appendix A to past progress reports. This document was separated from the progress report for the reporting period of April 1997 through September 1997 and published as reference material on the Project's site characterization program. This document is now planned to be revised annually. Revision 01 of *Documentation of Program Change*, for the reporting period of October 1997 through September 1998, is currently in progress (see Appendix B, Work in progress 1).





[Cover inset photo (YM-18735.jpg) is of a Project scientist examining a core sample under ultraviolet light.]

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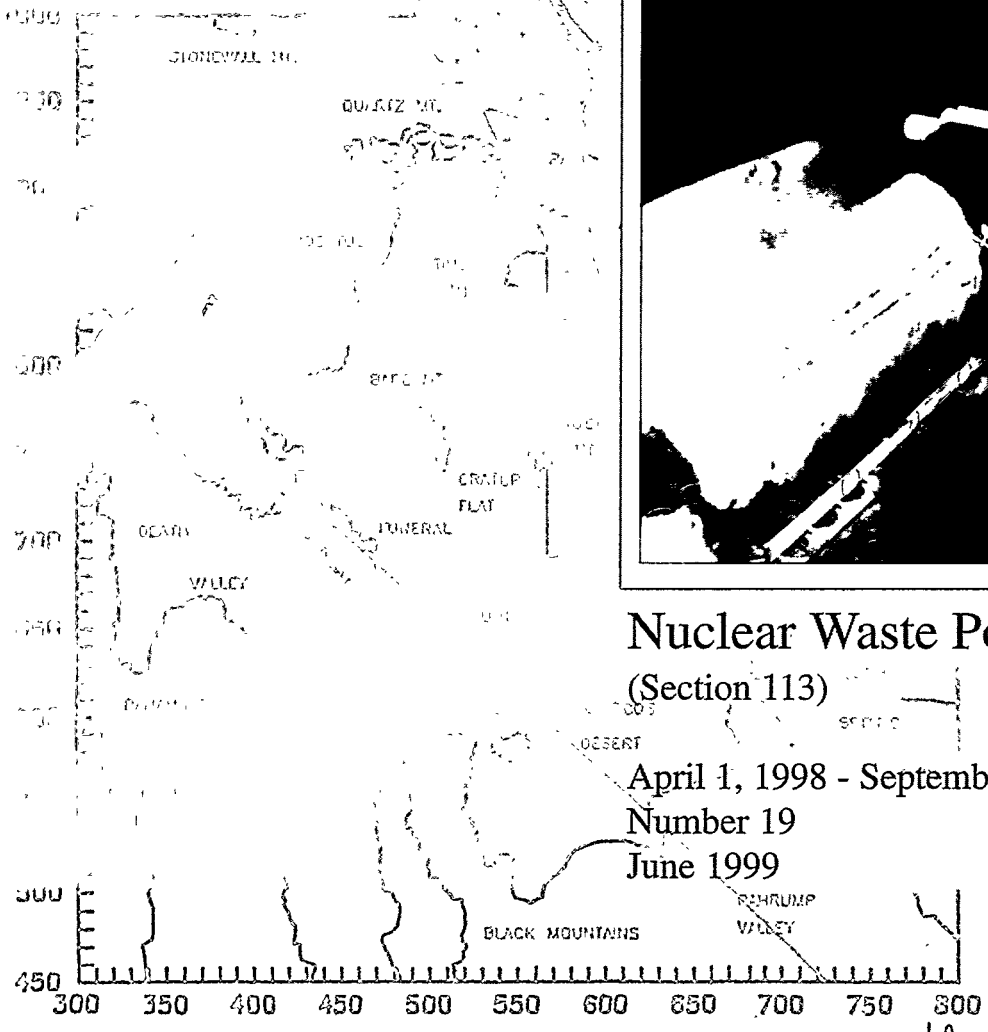

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CONTENTS

LIST OF FIGURES

Page

ACRONYMS

CFR	Code of Federal Regulations
CRWMS M&O	Civilian Radioactive Waste Management System Management and Operating Contractor
DOE	U.S. Department of Energy
EIS	Environmental Impact Statement
ESF	Exploratory Studies Facility
FR	Federal Register
NRC	U.S. Nuclear Regulatory Commission
NWPA	Nuclear Waste Policy Act of 1982, as amended
OCRWM	Office of Civilian Radioactive Waste Management
QA	Quality Assurance
TSPA	Total System Performance Assessment
TSPA-LA	Total System Performance Assessment-License Application
TSPA-VA	Total System Performance Assessment-Viability Assessment
YMP	Yucca Mountain Site Characterization Project

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SECTION 1 – EXECUTIVE SUMMARY

The nineteenth semiannual report of the Yucca Mountain Site Characterization Project (YMP) summarizes activities during the period from April 1, 1998, through September 30, 1998. Project activities are aimed at evaluating Yucca Mountain as a potential location for permanent geologic disposal of nuclear materials, as directed by the Nuclear Waste Policy Act of 1982, as amended (NWPA).

The progress report documents activities this period that contribute to completing the Project's near-term programmatic and statutory objectives. These objectives include completing the Viability Assessment, the Environmental Impact Statement (EIS), a possible U.S. Department of Energy (DOE) Secretarial Site Recommendation to the President, and, if the site is suitable, submittal of a license application to the U.S. Nuclear Regulatory Commission (NRC). Project work this period continued to be concentrated in three integrated activities: site characterization, engineering design and construction, and performance assessment. Accomplishments this period and their relation to near-term objectives are briefly summarized below. The three activities and the near-term objectives are presented in more detail in Sections 2 through 5.

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

For site geology, the Project completed an update to the Geologic Framework Model (GFM3.0), which was used successfully to predict rock stratigraphy in two boreholes and the repository block cross drift. These boreholes and the cross drift are part of continued exploration of the interior of Yucca Mountain (see Figures 1 and 2). The successful predictions have increased confidence in the Project's ability to predict geologic variability at Yucca Mountain, which in turn increases confidence in the models used for water flow and radionuclide transport.

To assess potential thermal effects of the wastes, the drift-scale heater test continued. After 10 months of the planned four years of heating, the drift wall temperatures reached 140°C (284°F). Laboratory tests were also conducted to study flow of heated water in fractured rock. The goal of these tests is to gain an increased understanding and refine models of thermal effects both near the waste packages and on a scale of the entire mountain.

In unsaturated zone testing, scientists working at Busted Butte are studying movement of injected tracer chemicals and using those results to evaluate fluid flow and transport behavior in rock of the Calico Hills Formation. The location of the study area is shown in Figure 2, and the study area is depicted in Figure 3. This same rock formation occurs in the unsaturated zone below the potential repository site and would be a principal barrier to radionuclide migration to the water table. Single borehole tracer tests began ahead of schedule on April 2, 1998, and multi-borehole, large-block tracer tests started on schedule on July 23, 1998. These tests are yielding information that can be used to evaluate how far and how fast key radionuclides may move in the unsaturated zone rocks below the repository.

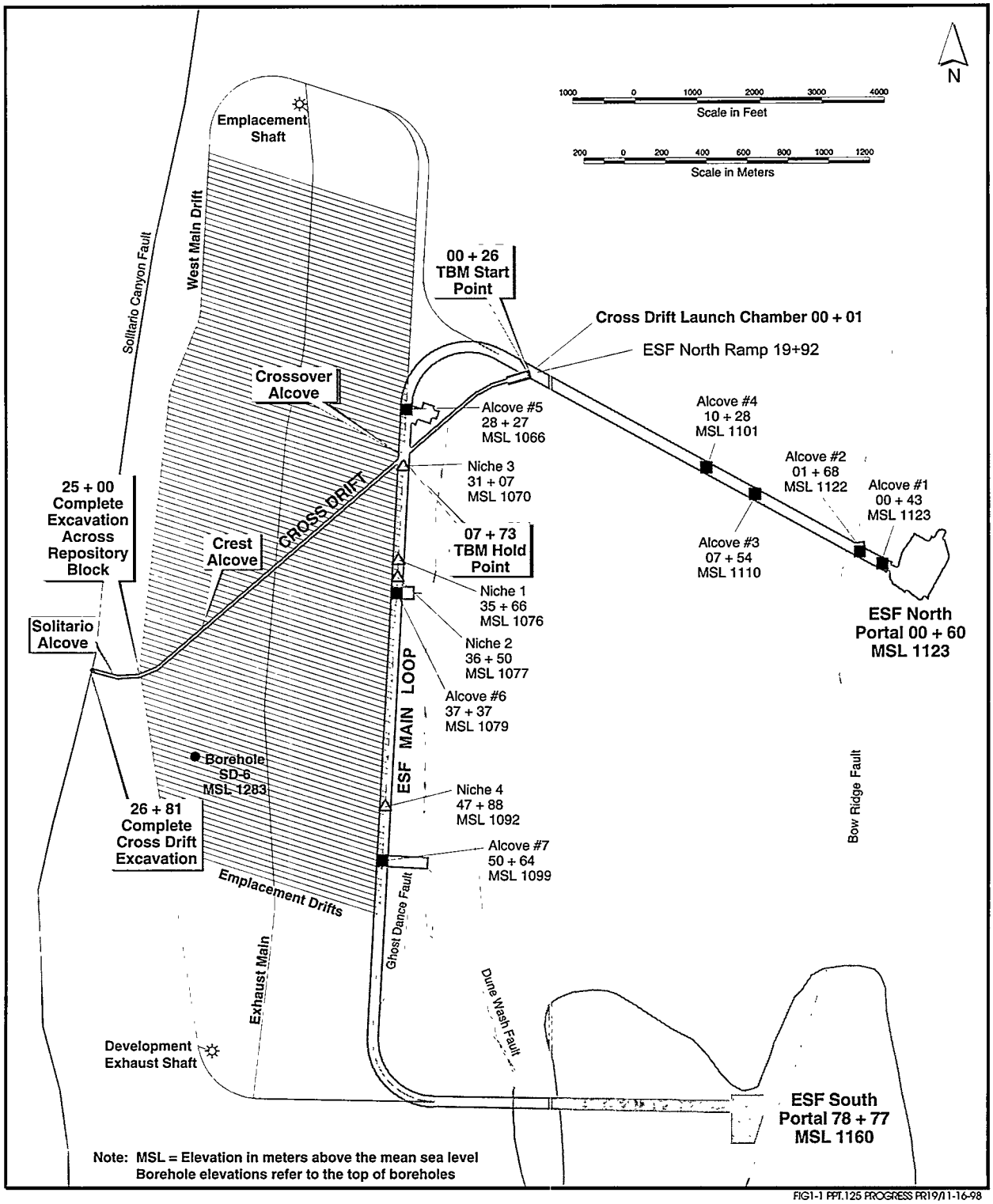

Figure 1. Exploratory Studies Facility, Showing Main Loop and Enhanced Characterization of the Repository Block Cross Drift

