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Management Assessment of Alternative Methods for Exploratory Shaft Construction/Testing Sequences and Additional Exploratory Drifting

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EXECUTIVE SUMMARY

Background/Purpose

After reviewing the Department of Energy's (DOE) plans for construction of the Exploratory Shaft Facility (ESF) at the April 11-12, 1989, meeting with DOE, the Structural Geology and Geoengineering Panel of the Nuclear Waste Technical Review Board (NWTRB Panel) offered suggestions related to improving in situ test data quality, minimizing disturbance of the rock mass surrounding the exploratory shafts and potentially related repository performance impacts, shortening the exploratory shaft construction and testing schedule, and obtaining data that would be representative of the proposed repository block (extent of exploratory drifting). More specifically, the NWTRB Panel suggested:

- Consider the use of mechanical mining methods (raise bore or V-mole) alone, or coupled with conventional mining methods (drill-and-blast) to improve data quality and possibly repository performance by limiting the amount of rock fracturing and drill fluid and blast gas intrusion during exploratory shaft construction; and consider the use of mechanical mining methods and the deferral or relocation of non-critical in-line ESF tests to expedite exploratory shaft construction;

- Consider exploratory drifts to the south to intersect the Ghost Dance fault, at additional locations, to obtain additional information for characterizing the fault; and consider additional exploratory drifting to the west across the proposed repository block, to identify and characterize significant north-south trending features which may exist in this area.

To address these suggestions the DOE authorized Golder Associates Inc. (Golder) and Roy F. Weston, Inc. (Weston) to perform detailed evaluations of the feasibility of the NWTRB Panel suggestions. Feasibility studies of these topics were completed by Golder and Weston. These have since been reviewed by DOE to consider the programmatic impacts of these feasibility studies. In the course of performing management assessments of the Golder and Weston feasibility studies, the DOE has identified certain other technical suggestions which appear worthy of further consideration. These issues are also addressed along with the NWTRB Panel suggestions in this management assessment report.

DOE Assessment of Feasibility Studies

The following discussion describes DOE actions based on the appraisal of the Golder and Weston reports. Such actions are directed at either implementing certain of the report recommendations or performing an integrated Subpart G evaluation comprised of several components described below to assess issues which were not fully addressed in the feasibility studies.

Alternative Exploratory Shaft Construction Methods and Testing Sequences

The following actions related to the NWTRB Panel suggestions to consider alternative ESF Shaft construction methods and testing sequences are derived from assessment of the information presented in the Golder report (Section 3.1), and the DOE assessment of the Golder conclusions and recommendations (Section 4.1).

- Assessment of the information presented in the Golder report concludes that there may be an overall advantage to have both a mechanically mined shaft and a conventionally mined shaft. This will provide two exploratory shaft construction methods that can be compared, and will also provide enhanced data quality beyond that which could be obtained from only conventionally mined shafts. On this basis, the Yucca Mountain Project Office (YMPO) should conduct a Subpart G evaluation of one mechanically mined shaft and one conventionally mined exploratory shaft. The results of the additional Golder evaluation (described below) will be included in this YMPO evaluation.

- The information provided in the Golder report indicates that constructing a conventionally mined exploratory shaft sequentially with a mechanically mined exploratory shaft will extend the ESF schedule beyond that which could be achieved by constructing two conventionally mined exploratory shafts concurrently. However, the information in the Golder report further indicates that such an extension in duration could be offset by a selective rescheduling of portions of the testing program, such that data quality requirements are not impaired. On this basis, the following re-sequencing of the ES-1 testing activities will be evaluated using Subpart G procedures by the YMPO, including appropriate treatment of design, schedule and cost aspects.

  - Delay vertical seismic profiling (VSP) until after completion of exploratory shaft construction.

  - Construct the Upper Demonstration Breakout Room (UDBR) in-line with exploratory shaft construction but delay all tests not providing data on transient effects of exploratory shaft construction (e.g., the ambient stress test, the construction of the rooms for the Demonstration Breakout Room (DBR) experiment, the heater test).

  - Drill the long radial boreholes (LRBs) but delay the tests until after exploratory shaft construction is complete.

  - All other testing in ES-1 should proceed as currently planned.