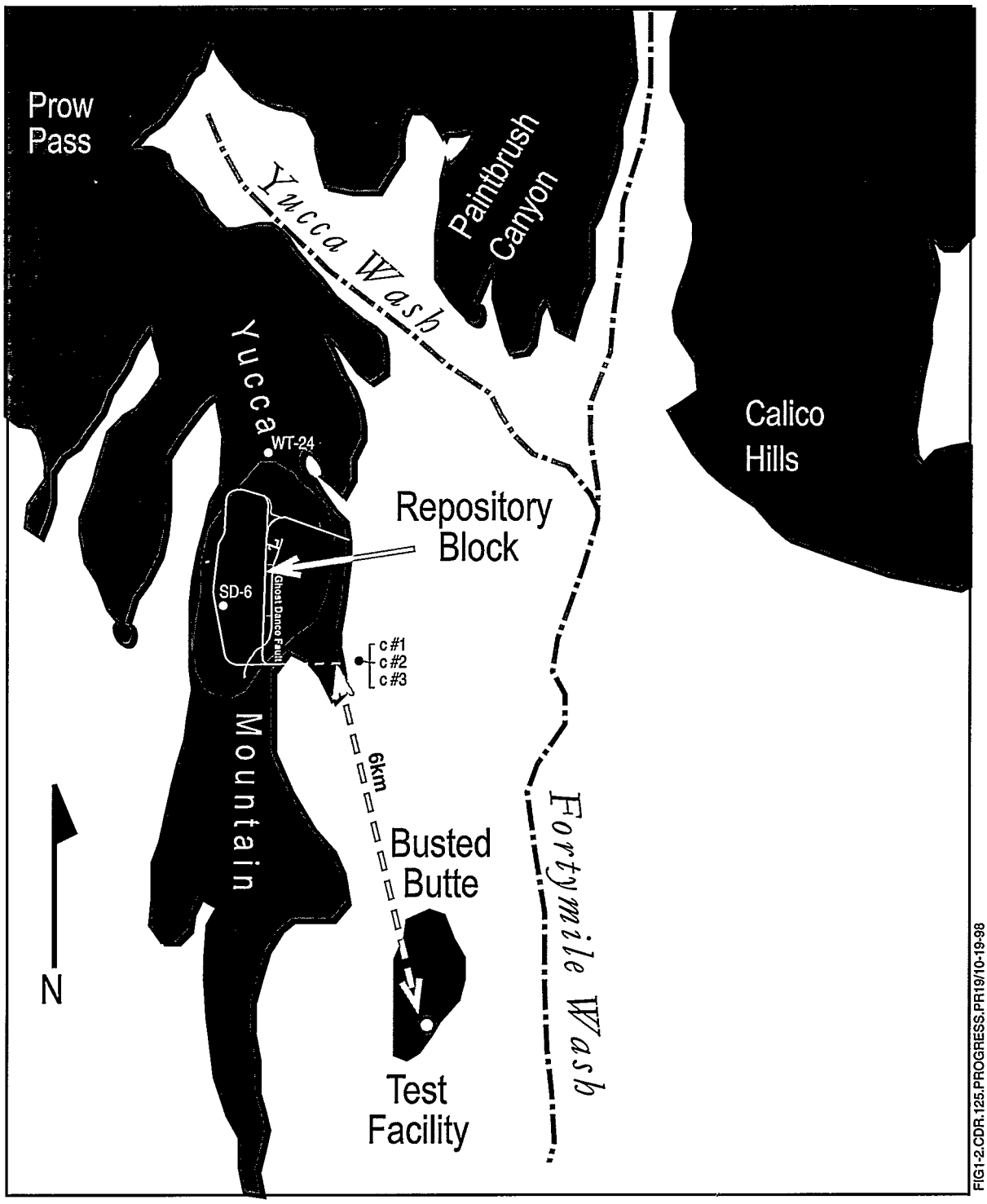

Figure 2. Location of Busted Butte Test Facility, Yucca Mountain, Nevada

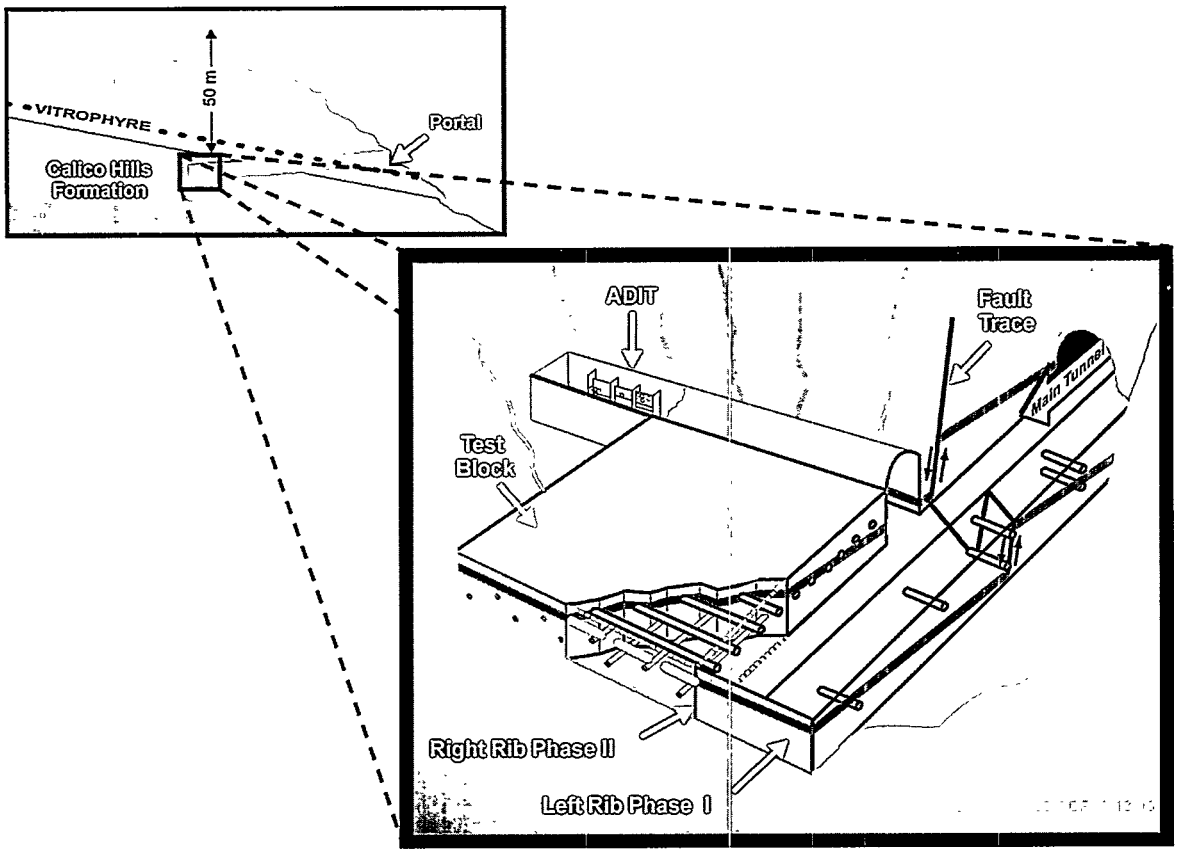

Figure 3. Location of Busted Butte Studies

Additional unsaturated zone tests were conducted in the Exploratory Studies Facility (ESF) to study the relation between infiltration of precipitation into the rock formations above the repository and seepage of water into emplacement drifts. Seepage is a principal factor in assessing repository performance. In one experiment, water was applied to Exile Hill 115 feet (35 meters) above the ceiling of Alcove 1 and recovered in the alcove after 58 days from initiation of application. Recovered water accounted for about 3 percent of total water applied. In another experiment deeper in the mountain, a drip detection system in the Southern Ghost Dance Fault Alcove has detected no water movement at the repository horizon as a result of the El Niño storms of last winter and spring. Other seepage testing in niches has helped determine seepage threshold values (the flux values for a given location at or below which water will no longer seep into the drift), and comparison of field data to modeling results shows good correlation.

In saturated zone testing, chemical tracer injection into the Prow Pass hydrogeologic unit was initiated between different wells in the C-well complex. This unit is the uppermost unit in the saturated zone below the repository. Results of these tests help confirm model predictions regarding fluid flow and transport in the Prow Pass unit.

In other saturated zone studies, evaluations of the oxidation-reduction potential of water from two boreholes indicate that reducing groundwater exists in the vicinity of Yucca Mountain. Reducing groundwater could greatly decrease the transport of technetium and neptunium in the saturated zone.

Engineering Design and Construction–Activities this period centered on completing engineering design work for the Viability Assessment and beginning a study of design alternatives. In addition, testing of waste forms, waste package materials, and construction materials continued, as did ESF construction.

Following completion of design work to support the Viability Assessment, the Project continued design work to support site recommendation and licensing. With support from site characterization and performance assessment activities, studies commenced on design alternatives to the reference design in the Viability Assessment. Design features that could be incorporated into multiple alternative designs are also being evaluated.

Additional work to support a design for site recommendation and licensing included formal revision of the *Controlled Design Assumptions Document* (CRWMS M&O 1998b). Also, the bases for system and subsystem design requirements and criteria continued to be strengthened and verified to ensure that the design for any license application will be defensible.

Waste form testing showed that a large proportion of neptunium could accumulate in a degraded form of uranium oxide, suggesting that the release rate of this important radionuclide could be significantly lower than previously assumed (Stout and Leider 1998). Waste package design progressed with successful demonstrations of remote welding and non-destructive examination of the welds. Shrink fit of two cylindrical shells similar to those under consideration for the waste package was accomplished with a much lower preheat than had previously been demonstrated, which resulted in little oxidation on the contacting surfaces, thus facilitating complete contact (CRWMS M&O 1998c). In other waste package testing, long-term corrosion testing of candidate materials continued. In construction materials testing, laboratory tests were conducted to improve the geochemical stability and strength of concrete that could be used as ground support in the emplacement drifts (CRWMS M&O 1998d).

ESF construction progressed significantly. Excavation of the cross drift was near completion, and the Project completed construction of Niches 3 and 4 in the ESF main drift.

Performance Assessment–Performance assessment activities centered on three topics: postclosure repository performance, preclosure repository performance, and performance confirmation. Work

focused on final development and refinement of the postclosure repository performance for the Viability Assessment and documentation of its technical basis. This performance assessment presents analyses using the Viability Assessment reference design, as well as sensitivity analyses that examine alternative models and parameter sets. Other analyses for the Viability Assessment include consequence analyses for disruptive events and analyses of alternative engineered barrier system designs. These analyses show which factors (such as waste package corrosion rates and net infiltration rates) have the most influence on dose rate during different time intervals. The results of these analyses are assisting design of a repository that will protect the environment and public health and safety, using the best available technology. These results have been used in preparation of the draft EIS.

For preclosure repository performance, preliminary calculations were completed to establish the bounds of internal, seismic, loss of offsite power, and criticality design basis events (CRWMS M&O 1998e). These calculations will provide a basis for future design analyses that will be needed to show compliance with radiological dose limits.

For performance confirmation, the Project prioritized the parameters to be measured, based on the attributes and principal factors of the repository safety strategy, uncertainties, and the need to reduce those uncertainties before repository closure. Performance confirmation activities, which will continue until closure, are conducted to ascertain whether conditions are within the expected range and whether the natural and engineered barriers are performing as expected.

Program Progress and Plans–The Project's work activities are integrated and focused on near-term objectives. A prime example of this integration and focus is the refinement of the postclosure repository safety strategy in support of the Viability Assessment. The strategy is intended to ensure that public health and safety are protected against potential risks posed by the repository in the postclosure period. The strategy helps define technical work needed to support site recommendation and licensing. It will continue to be refined to take advantage of the increasing state of knowledge about the natural systems and the principal factors that will affect postclosure repository performance.

A major effort of the Project during this period was completing a draft of the Viability Assessment. As discussed more fully in Section 5, this five-volume document provides stakeholders an informed assessment of the viability of licensing and constructing a geologic repository at Yucca Mountain. It clarifies the remaining work required to evaluate the site and prepare a license application and provides an estimate of costs to construct, operate, monitor, and decommission a repository. It is essentially a technical status report on the Project's ongoing investigations. Since the close of the reporting period, DOE submitted the document to Congress on December 18, 1998 and distributed it to the public in both electronic (Internet and CD-ROM) and paper media.

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

Following the EIS and after site characterization is complete, the Secretary will decide, with input from the public, states, Native American tribes, and the NRC, whether to recommend approval of the site to the President. A recommendation and a comprehensive statement of the basis for the recommendation would be submitted to the President and provided to the public, as required by the NWPA. In support of that objective, a Site Recommendation Management Plan was completed during this reporting period. The Plan is a "road map" for completing a comprehensive site recommendation statement for submission to the President.

This period, the Project also continued pre-licensing interactions with the NRC to gain assurance that the technical work would be sufficient for inclusion in any license application. In addition to technical meetings, the Project had two meetings on quality assurance. A number of quality assurance (QA) issues were identified. Cross-cutting deficiencies related to traceability of technical data, procurement services, software verification and validation, and model development are being addressed through integrated corrective actions. An appropriate level of resources and management attention will be devoted to ensuring that full compliance with nuclear QA requirements can be demonstrated prior to any site recommendation and license application.

The Project also continued development of the technical guidance for preparing a license application (YMP 1998d) and preparatory work to support a working draft license application outline in Fiscal Year 1999. The primary purpose of this work is to establish a workable process to support subsequent development of a license application to be submitted to the NRC.

The Eighth International Conference on High-Level Radioactive Waste Management was held in Las Vegas, Nevada on May 11 through 14, 1998. DOE/OCRWM sponsorship of these conferences provides not only a valuable forum for scientific discussion, but also a published proceedings volume for future reference and use by the scientific community. The proceedings of the conference have been published by the American Nuclear Society (1998).

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SECTION 2 – SITE CHARACTERIZATION

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

2.1 GEOLOGIC INVESTIGATIONS

Geologic Framework Model /Integrated Site Model–The Geologic Framework Model (GFM3.0) was completed: qualification is expected by the end of Fiscal Year 1999. GFM3.0 updates the previous geologic framework models, including a new set of correlated, standardized borehole stratigraphic data and the site area geologic map (Day, Dickerson et al. 1998; Day, Potter et al. 1998). The resulting model successfully confirmed predictions of stratigraphy in boreholes USW WT-24 and USW SD-6, and the Enhanced Characterization of the Repository Block Cross Drift. The testing of GFM3.0 with information from the new boreholes and drift has increased understanding of geologic variability in Yucca Mountain and confidence in the Project's predictive capabilities using the model.

The Integrated Site Model (ISM3.0, EARTHVISION V.4.0, 30035 V.4.0, SGI) was completed. ISM3.0 is the integration of the geologic framework with rock properties and mineralogical models, which have been updated with new data using refined modeling techniques. Components of the Integrated Site Model have been written in a format that can be read by software for use in fluid flow and transport and design modeling activities; documentation of ISM 3.0 is scheduled for completion in mid-year 1999 (Appendix B, Work in progress 2).

Enhanced Characterization of the Repository Block Cross Drift–The cross drift geotechnical mapping was completed to station 24+00. Steel-set supports and full steel lagging were required in the Solitario Canyon fault zone at the west end of the drift, but only rock bolts and wire mesh were needed in the rest of the drift. The station locations of stratigraphic contacts and faults are close to predictions from GFM3.0. A few unpredicted faults, having offsets estimated to be 3 meters to greater than 5 meters, were encountered in the western half of the block and contributed to differences from predictions. The faults are not apparent at the ground surface and are thought to be older than the Tiva Canyon Tuff, which would indicate that there has been no movement on these faults during the last 12 million years. Documentation of this work is scheduled for completion in mid-Fiscal Year 1999 (Appendix B, Work in progress 3).

Geologic Field Investigations–A preliminary version of the 1:50,000-scale geologic map for the site saturated zone flow model was completed and submitted for U.S. Geological Survey review this reporting period. Preparation of cross sections, subsurface structure maps, and descriptive text continued. The map is due for completion in mid-Fiscal Year 1999 (Appendix B, Work in progress 4).

Drilling of borehole USW WT-24 reached a depth of 2,834 feet (864 meters), which is 1,065 feet (324 meters) into the Calico Hills Formation. The borehole is located north of the ESF in the area of the large hydraulic gradient. Drilling of borehole USW SD-6 was paused at a depth of 2,541 feet (774 meters) on May 7, 1998; no perched water was encountered at this borehole location. The borehole is located on Yucca Crest at the western edge of the proposed repository footprint. A decision whether or not to continue drilling is pending. Analysis of the lithostratigraphy and geophysical logs of both boreholes is underway and will be incorporated into updates of the Geologic Framework Model and the Integrated Site Model. These stratigraphic data provide better control than previous estimates of depths to the proposed repository horizon and the saturated zone.

2.2 ALTERED-ZONE AND NEAR-FIELD ENVIRONMENT

Thermal Tests–The primary objective of the thermal tests in the ESF is to gain an in-depth understanding of the coupled thermal-mechanical-hydrological-chemical behavior anticipated in the local rock mass surrounding the potential repository site at Yucca Mountain. Results from the thermal tests will provide input to near field process and performance assessment abstraction models as well as repository and waste package design. During this last six-month period, Drift Scale Test activities included the preparation of a progress report (CRWMS M&O 1998f). Test results indicated that temperatures along the drift wall have reached 140°C (284°F) after 10 months of heating. Water collected from the Drift Scale Test block is currently being analyzed. Two quarterly thermal test workshops were also held during this period in which updates of the most recent sets of measurements and predictions were presented and discussed. Activities for the next six-month period include continued data collection, numerical simulations, and conducting two workshops. Activities for the Large Block Test will include post-test characterization, analyses, and preparation of a final report (Appendix B, Work in progress 5).

Near-Field/Altered-Zone Models–The near-field models program has continued to refine models of the thermally driven processes that will affect repository performance. The movement of water in the host rock and the chemical environment in the repository are simulated using state-of-the-art modeling tools. To validate such tools for use in predicting conditions far in the future, key aspects of the models are tested in experiments such as the Drift Scale Test. For some aspects, laboratory experiments have proven to be effective for model validation, and several such experiments were conducted this period to evaluate the nature and rate of interaction of water with the rock. For example, the program completed a set of experiments in which the flow of water in a heated sample of fractured rock was observed in real time using x-ray and thermal imaging techniques. Data from these will be documented in a future report (Appendix B, Work in progress 6).