- In the interest of improving ESF data quality, the NWTRB Panel addressed the use of mechanical mining methods in both exploratory shafts. More specifically, conventionally mine ES-1 to a 8 to 10 foot diameter, performing only required in-line testing, then raise bore ES-2 and finally mechanically ream ES-1 to full diameter. Golder's report (Section 4.7) discussed this approach briefly, but did not perform a complete analysis. Golder will be directed to:

  - Expand the scope of their previous study, such that the construction method and testing sequence involving mechanical mining of both exploratory shafts, as suggested by the NWTRB

Panel, is evaluated at the same level of detail as the other case studies;

- Evaluate various reaming techniques (e.g., raise boring, V-mole, etc.) which would yield improved and/or optimized results for this case, especially from a schedule viewpoint, consistent with the ESF Title I Design requirements.

- A Subpart G evaluation shall be conducted by the YMPO for constructing larger diameter exploratory shafts which may be sufficiently large enough to facilitate tunnel boring machine (TBM) access and enhance overall ESF efficiency (muck handling and ventilation).

Additional Exploratory Drifting

The following actions related to additional exploratory drifting are derived from the evaluation of the information presented in the Weston feasibility studies prepared in response to the NWTRB Panel's suggestions regarding the possible need for additional exploratory drifting (Section 3.2) and the DOE evaluation of the Weston conclusions and recommendations (Section 4.2).

- The feasibility, usefulness, schedule, and cost of augmenting the planned surface-based testing program by adding the following activities will be evaluated by the YMPO using Subpart G procedures.
  - Drill several closely-spaced lines of boreholes across the Ghost Dance fault.
  - Conduct detailed surface geologic mapping along the surface trace of the Ghost Dance fault and in east-west strips between the Ghost Dance and Solitario Canyon faults, across the trend of structural features identified on the basis of currently planned surface-based studies.
  - Drill inclined boreholes to intersect the Ghost Dance fault and other steeply-dipping structural features detected through surface-based studies.
  - Evaluate the technology and methodology for dry-drilling and coring of inclined boreholes by a prototype testing activity.
- A Subpart G evaluation of the proposed exploratory drift to the Ghost Dance fault will be conducted by the YMPO and, if appropriate, an action plan will be developed for implementation of this exploratory drift that will include appropriate treatment of design, schedule, and cost aspects. The evaluation will also include an assessment of potential impacts to waste isolation and interferences from construction and testing.
- A Subpart G evaluation of the adequacy of the current plan to defer exploratory drifting to the western boundary of the proposed repository until data from new site characterization activities are available will be conducted by the YMPO.

1.0 INTRODUCTION

1.1 Background

The Department of Energy (DOE) has developed a Site Characterization Plan (SCP) that describes the program for investigating the suitability of the Yucca Mountain site in Nevada. The program has been defined in accordance with Section 113 of the Nuclear Waste Policy Amendments Act of 1987. The SCP was submitted in December 1988 to the Nuclear Regulatory Commission (NRC), the State of Nevada (the State), and affected local governments for review and comment prior to the start of exploratory shaft construction. The SCP has also been provided to industry and a wide spectrum of other interested parties.

The Nuclear Waste Policy Amendments Act of 1987, established a Nuclear Waste Technical Review Board (NWTRB) to evaluate the technical and scientific validity of activities undertaken by the Secretary of Energy including site characterization activities. At a meeting with the DOE on April 11-12, 1989, the Structural Geology and Geoengineering Panel of the NWTRB (NWTRB Panel) made a number of observations relative to the plans for construction of the Exploratory Shaft Facility (ESF) and the associated testing program. The NWTRB Panel offered a number of suggestions relative to alternative exploratory shaft construction methods and test sequencing and the plans for exploratory drifting and testing to characterize known or suspected fault zones. DOE committed to evaluating these suggestions and discussing results with the NWTRB at some future meeting. The NWTRB Panel consists of Don U. Deere, Chairman, NWTRB, Clarence Allen, NWTRB Panel Chairman, and Warner North.

1.2 Purpose

The purpose of this report is to summarize the suggestions made by the NWTRB Panel at the April 11-12, 1989, meeting, describe the technical evaluations that were performed with respect to the NWTRB Panel suggestions, and set forth DOE's views and planned actions for further consideration and for future discussions with the NWTRB.

2.0 NWTRB PANEL COMMENTS

2.1 Alternative Exploratory Shaft Construction Methods and Testing Sequences

Based on presentations made by the DOE on exploratory shaft design and construction (April 11-12, 1989), the NWTRB Panel acknowledged that:

- Conventional drilling with fluids may not be compatible with the need to minimize impact on the natural barriers at the site, and

- The initial exploratory shaft should be mined by the controlled drill-and-blast procedures as currently planned.