Further applications of the near-field models to performance assessment were developed, particularly in the evaluation of mountain-scale effects of heating. A modeling tool was developed to efficiently predict environmental conditions inside the repository drifts, at any location within the repository layout. This tool, called the multi-scale abstraction tool, is described in the *Near-Field/Altered Zone Models Report* (Hardin 1998). The multi-scale abstraction tool was verified by comparison to mountain-scale simulations, and sensitivity analyses were conducted to refine the values used for thermal-hydrologic properties in repository simulations (Buscheck et al. 1998). In another activity, sensitivity analyses were conducted to refine the values used for thermal-hydrologic properties in repository simulations.

2.3 SITE UNSATURATED ZONE FLOW AND TRANSPORT

Busted Butte Test–The Busted Butte test is designed to generate spatial and temporal scaling information about unsaturated zone flow and transport of key radionuclides (technetium, iodine, neptunium, uranium, and colloidal plutonium) in the non-welded rocks below the repository. Data generated from this test will feed unsaturated zone flow and transport process models, as well as performance assessment abstraction models for site recommendation and license application. Single borehole (Phases 1a and 1b) tests with nonradioactive tracers began ahead of schedule on April 2, 1998. In the 10 milliliters-per-hour Phase 1b collection borehole, tracer breakthrough occurred in 30 days (30 centimeters of travel). From May to July construction design was completed, which allowed the multi-borehole (Phases 2a, 2b, and 2c) large block tracer tests to be started on schedule on July 23, 1998. Tracer breakthrough has occurred in the Phase 2b collection boreholes. Predictions of tracer mobility, generated in July 1998, for the Phase 2 tests will be verified and updated in Fiscal Year 1999. Excavation of the Phase 1 tests to determine partial distributions of reactive and non-reactive tracers is scheduled to begin in early Fiscal Year 1999 (Appendix B, Work in progress 7).

Exploratory Studies Facility Alcove and Niche Studies–On March 6, 1998 a controlled experiment began to determine the infiltration rate and travel time through the Tiva Canyon Tuff from the surface (Exile Hill) to the ESF-Upper Tiva Canyon Alcove. After 58 days, bromide-tagged water began dripping into the alcove, which is about 115 feet (35 meters) below land surface. This initial time period for water penetration likely was caused by the initial wetting-up of the water-flow pathway in the highly fractured and fairly dry Tiva Canyon Tuff. Data from the electromagnetic equipment used to monitor infiltration at the surface indicated that the column of water moved directly downward with little lateral migration. There is no evidence of structural control on water flow in the Tiva Canyon Tuff, which is the uppermost bedrock unit at the site. As of the end of August 1998, 63,375 gallons (239,875 liters) of water had been applied to an area 40 feet by 40 feet (12.2 meters by 12.2 meters) at the surface (which is equivalent to approximately 64 inches (162 centimeters) of rainfall on this area) and 1,899 gallons (7,188 liters) had been collected from approximately 146 collection trays inside the alcove. Further tracer testing and monitoring of this experiment is planned to determine the relationship between infiltration and seepage (Wang et al. 1998, Chapter 5).

Preliminary results of three-dimensional cross-hole gaseous tracer testing conducted in the Northern Ghost Dance Fault Alcove indicate that the effective porosity is 1 to 2 orders of magnitude larger than the estimated fracture porosity values. Consequently, this suggests that particle transport times will be 1 to 2 orders of magnitude longer than times calculated using fracture-porosity estimates.

Despite being in place since December 1997, the drip-detection system installed in the Southern Ghost Dance Fault Alcove has detected no water dripping from the ceiling of the alcove. The alcove, which is about 650 feet (200 meters) below land surface, was sealed in an attempt to observe natural percolation of water resulting from the El Niño storms of last winter and spring, to the depth of the potential repository.

Pre-excavation air-permeability tests and liquid-release tests were completed at Niche 3 (31+07) and Niche 4 (47+88) in the ESF. Forty liquid-release tests were performed on 16 test intervals positioned above Niche 2 (36+50) to determine the seepage threshold flux, defined as the liquid-release flux at or below which water will no longer seep into the drift (Wang et al. 1998, Chapters 1 and 2). Seepage threshold fluxes, quantified for 10 out of the 16 test intervals that seeped, ranged from 6.35×10^{-9} to 4.31×10^{-6} meters per second. Analyses of seepage threshold and wetting front arrival time data suggested that the porosity of certain seepage flow paths could be as large as 2.4 percent (Wang et al. 1998, p. 1-9). Multiple liquid release tests were conducted in one high-permeability zone and one low-permeability zone in the fracture/matrix test bed in the Northern Ghost Dance Fault Alcove. The borehole test intervals were approximately 5.3 feet (1.6 meters) above the 6.6 feet (2 meters) wide slot excavated to capture the water released during the test. Preliminary results from liquid-release tests and modeling studies indicate that for quasi-steady releases into one high-permeability zone, approximately two-thirds of the fluid flux was through active fracture flow paths, and the remaining one-third was retained in the formation above the slot (Wang et al. 1998, p. 1-10).

Unsaturated Zone Modeling–Recent modeling studies from land surface to the water table have updated the understanding of unsaturated zone flow and transport. Significant improvements in simulating infiltration have been accomplished. One of the key features evaluated this reporting period is lateral flow of groundwater in the unsaturated zone. Lateral flow of water occurs along stratigraphic contacts where a relatively lower permeability zone underlies a more permeable zone. There are two major zones of lateral diversion in Yucca Mountain: 1) from the bottom of the Paintbrush nonwelded hydrogeologic unit to the top of the Topopah Spring welded hydrogeologic unit, and 2) from the top of the Calico Hills nonwelded hydrogeologic unit to the water table. These zones can cause a focusing of flow, resulting in percolation fluxes at particular locations higher than the surface infiltration rate and reaching nearly 40 millimeters per year (Wu et al. 1997, p. 13). This work on lateral flow in the unsaturated zone was

scheduled to be documented in milestone deliverable SP3CKFM4, Letter Report: PTn and CHn Lateral Flow Model. However, the results of this work are now planned to be reported in milestone deliverable SP3538M3, scheduled for delivery to the DOE in January 2000 (Appendix B, Work in progress 8). The work on unsaturated zone flow in faults is referenced to the same document.

Another feature evaluated is the role of fault zones on flow. Based on testing data at the Ghost Dance fault, faults are generally more permeable than the surrounding material. Within and above the Topopah Spring welded hydrogeologic unit, flow is limited in the fault zone because the fault functions as a capillary barrier. Below the Topopah Spring welded hydrogeologic unit, the fault becomes less permeable (but still more permeable than the surrounding rock) and serves as a preferential pathway to structural traps for perched water. The significance of this work is that faults spatially focus the surface infiltration. Model analysis of these features has refined knowledge of the spatial variation in percolation at depth. The Project will continue to enhance the conceptual and numeric models of the site in Fiscal Year 1999. Refinements will include representing the features described above at a finer degree of resolution and considering the results of recently collected testing information.

Enhanced Characterization of the Repository Block–This period, the Project began moisture monitoring in the Enhanced Characterization of the Repository Block Cross Drift. Available cross drift construction data (daily Tunnel Boring Machine advance rates, water use in the cross drift, and changes to the ventilation system) were compiled and will be used to calculate the amount of water lost from the cross drift due to evaporation. That information, combined with the Tunnel Boring Machine water-migration data, is being used to determine the loss of construction water relative to formation water. To date, 21 horizontal HQ-size (4 inches diameter) drill holes 6.6 feet (2 meters) deep have been drilled in the walls of the cross drift and monitored for moisture content using a neutron-moisture meter. Water potential and wetting front signals from cross drift excavation were detected at least 15.5 feet (4.7 meters) in depth and could be up to 36.6 feet (11.1 meters) in depth near the cross drift starter tunnel. No seepage was observed in the ESF main drift, 57.7 feet (17.5 meters) below, when the Tunnel Boring Machine passed over the drift. This work was documented as part of Milestone Report SPH361M4 (Memorandum "Milestone SPH361M4" from D. Hudson (U.S. Geological Survey) to R. Craig (U.S. Geological Survey) on October 19, 1998. DTN: GS980908312242.036: Moisture Monitoring in the ECRB from 04/08/98 to 07/31/98. ACC: MOL.19981125.0225).

2.4 SITE SATURATED ZONE FLOW AND TRANSPORT

C-holes Testing–Testing in the Prow Pass welded hydrogeologic unit is important to assessing repository performance because this unit is the uppermost hydrogeologic unit in the saturated zone immediately downgradient from the potential repository. In mid-June, a conservative tracer test from borehole UE-25 c#3 to UE-25 c#2 was started by injecting sodium iodide and 2,4,5-trifluorobenzoic acid into UE-25 c#3 while UE-25 c#2 continued to be pumped. Forty hours after the injection, the tracers were found in water pumped from UE-25 c#2. According to preliminary data, the peak for the trifluorobenzoic acid breakthrough curve occurred after about six days, whereas the iodide peak occurred after eight days. In late July, 2,3,4,5-tetrafluorobenzoic acid was injected into borehole UE-25 c#1 to initiate a primarily convergent tracer test from UE-25 c#1 to UE-25 c#2 (Appendix B, Works in progress 9 and 10).

Saturated Zone Redox Measurement–This period, the Project completed studies of the oxidation-reduction potential of saturated zone waters from wells UE-25 WT#3 and UE-25 WT#17. Results from UE-25 WT#17 indicate that reducing groundwaters exist at Yucca Mountain. Reducing conditions in the saturated zone greatly decrease the transport of the problem radionuclides technetium and neptunium. This information is being used in performance assessment calculations to obtain parameter values for the saturated zone flow and transport model (Appendix B, Work in progress 11).

Saturated Zone Flow and Transport Modeling–Progress continues in developing the new site-scale saturated zone flow and transport model, which is used for Total System Performance Assessment (TSPA). The numerical grid was refined from 4,950 feet (1,500 meters) to 1,650 feet (500 meters), and recently acquired hydrogeologic data, hydrochemical data, chemical and biochemical data, and transport data are being incorporated. Future improvements will include incorporating new data to develop a credible and defensible saturated zone flow and transport model for use in a site recommendation and license application (Appendix B, Work in progress 12).

Large Hydraulic Gradient–Since encountering the water-filled fracture at a depth of 2,492 feet (760 meters) below land surface on May 12, 1998 in the USW WT-24 borehole, no other water-bearing fractures have been encountered. While this fracture was open to the borehole, the water level rose to a depth of 2,172 feet (662 meters) below land surface, but it is inconclusive whether equilibrium of the water table, or connection with the regional water table, had been achieved when drilling resumed. Further characterization of the aquifer is planned, and the site-scale model will be used to test the perched-water table conceptual model scenario against the large hydraulic gradient scenario to see if the different conceptualization results in any difference in the flow field configuration.

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SECTION 3 – DESIGN AND CONSTRUCTION

The Project continued to develop and refine the documents that establish and form the hierarchical structure for repository design requirements. To this end, the Project completed or revised several analyses to substantiate or resolve assumptions related to requirements and criteria.

The Project progressed in consolidating and enhancing the technical requirements that form the basis for license application design by:

- Developing thirty System Description Documents (CRWMS M&O 1998g through 1998aj) to consolidate the license application design requirements.

- Revising the *Controlled Design Assumptions Document* (CRWMS M&O 1998b) to assure consistency with assumptions that will be reflected in the Viability Assessment.

- Completing the *Preliminary Preclosure Design Basis Event Calculations for the Monitored Geologic Repository* report (CRWMS M&O 1998e), which identified internal, seismic, loss-of-offsite power, and criticality design basis events as defined in the Code of Federal Regulations (CFR) Title 10, Part 60 (10 CFR 60) and as defined in a new regulation being developed by the NRC, 10 CFR 63 (see the Federal Register (FR), volume 64, for February 22, 1999, 64 FR 8640) for the repository radiological systems or areas. It also provides a basis for future design analyses to support a site recommendation and license application.

- Revising QAP-2-3, *Classification of Permanent Items* (CRWMS M&O 1998ak), to remove from the *Q-List* (YMP 1998a) QA classification categories for items required for physical protection and items required to control occupational radiation exposure.

The Project began a study of design features and design alternatives that will be a basis for selecting the license application reference design. Features are design enhancements that can be easily incorporated within multiple alternative designs; alternatives involve significant changes to the fundamental concepts on which the Viability Assessment is based. Each has the potential for improving repository performance, simplifying the safety strategy, or both. A constructability analysis, begun in the previous reporting period, was completed and will be used as the basis for study of several design features.

3.1 REPOSITORY

The Project completed all design work required to support the Viability Assessment. Efforts were then turned to refining the Viability Assessment concepts to develop an acceptable design to support a site recommendation and license application.

In subsurface design, completed laboratory testing showed that the addition of silica fume may be effective in reducing concrete pH to increase the long-term geochemical stability of the repository (CRWMS M&O 1998d, p. 8). Superplasticizers would be used to counter workability effects of the silica fume on the concrete mix. The testing showed that organic compounds are unlikely to decompose and leave the concrete as CO_2 at temperatures up to 200°C (392°F) (CRWMS M&O 1998d, p. 29). Lack of CO_2 development means that carbonation of the concrete will probably not be caused by decomposition of superplasticizers in the emplacement drifts. A laboratory testing program was started to determine thermomechanical properties of concrete for use as ground support in emplacement drifts. The testing will evaluate the ability of concrete to retain adequate strength and stiffness for the anticipated range of

repository temperatures and loads. An analysis of heating and cooling cycles (CRWMS M&O 1998al, p. 39) showed that there is no need to limit the number and magnitude of these cycles as an effort to maintain overall stability of emplacement drifts. Multiple cycles of heating and cooling in the emplacement drifts can produce increased stress and deformation in the rock and ground support systems, but, based on the information used in the model, did not produce failure.

In surface design, the Project completed one technical report (CRWMS M&O 1998am) and prepared a total-system life-cycle cost estimate to support the Viability Assessment. To support development of the design for license application, the Project completed one design analysis (CRWMS M&O 1998an) and four technical reports (CRWMS M&O 1998ao, 1998ap, 1998aq, and 1998ar) involving waste handling system, equipment, and resources studies and simulations.

3.2 WASTE PACKAGE

Waste package closure weld development proceeded with demonstrations of remote welding and successful non-destructive examinations of two sets of container lids. Shrink-fit was accomplished with a much lower preheat, which resulted in little oxidation on the contacting surfaces and ultrasonic inspection of this interface showed 100 percent contact (CRWMS M&O 1998c).

The Project developed 12-PWR and 21-PWR thermal-analysis models for waste package designs and performed initial evaluations of the temperature distributions (CRWMS M&O 1998as). Calculations were performed for developing conceptual designs for the 5-HLW/DOE Spent Fuel waste package and the 5-HLW/DOE Spent Fuel-Long waste package (CRWMS M&O 1998at). The *Disposal Criticality Analysis Methodology Topical Report* neared completion (CRWMS M&O 1998au). A set of loading curves was developed for commercial pressurized-water reactor spent nuclear fuel based on the topical report burnup credit methodology. The loading curves demonstrate the capabilities of each of the criticality control measures (CRWMS M&O 1998au, Figure C-27a and Figure C-27b). A criticality evaluation of a degraded model of the 44-BWR waste package was performed. The evaluation indicated that the methodology outlined in the topical report works smoothly (CRWMS M&O 1998au, p. ix).

The Project completed Revision 01 of the *Evaluation of Codisposal Viability for Aluminum-Clad DOE-Owned Spent Fuel: Phase II Degraded Codisposal Waste Package Internal Criticality* report (CRWMS M&O 1998av). This report documents analyses of the first of nine DOE-owned spent fuel types, and includes optimization of the criticality control material, using insoluble gadolinium phosphate for neutron absorption (CRWMS M&O 1998av, p. v). The Project also completed the two-volume *Report on Intact and Degraded Criticality for Selected Plutonium Waste Forms in a Geologic Repository, Volume I: MOX SNF* and *Volume II: Immobilized In Ceramic* (CRWMS M&O 1998aw).

The Project completed Revision 1, Version 1.3, of the *Waste Form Characteristics Report* (Stout and Leider 1998). Flow-through tests on high-burnup spent fuel and glass waste forms continued. The estimated U:Np ratio in dehydrated schoepite (a partially hydrated form of uranium oxide) from unsaturated drip tests on spent fuel indicates a large proportion of neptunium accumulates in the alteration product. This finding suggests the release rate of this crucial radionuclide may be significantly lower than previously thought. Two new test series were initiated: the High Surface-Area-to-Solution Volume Batch Tests (to accelerate the results of the unsaturated drip tests) and the Clad Fuel Drip and Vapor Tests (to determine whether alteration of the fuel in unsaturated and vapor conditions will split the fuel cladding). This work in progress has been discussed in an Activity Plan (Stout 1998). Development continues on film-flow release-rate models for the spent-fuel unsaturated drip-tests.

Corrosion testing of candidate materials continued. Additional specimens were acquired and installed for exposure in the large chambers maintained under controlled temperatures and humidity levels. The

Project initiated an experimental study for measuring the composition of the ionic salts as they concentrate on heated metal surfaces. This study has been discussed in an Activity Plan (Gdowski 1998). Testing started on Alloy C-22 and titanium specimens under controlled slow-strain rates. These tests are described in an Activity Plan (Roy 1998). The Project completed the Viability Assessment update for the *Engineered Materials Characterization Report* (McCright 1998). The report provides all of the test results and performance models generated in the past two years.

3.3 EXPLORATORY STUDIES FACILITY

The Project completed designs for Test Niches 1 and 2 in the Enhanced Characterization of the Repository Block Cross Drift (CRWMS M&O 1997a). The Project completed construction of Niches 3 and 4 in the ESF main drift and 2,578 meters (8,460 feet) of excavation of the cross drift in the repository block. Completion of the cross drift is expected early in Fiscal Year 1999. The cross drift starts at a position 1,992 meters (6,536 feet) from the beginning of the North Ramp and is planned to extend 2,823 meters (9,262 feet) southwest across the repository block.[1] In addition, final construction was completed supporting the Drift Scale Test in the Thermal Testing Facility.

[1] Cross Drift excavation ended on October 13, 1998, at a location 2,681 meters (8,796 feet) into the cross drift. While this location is short of that planned, excavation is sufficient to obtain needed information.

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SECTION 4 – REPOSITORY PERFORMANCE

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

4.1 PRECLOSURE RADIOLOGICAL SAFETY ASSESSMENT

Preclosure radiological safety input is required to support ongoing project studies and documents. To provide that input, the Project issued an engineering calculation and a procedure revision. The engineering calculation, *Preliminary Preclosure Design Basis Event Calculations for the Monitored Geologic Repository* (CRWMS M&O 1998e), identifies bounding internal, seismic, loss of offsite power, and criticality design basis events that must be considered in the design of the Monitored Geologic Repository radiological systems. This calculation provides a basis for future design analyses that must demonstrate compliance with applicable radiological dose limits. It also includes calculations for event scenario frequencies and dose consequences at the proposed site boundary.

Procedure QAP-2-3, *Classification of Permanent Items* (CRWMS M&O 1998ak), was revised to remove from the *Q–List* (YMP 1998a), items required for physical protection and items required to control occupational radiation exposure. The resultant changes will be reflected in a revision to *Classification of the Preliminary MGDS Repository Design* (CRWMS M&O 1997b). The changes will also provide input to the design bases for structures, systems, and components.