The NWTRB Panel observed that the quality of data from in-shaft testing may be improved by using alternative construction methods, (NWTRB Panel meeting transcripts, April 11-12, 1989) such as raise boring or V-mole, to provide an exploratory shaft wall that would be minimally altered from construction (blast induced-damage and infiltration of construction fluids).

The NWTRB Panel suggested consideration of alternatives to improve data quality as follows:

- For Exploratory Shaft Number One (ES-1), either
  - Conventionally sink to full diameter; or
  - Conventionally sink to a small diameter (8 to 10 feet) then ream to full diameter (14 to 15 feet).

- For Exploratory Shaft Number Two (ES-2), either
  - Conventionally sink to a small diameter (8 to 10 feet), then ream (V-mole) to full size diameter;
  - Raise bore to a small diameter (6 to 8 feet), then ream (V-mole) to full size diameter; or
  - Raise bore to full diameter in one pass

The NWTRB Panel also observed that the schedule for ESF completion may be improved by:

- Use of mechanical mining methods (raise or V-mole boring) for ES-2; and

- Delaying or transferring to another location some of the in-line tests planned during the excavation of ES-1.

2.2 Additional Exploratory Drifting

At the April 11-12, 1989, meeting with the NWTRB Panel, the DOE presented plans for both surface-based testing and underground exploratory drifting to collect information relative to known features within and adjacent to the proposed repository block. Based on the DOE presentations, the NWTRB Panel recognized that a perimeter exploratory drift is not appropriate at this time; however, they expressed concern about the ability to demonstrate without additional exploratory drifting that the site has been sufficiently characterized. The NWTRB Panel requested that DOE consider expanding the currently planned program of exploratory drifting. The NWTRB Panel specifically requested consideration of the following as additions to the current plan:

- Exploratory drifting to the south to intersect the Ghost Dance fault, which is thought to be a hinge fault, in additional locations where the vertical offset appears to be greater (displacements as great as 125 feet have been observed in exposures).

- Exploratory drifting across the full east-west width of the proposed repository block, preferably across the central portion rather than the northern portion.

In presenting these views, the NWTRB Panel observed that further surface exploration and drilling is not needed to establish that additional exploratory drifting should be carried out. Rather, such additional exploration, including inclined (or slant) boreholes, should be used to help determine locations and orientations for the proposed additional exploratory drifts.

3.0 SUMMARY OF FEASIBILITY STUDIES

DOE's Office of Civilian Radioactive Waste Management (OCRWM) directed two contractors to evaluate the feasibility of the NWTRB Panel's technical concerns and suggestions. Golder Associates Inc. of Redmond, Washington, was assigned the lead for the evaluation of alternative exploratory shaft construction methods and test sequences, and Roy F. Weston, Inc., of Washington, D.C., was assigned the lead for evaluation of additional exploratory drifting. Participants from the Yucca Mountain Project (YMP) who were involved in the development of the SCP were made available to these contractors for consultation.

Overall guidance for these evaluation efforts was provided by OCRWM's Office of Facilities Siting and Development (OFSD), with support and review by the Office of Systems Integration and Regulations (OSIR) and the Office of External Relations and Policy (OERP).

The results of these evaluation activities are set forth in two feasibility studies:

- "Evaluation of Alternative ESF Shaft Construction Methods and Test Sequences," Golder Associates Inc., June 22, 1989
- "Evaluation of Additional Drifting for Site Characterization at Yucca Mountain Project," Roy F. Weston, Inc., July 14, 1989.

The following is a synopsis of the findings and recommendations of both the Golder and Weston feasibility studies. Section 3.1 of this report discusses alternatives for exploratory shaft construction and test sequencing (Golder report). Section 3.2 of this report addresses the potential need for additional exploratory drifting (Weston report).

3.1 Alternative Exploratory Shaft Construction Methods and Testing Sequences

3.1.1 Alternative Construction Methods

NWTRB Panel Suggestions

The ideas expressed by the NWTRB Panel on these topics were:

- Site characterization could possibly be improved by:
  - Reducing blast-induced damage to the exploratory shaft walls; and
  - Reducing contamination of samples taken from the immediate vicinity of the exploratory shaft due to the introduction of construction fluids and blast gases.
- The exploratory shaft construction duration could possibly be shortened by:
  - Delaying some of the tests until after exploratory shaft construction is complete (rather than in-line with exploratory shaft construction);
  - Using different construction methods.

- Long-term repository performance could possibly by improved by reducing the disturbance associated with exploratory shaft construction.