4.2 POSTCLOSURE PERFORMANCE ASSESSMENT

The focus of this reporting period has been on final development and refinement of the approach, methodology, and technical basis for assumptions and results of the Total System Performance Assessment–Viability Assessment (TSPA-VA) (DOE 1998b) and the supporting TSPA Technical Basis Document. Analysts interacted with document production staff and reviewers on several progressively refined versions of these documents. Revision 1 of the final TSPA-VA document is in production and the Technical Basis Document is under review. The Revision 1 base case results and sensitivity analyses for the TSPA-VA were presented to the Nuclear Waste Technical Review Board in Albuquerque, New Mexico on April 23-24, 1998.

TSPA-VA products documented in Revision 1 include: (1) a set of deterministic and probabilistic analyses representing the "base-case" parameters and models for the Viability Assessment reference design, (2) sensitivity analyses on the reference design that examined less likely alternative models and parameters sets, (3) consequence analyses for the effect of disruptive events, and (4) analyses of alternative engineered barrier system designs. The deterministic base-case analyses used a single realization of the input parameters to produce one typical dose history of future behavior over three time periods: 10,000 years, 100,000 years, and 1,000,000 years into the future. Significant results of TSPA-VA analyses include determination of which factors (Alloy 22 corrosion rates, net infiltration rates, etc.) have the most influence on dose rates during different time intervals. This information will be useful in conducting site and design activities as the Project enters the license application phase.

Near-field geochemical environment analyses provided water compositions modified from interactions with concrete as input to TSPA-VA sensitivity analyses. The near-field geochemical environment studies used process-level sensitivity analyses to assess the growth of microbes in the drifts and the types and amounts of salt deposits on a waste package (CRWMS M&O 1998ax).

The waste package degradation model was developed for TSPA-VA using information that included the waste package degradation expert elicitation (CRWMS M&O 1998ay) and the Project's corrosion testing and modeling programs (McCright 1998). Waste package degradation in the potential repository was simulated with WAPDEG (WAPDEG V.3.06, 30048 V.3.06, HP and PC), Waste Package Degradation, (CRWMS M&O 1998az). Improvements to the preliminary zircaloy cladding model and colloidal transport model were integrated into the base-case analyses, and the waste-form models incorporated analyses of DOE-owned spent nuclear fuel and plutonium disposition waste forms (CRWMS M&O 1998ba).

Sensitivity studies for unsaturated zone transport were conducted for TSPA-VA to assess the effects of matrix diffusion, infiltration, sorption, rock type, dispersion, and conceptual flow models in three-dimensional unsaturated zone transport simulations. Unsaturated zone transport simulations were also performed to investigate the effects of release location within the repository block on travel times and pathways to the water table (CRWMS M&O 1998bb).

Sensitivity analyses for saturated zone flow and transport were completed for the TSPA-VA. Issues addressed in saturated zone sensitivity analyses included dual-porosity transport in fractured tuff, heterogeneity and flow channelization, and modeling of kinetic processes in colloid-facilitated plutonium transport. Documentation of base case and sensitivity analyses for the saturated zone was completed for both the TSPA-VA and the Technical Basis Document (CRWMS M&O 1998bc).

Biosphere modeling activities conducted for TSPA-VA included completion of a parametric sensitivity study of the modeling input parameters. Findings provided information on important modeling uncertainty parameters that can be used to support future allocation of modeling resources. Sensitivity studies included a comparative assessment of the relative importance of individual pathways to total exposure (CRWMS M&O 1998bd).

Disruptive events analyses refined the model for magmatic interactions with waste packages, an interaction which could potentially increase the chances of breach. The criticality analysis was re-done to provide information that could be used by the CRWMS M&O Waste Package Development Group (CRWMS M&O 1998be).

The Project has been undergoing a transition toward implementing QA procedures that are compliant with the DOE OCRWM *Quality Assurance Requirements and Description* (DOE 1998c). *QA Processes for TSPA-LA Development Report* (CRWMS M&O 1998bf) documents the strategy, planning, and implementation to date of the application of the QA program to the Total System Performance Assessment–License Application (TSPA-LA) activities.

Extensive support to determine potential environmental impacts for the repository EIS (Appendix B, Work in progress 13) continues. Preliminary results are being integrated into the preliminary draft EIS. As modeling and results mature, new results will be incorporated in either the draft EIS or the final EIS, depending on the availability of such new results.

4.3 PERFORMANCE CONFIRMATION

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

This period, the Project developed bases for criteria related to performance confirmation facilities and equipment, and substantiated System Description Documents criteria (CRWMS M&O 1998m, Volume II, p. 3 to 10). The performance confirmation program cost estimate also was finished (DOE 1998d, Appendix E, p. E1 to E10). A performance confirmation parameter reassessment established an initial prioritization for performance confirmation parameters. The prioritization considered attributes of the repository safety strategy, significance of uncertainties in TSPA factors, and confidence goals for these factors at the time of closure. This reassessment will be refined to address the license application design selection and used to update the *Performance Confirmation Plan* (CRWMS M&O 1997c), which is planned for July 30, 1999 (Appendix B, Work in progress 14).

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SECTION 5 – PROGRESS TOWARD NEAR-TERM OBJECTIVES

During the reporting period, Project activities supported the near-term objectives. This section describes how the activities discussed in Sections 2 through 4 of this report relate to the Viability Assessment, the EIS, a site recommendation, and licensing. In addition to the activities discussed below, the repository safety strategy, previously described in the Repository Safety Strategy document (YMP 1998b), was revised and included in the draft Viability Assessment. This strategy takes into account the additional information about the site acquired over the past six months and a focused set of issues. The strategy defines the technical work needed to complete the postclosure safety case. It also defines design decisions that need to be made to support a site recommendation and a license application, should the site be found suitable.

5.1 VIABILITY ASSESSMENT

The Energy and Water Development Appropriations Act, 1997 (Public Law No. 104-206) directed the DOE to complete in 1998 a Viability Assessment of the Yucca Mountain site. During this reporting period, the Project completed a draft of the Viability Assessment. The DOE planned to issue the document in December 1998 and to publish it in three media: paper, compact disc (CD-ROM), and the Internet.

The draft Viability Assessment describes what DOE has learned to date about the Yucca Mountain site, the current "reference" repository design, projections of repository performance, the remaining uncertainties that are relevant to repository performance and design, and DOE's approach to addressing the remaining uncertainties. The Viability Assessment also identifies work that must be completed before a decision on site recommendation that could lead to a license application, the estimated costs of licensing a repository, and the estimated costs of constructing, operating, monitoring, closing, and decommissioning a repository at Yucca Mountain.

The 5-volume, approximately 1,450-page draft Viability Assessment is organized as follows:

- An overview (DOE 1998e) of the 5-volume Viability Assessment will be bound for separate distribution.

- Volume 1, "Introduction and Site Characteristics" (DOE 1998f), includes a high-level summary of the results of the viability assessment and some additional background information. Section 1 of Volume 1 provides introductory information about the types of waste that are destined for geologic disposal, the challenges posed by geologic disposal, a history of efforts to site a geologic repository in the United States, a brief description of how DOE manages the repository program, a description of the key technical components of the repository program, and a summary of the DOE's approach to identifying and prioritizing the remaining work required to complete a license application. Section 2 of Volume 1 summarizes DOE's understanding of the natural geologic and hydrologic systems of the Yucca Mountain site.

- Volume 2, "Preliminary Design Concept for the Repository and Waste Package" (DOE 1998g), describes the current reference designs for the repository surface facilities, underground facilities, and waste packages. Volume 2 also describes options, now referred to as features (e.g., use of backfill in the repository, addition of drip shields to the waste package design, etc.), that could be incorporated into the reference design to enhance performance, and it describes the substantially different alternative repository design concepts that DOE is considering. Alternatives generally

reflect significantly different approaches to design—different layouts or different bases for a disposal concept (e.g., low-thermal loading, continuous postclosure ventilation, etc.).

- Volume 3, "Total System Performance Assessment" (DOE 1998b), presents results from computer models of the expected performance of a geologic repository at Yucca Mountain under a range of conditions and various design options based on current scientific data and analyses.

- Volume 4, "License Application Plan and Costs" (DOE 1998h), identifies the remaining work that must be completed to support a decision to recommend a site at Yucca Mountain, and, if suitable, submittal of a license application and provides an estimate of the cost of this work. This volume also describes the DOE's approach to identifying and prioritizing the remaining work.

- Volume 5, "Costs to Construct and Operate the Repository" (DOE 1998d), provides an estimate of the costs to construct, operate, monitor, close, and decommission a repository, based on the preliminary design concepts.

5.2 ENVIRONMENTAL IMPACT STATEMENT

The NWPA (42 U.S.C. 10134 (f)(1)) requires that the final EIS serve as one of the supporting elements for a decision on site recommendation and that it accompany a Secretarial site recommendation to the President. The Project continued drafting the EIS for the Yucca Mountain site and is on schedule for completion of the draft in July 1999. Internal reviews continued to ensure consistency of information with the preliminary draft Viability Assessment and site description.

The Project continued to collect data and perform analyses in areas such as transportation, socioeconomics, sensitive ecosystems, air quality, aesthetics, archaeology, biology, environmental justice, health and safety, repository performance, noise, regulatory issues, soils, facilities, subsurface activities, waste package design, water resources, utilities, and energy. These data and analyses are being used to determine the environmental impacts of repository development, monitoring, operation, and closure at the Yucca Mountain site.

Prior to issuance of the final EIS (scheduled for August 2000), the technical analyses supporting the EIS will be updated as appropriate to reflect the ongoing progress of site studies. Updates will also be made, as needed, to resolve public, agency, or Native American tribal comments on the draft EIS. This activity will be integrated with work in the site characterization, design, and performance assessment activities.

5.3 SITE RECOMMENDATION

Following completion of the Viability Assessment, the Project focus will shift to work remaining for a decision on site recommendation. After hearings in the vicinity of the Yucca Mountain site and site characterization are completed, the DOE will then decide whether to recommend the site to the President. Together with this recommendation, the DOE will make available to the public, and submit to the President, a comprehensive statement of the basis for a site recommendation, as described in the NWPA (42 U.S.C. 10134 (a)(1)).

In support of that goal, a *Site Recommendation Management Plan* (YMP 1998c) was completed during the reporting period. The Plan includes:

- A brief table of contents for the Site Recommendation Statement, which would be the document recommending the site to the President

- A description of the process for review of the Site Recommendation Statement
- A description of a process for monitoring progress on technical and regulatory activities that will support the basis for a site recommendation
- A description of the format and content of the Site Recommendation Statement
- A plan for integrating available and relevant data and information that would support a site recommendation into a Site Recommendation Report
- A plan for transitioning the program from a focus on the Viability Assessment to a focus on a site recommendation, and then to a focus on a license application.

An integrated schedule is being developed to define the program logic, strategy, and key deliverables that will be completed to support a potential site recommendation.

5.4 LICENSING

Although the near-term focus of Project work will be on the decision whether to recommend the site, the Project is continuing interactions with the NRC to ensure that its activities are consistent with submitting a successful repository license application in 2002, should the Yucca Mountain site be recommended for approval. Interactions continue to focus on the NRC's ten Key Technical Issues and on the associated NRC Issue Resolution Status Reports that provide a framework for addressing the Key Technical Issues. This reporting period, the Project reviewed, analyzed, and developed comments on four NRC Issue Resolution Status Reports (NRC 1998a, 1998b, 1998c, and 1998d).

The DOE and NRC conducted Technical Exchanges on the geologic framework model for the Yucca Mountain site, the License Application Plan volume of the Viability Assessment, and technical guidance that DOE plans to provide its authors of a license application. These Technical Exchanges helped to identify issues in which there is agreement and those that require additional work.

In addition to the Technical Exchanges, two Quarterly Technical Meetings and five Appendix 7 Meetings were conducted during this reporting period. These interactions facilitated information exchange with NRC on various topics, including fracture-matrix interactions, Hanford N-Reactor spent fuel, the NRC design process review, graded quality assurance, and cementitious materials. 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 gain understanding of external issues and concerns.

The Project also developed the *Technical Guidance Document for License Application Preparation* (YMP 1998d). This document provides format and content guidance for a license application that will be developed and submitted to the NRC should the site be recommended and approved.

Preparations were made for beginning the Working Draft License Application Outline in the first quarter of Fiscal Year 1999. This document is intended to ensure that a workable process for any license application development and review is in place in order to support timely development and submittal of a license application. Other objectives include supporting project management's review of progress in developing any license application, as well as giving the authors an opportunity to begin making the necessary safety case. The document is also expected to provide supporting information for a site recommendation. Some of the technical work to support a license application will be completed after the Working Draft License Application Outline is completed. Therefore, many sections of a license

application scheduled for 2002 will be significantly different in content from the corresponding sections in the working draft outline.

Draft guidelines were developed for providing, in the repository design, defense-in-depth against postclosure release of radioactive material from the repository. The guidelines include a methodology for quantitative evaluation of the contribution of candidate repository design features and alternatives to overall defense-in-depth. Use of this methodology is expected to be part of the process for identifying the reference design for a license application.

5.5 KEY PLANNED ACTIVITIES THROUGH SEPTEMBER 30, 1999

Key site characterization studies, design and construction, performance, and programmatic activities planned for Fiscal Year 1999 (October 1, 1998 to September 30, 1999) will include providing to Congress the five-volume Viability Assessment document, as well as other activities to support the key upcoming milestones. These activities include:

Site Characterization

- Continuing data collection and numerical simulations for the Drift Scale Test.
- Performing post-test characterization and analyses and preparing a draft report for the Large Block Test.
- Verifying and updating Busted Butte Phase 2 test predictions.
- Completing *Topical Report: Preclosure Seismic Design Basis for a Geologic Repository at Yucca Mountain*, (Appendix B, Work in progress 15) which will describe the seismic design inputs to be used for repository design.
- Completing improved process models of unsaturated and saturated zone flow and transport for use in abstraction to support the TSPA for a potential license application.
- Continuing site characterization activities for C-wells hydraulic and tracer testing, natural resources, climate, and pneumatic monitoring.

Engineering Design and Construction

- Developing criteria to support initial selection of the license application reference design. These criteria will explicitly address impacts of design features on (1) quantitative estimates of off-site (public) dose rate, (2) design margin and defense-in-depth, (3) effects of credible disruptive processes and events, (4) ability to verify performance of key design features and natural elements of the system, and (5) the performance confirmation plan.
- Completing analyses for the waste handling systems, waste treatment systems and site-wide systems to support a license application design.
- Completing technical reports to support a license application design selection for the repository and waste package (Appendix B, Work in progress 16).

- Completing investigation of alternative waste package designs, including using two corrosion-resistant materials (Appendix B, Work in progress 16).

- Submitting the *Disposal Criticality Analysis Methodology Topical Report* (CRWMS M&O 1998au) to the NRC.

- Continuing short-duration and long-term tests to support waste package material selection for a license application design.

- Continuing waste form characterization.

- Revising the *Classification of the Preliminary MGDS Repository Design* (CRWMS M&O 1997b) to (1) provide input to the design bases for the structures, systems, and components, (2) identify the administrative, design, and operational features required to meet radiological safety or waste isolation functions, and (3) provide input to system description documents, a potential site recommendation, a license application design, and quality assurance and seismic classification of structures, systems, and components.

Performance Assessment

- Completing the fourth phase of the TSPA Peer Review Panel's activities. This phase, which consists of a formal review of the Technical Basis Document, began in July 1998 and will conclude in early 1999 with issuance of the Panel's final Peer Review Report. The major goal of the Panel's review is to help guide the performance assessment program in preparation of a technically defensible, traceable, and transparent TSPA-LA and the associated Technical Basis Document. Lessons learned from the peer review will also be implemented in future TSPA activities.

- Developing the TSPA-Site Recommendation/License Application Methods and Assumptions Document (Appendix B, Work in progress 17). This deliverable will include:

  - A synopsis of each of the performance assessment abstraction workshops on unsaturated zone flow and transport, disruptive events, waste form alteration and mobilization and engineered barrier system transport, saturated zone flow and transport, thermal-hydrology and coupled processes, near-field geochemical environment, and waste package degradation

  - Discussion of the abstraction plans developed at individual workshops

  - Documentation of plans to refine and update performance assessment models, methodologies, and strategies.

- Updating the *Performance Confirmation Plan* (CRWMS M&O 1997c) based on the results of the performance confirmation parameter reassessment (Appendix B, Work in progress 14).

- Preparing a formal comment response document to report the disposition of comments and recommendations made by the Performance Assessment Peer Review Panel (Appendix B, Work in progress 18).

- Providing a report on the approach and results of analyses with different thermal loads, waste inventories, and population locations to support the draft EIS (Appendix B, Work in progress 19).

- Supporting development of and analyses for the License Application Design Selection Report (Appendix B, Work in progress 16).

- Performing and documenting analyses to address disposal impacts of waste forms containing surplus plutonium (Appendix B, Work in progress 20) and identifying and describing surface and subsurface preclosure design basis events for plutonium waste form canisters (Appendix B, Work in progress 21).

Progress Toward Near-Term Objectives

- Updating the Repository Safety Strategy to reflect any new site information, evaluations of design alternatives and options, updated TSPA model abstractions, the proposed 10 CFR 63 (see 64 FR 8640), and the proposed U.S. Environmental Protection Agency standard, if available. The revision will discuss changes to the safety case and the status of the elements of that case and will identify critical remaining issues that will need to be addressed before the decisions regarding site recommendation and licensing are made.

- Continuing development of a revision to the *Technical Guidance Document for License Application Preparation* (YMP 1998d) to incorporate additional regulatory analyses and the NRC's proposed site-specific regulations in 10 CFR 63 (see 64 FR 8640).

- Transmitting to the NRC additional DOE comments from reviews of the NRC issue resolution status reports.

- Completing development of the Working Draft License Application Outline.

5.6 EPILOGUE

Since the close of the reporting period, several important developments have occurred on the Project. The most important was DOE's issuance of the Viability Assessment on December 18, 1998 (DOE 1998e, 1998f, 1998g, 1998b, 1998h, and 1998d). The overview states that DOE believes that Yucca Mountain remains a promising site for a geologic repository and that work should proceed to support a decision in 2001 on whether to recommend the site to the President for development as a repository. The overview acknowledges that uncertainties remain about key natural processes, the preliminary design, and how the site and design would interact. To address these uncertainties, DOE plans to advance the design, complete critical tests and analyses, and prepare draft and final environmental impact statements. When this work is completed in 2001, a decision will be made by the Secretary of Energy on whether to recommend the site to the President.

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

The report states that the preliminary repository design includes a long-lived waste package and takes advantage of the desert environment and geologic features of Yucca Mountain. Together, the natural and engineered barriers can keep water away from the waste for thousands of years. Analyses of the preliminary design using mathematical models, though subject to uncertainties, indicate that public health and the environment can be protected. For 10,000 years after the repository is closed, people living near Yucca Mountain are expected to receive little or no increase in radiation exposure. The maximum radiation exposure from the repository is expected to occur after about 300,000 years. People living

approximately 20 kilometers (12 miles) from Yucca Mountain at that time might receive additional radiation exposures equivalent to present-day background radiation.

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

- Obtain more information on key natural processes, including how radionuclides could be transported by groundwater beneath the repository
- Test the performance of candidate waste package materials and evaluate alternative repository designs
- Continue analyzing the expected interaction between the repository and the natural processes
- Prepare an environmental impact statement, publish it for public comment in 1999, and finalize it in 2000.

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

Because a monitored geologic repository is one component of a total waste management system, the Viability Assessment also addresses the total estimated future cost to complete the program. Including transportation of waste and storage at the repository, that estimated cost is $36.6 billion, in constant 1998 dollars. This includes costs from 1999 through closure and decommissioning, assumed to begin in 2110 and to be completed in 2116. It does not include $5.9 billion that has been spent on the program through Fiscal Year 1998.

In addition to the release of the Viability Assessment, other notable events occurred. These included the following:

- Excavation of the repository block cross drift was terminated on October 13, 1998, approximately 142 meters short of the excavation originally planned. Excavation was terminated after analysis concluded that it is more advantageous from several standpoints to stop short of the west splay of the Solitario Canyon Fault, and that the drift length is sufficient to conduct necessary characterization activities.
- Revision 01 of the TSPA-VA Technical Basis Document (CRWMS M&O 1998bg, 1998bh, 1998bi, 1998ax, 1998ba, 1998bj, 1998bb, 1998bc, 1998bd, 1998be, 1998bk) was issued in November 1998. This document provides the technical basis for assumptions and results of the TSPA-VA (DOE 1998b).

- On February 22, 1999, the NRC issued a proposed rule on Disposal of High-Level Radioactive Wastes in a Proposed Geologic Repository at Yucca Mountain, Nevada (64 FR 8640). If issued as planned as 10 CFR 63, the new rule would supersede 10 CFR 60, which would no longer apply to the proposed Yucca Mountain repository.

- Significant attention continues to be placed on corrective actions for the cross-cutting QA deficiencies identified during the reporting period. Formal root cause evaluations will be completed by the end of March 1999 and additional actions needed to ensure full compliance with nuclear QA requirements will be taken, as required. Training programs have been implemented to improve understanding of the requirements for working to nuclear quality assurance standards.

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APPENDIX A

LIST OF PROJECT DELIVERABLES COMPLETED

April 1, 1998 to September 30, 1998

PROGRESS REPORT #19

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Document Control Number	Deliverable Number	Title and Revision
2003	SLTDM7R1	Site Atlas Update
2022	SC833M3	Begin Enhanced Characterization of the Repository Block Cross Drift Excavation
2004	SLN190M3	Approve Plan for Implementation of QA Program for TSPA
1066	SLSR52M3	Comment Response on the Second Interim Report
984	3781MR1	Resubmit Synthesis of Volcanism Studies
2006	SLTDMB	2nd Quarter Statement of Data Submitted and Incorporated - Ltr. Rpt.
2007	SS9945	Annual Report on Compliance with Program Agreement on Historical Significance
2011	RP9440M3	Issue #11: Viability of Underground Remote Control Concepts
2012	SE9240M3	Issue #13: Repository Seals Requirements & Concepts
2016	RP9420M3	Issue #6: Retrievability Concept
2018	RP9430M3	Issue #7: Confirmation of High Volume/Long Period Waste
2017	SE9230M3	Issue #8: Disposal of Site Generated Waste
2024	SL21M3K	Submit Quarterly Interaction Summary Report
2027	SS9935	Annual Inventory of Collect Archaeological Materials
2013	RP9450M3	Issue #19: Subsurface Development
2014	RP9460M3	Issue #20: Surface Development
2015	RP9470M3	Issue #21: Site Development
2025	SC815M3	Complete Flow-Through Ventilation
2008	SSNEX10M	Deliver Final Biosphere Dose Conversion Factors
2021	SE168 M3	Transportation System to MGDS Interface Control Document
2026	SS9830	Quarterly Report on Underground Injection Control Permit
2028	SSH13JM3	Letter Report - 2nd Q FY 1998 (Groundwater data)
2038	SE9250M3	Issue #14: Regional Servicing Contractor/Interim Storage Facility Interface
2035	SC814M3	Resolve Locomotive Diesel Emissions Issue
2010	SE9110M3	Issue #1: Thermal Loading
2031	WP9310M3	Issue #16: Waste Package Size & Weight
2030	SE9210M3	Issue #2: Engineered Barrier System Performance Enhancement
2036	SLPR18M3	PR18 AM Review
2041	SP39B1M3R1	Predictive Report for USW WT-24 Borehole
2049	SL3006S	Submit Draft Technical Guidance Document to YMSCO
2002	SP39V1M3	Predictive Report, East-West Drift Tunnel (Geotechnical)
2043	SS9964	Annual EPCRA Section 313 Report
2039	SS9915	Ambient Air Quality Report
2020	SE420M3	Final VA Test and Evaluation Plan
2046	WP9330M3	Issue #3: Criticality Control
2050	SLPR18B3	PR 18 HQ Concurrence Draft
2051	SLTDMC	3rd Qtr. Statement of Data Submitted and Incorporated - Ltr. Rpt.
2044	SL5X41CM	Submit Near-field Coupled Effects Report
2048	SSNE125M	Provide Draft Baseline/Module Information

Document Control Number	Deliverable Number	Title and Revision
2040	SLSR905M	Complete Site Recommendation Management Plan
2042	SL23DM3A	Documenting Decisions Assessment
2045	SL5X4DM3	Waste Form Dissolution/Radionuclide Mobilization Report
2033	SP3320H3	Drift Scale Test As Built Report
2064	SLWB2295	Submit Letter Report on Web-Based Information System
2067	SS9840	Quarterly Report on Underground Injection Control Permit
906	SS8001	Submit Draft Inventory Data Call Letters for EIS
2053	SS10005	Socioeconomic Monitoring Program Procurement Quarterly Data Report
2055	SS9860	Annual Site Environmental Report
2058	SP39V2M3	East-West Drift Hydrologic Properties Predictive Report
2073	SSH13KM3	Letter Report - 3rd Q FY 1998 (Groundwater data)
1093	SPG28MM3	Ltr. to DOE: Probabilistic Seismic Hazards Assessment Final Report Completed
1092	SP32IM3	Report: Probabilistic Seismic Hazard Assessment for Yucca Mountain, Nevada
2054	SL300110	Publish Lead/Support Author List for License Application Development
2069	WP20AM3	Engineered Materials Characteristics Report Update
2070	BM2034M3	Evaluate Full-Text Search & Retrieval System for Project Records
2081	SS9925	Ambient Air Quality Report
2047	SE9140M3	Issue #18: Design Basis Model
2075	RP478M3	Concrete Chemical Evolution
2066	SE460M3R1	Waste Package Size Study Report
2057	SE408AM3	Complete MGDS Concept of Operations VA Update
2079	SC1902M3	Complete Drift Scale Test Construction
2084	BM143M3	Reprocess 30% of Records Previously Submitted to the Records Center
2086	SS9850	Environmental Regulatory Compliance Plan
2078	SS9997	Socioeconomic Monitoring Program Employment Quarterly Data Report
2082	SLSR906E	Submit Draft Compliance Report Management Plan to YMSCO (10 CFR 960)
2088	SL500M3	Complete Viability Assessment Document
2105	SLTDMD	4th Qtr. Statement of Data Submitted and Incorporated - Ltr. Rpt.
2096	SLTDB5M3R1	Confirmation of Volcanism Data Submitted to GENISES - Ltr. Rpt.
2085	SLTDB3M3	Identification of Updated Data Items - Ltr. Rpt. (Reference Information System)
2095	SLTDB1M3	Number of FY98 Identified Data Items - Ltr. Rpt. (Automated Technical Data Tracking System)
2089	SLSR390F	Submit VA Technical Record
2104	SLN155M3	QA Processes for TSPA-LA Development Report
2087	SL3006V	Submit Final Technical Guidance Document to YMSCO
2093	WP2355M3	Disposal Criticality Analysis Methodology Topical Report
2056	BM2033M3	Technical Implementation Plan for Electronic Management of E-mail as Federal Records
20029	SC835M3	Complete Enhanced Characterization Of The Repository Block Excavation Across Repository Block To Station 25+00
2068	WP20BM3	Waste Form Characteristics Report Update

APPENDIX B

LIST OF FUTURE PROJECT DELIVERABLES

PROGRESS REPORT #19

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Work in Progress Number	Deliverable ID Number	Proposed Title	Expected Completion Date
1	SLPRAMM3	Documentation of Program Change to YMSCO AMS for Review	2/2/99
2	SP32P4M3	Report: ISM3.1; Addendum to ISM3.0 Report	5/28/99
3	SPG42GM3	Geology of the Enhanced Characterization of the Repository Block Drift	3/31/99
4	SPG258M3	Preliminary Geologic Map for Saturated Zone Site Area	3/5/99
5	SP9904M3	Large Block Test Final Report	8/12/99
6	SP4CK1M4	Laboratory Experiments of Coupled Thermal-Hydrological Processes	—
7	SPU85M4	Submit License Application Testing Status Report	9/30/98
8	SP3538M3	Unsaturated Zone Flow and Transport Model for Site Recommendation	1/18/00
9	SP32E1M3	Report: Prow Pass Reactive Tracer Test	4/1/99
10	SP32E7M4	Report: Prow Pass Reactive Tracer Test	2/12/99
11	SPU17M4	Submit Report on Eh and Ph Measurements WT-24 and SD-6	9/30/98
12	SPV248M3	Report: Saturated Zone Flow & Transport Model for Site Recommendation/License Application	1/28/00
13	SS19DM3	Distribute Draft EIS	7/30/99
14	SEA282M3	Performance Confirmation Plan, Revision 1	7/30/99
15	SLSTRBM3	Submit Seismic Topical Report (STR) III for QAP6.2/YAP-30.12 Reviews	9/30/99
16	M2MQ	License Application Design Selection Report	5/28/99
17	SL915M3	TSPA-Site Recommendation/License Application Methods and Assumptions Document	6/30/99
18	SLSRM3	Performance Assessment Peer Review Panel	5/28/99
19	SL916M3	Draft EIS	2/26/99
20	SEAA21M3	Criticality Analysis of Pu Waste Forms in a Geologic Repository	9/30/99
21	SEA1A9M3	Design Basis Events Analysis of Immobilized Pu Waste Form	9/30/99

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