Thus these three ideas expressed by the NWTRB Panel addressed the topics of site characterization data quality, ESF construction schedule, and long-term repository performance. In addressing these three topics for suggested improvements, Golder formulated (on the basis of their experience and judgement) alternative combinations of exploratory shaft construction methods and testing sequences which would perform acceptably or better with respect to the NWTRB Panel suggestions. These were comparatively evaluated with a base case, Case 0 (i.e., the current ESF design entailing two conventionally excavated exploratory shafts and all testing performed in-line). The four alternative cases included one case with two conventionally-mined exploratory shafts and two alternative combinations of revised test sequencing (Case 1a and 1b); and three cases involving one conventionally mined exploratory shaft and one mechanically mined exploratory shaft, each with two alternative combinations of revised test sequencing (Case 2a and 2b, Case 3a and 3b, and Case 4a and 4b). The base case and four alternatives were then comparatively evaluated with respect to the topics suggested by the NWTRB Panel (i.e., data quality and schedule), as well as other important factors (i.e., constructability, health and safety, and cost).

In performing the evaluations, Golder concluded that although data quality was "Best" for a mechanically mined exploratory shaft, data quality was not very discriminating among the cases evaluated since the combinations of construction methods and test sequences had been selected to provide above average performance in this area; however, Golder indicated that data quality was "Best" with the mechanically mined methods case 3a and 4a (Table 1). Thus, the other evaluation criteria provided relatively better discrimination among cases, such as "Schedule" which provided a two to one distinction between the fastest and the slowest case. The following subsections review and summarize Golder's evaluation of the base and four alternative cases considered, with respect to the NWTRB Panel suggestions and the other evaluation criteria.

Technical Evaluation

In keeping with the needs for testing, as summarized in Section 3.1.2 of this report and suggestions by the NWTRB Panel, four alternative construction methods were evaluated. A fifth suggestion which considered two mechanically mined shafts was made by the NWTRB chairman in separate discussions with DOE subsequent to the April 11-12, 1989, meeting with the NWTRB Panel. This suggestion was not explicitly considered by Golder since their scope of work was limited to suggestions included in the transcripts of the summary discussions at the April 11-12, 1989, meeting. The four construction methods considered were:

Method 1: Conventional (drill-and-blast) construction of both exploratory shafts (ES-1 and ES-2). This is the current plan (Case 0, 1a and 1b).

Method 2: Conventional construction of ES-1; raise bore ES-2 in a single pass (Case 2a and 2b).

TABLE 1

SUMMARY EVALUATION OF ALTERNATIVE EXPLORATORY SHAFT CONSTRUCTION METHODS & TESTING SEQUENCES

EXPLORATORY SHAFT CONSTRUCTION METHOD SEQUENCE	EVALUATION CRITERIA: TEST DATA QUALITY	CONSTRUCT-ABILITY	SCHEDULE INCREASE (MONTHS)	HEALTH/ SAFETY	COST INCREASE ($ MILLION)
(Conventional)					
CASE 0	GOOD	BEST	0	SATISFACTORY	0
(Conventional)					
CASE 1a	GOOD	BEST	-7	SATISFACTORY	-4
CASE 1b	GOOD	BEST	-12	SATISFACTORY	-7
(Single-Pass Raise Bore)					
CASE 2a	GOOD	SATISFACTORY	+1	BEST	-5
CASE 2b	GOOD	SATISFACTORY	-4	BEST	-8
(Raise Bore/V-Mole)					
CASE 3a	BEST	GOOD	+3	GOOD	-2
CASE 3b	GOOD	GOOD	-2	GOOD	-4
(Conventional/V-Mole)					
CASE 4a	BEST	BEST	0	SATISFACTORY	+1
CASE 4b	GOOD	BEST	-6	SATISFACTORY	-1

NOTE: EACH CASE IS RATED QUALITATIVELY (EXCEPT FOR SCHEDULE AND COST WHICH ARE RATED QUANTITATIVELY) WITH RESPECT TO SATISFYING THE CRITERION IN TERMS OF BEST, GOOD OR SATISFACTORY. IT SHOULD BE NOTED THAT ALL OF THE CASES EVALUATED WERE CONSIDERED TO BE ACCEPTABLE WITH RESPECT TO SATISFYING EACH OF THE ABOVE CRITERIA.

NOTE: COLUMN FOUR (SCHEDULE INCREASE) WAS NORMALIZED TO CASE 0. CASE 0 WAS USED AS A ZERO DATUM OR BASE CASE FOR SCHEDULE.

(After Golder, 1989)

Method 3: Conventional construction of ES-1; raise bore pilot exploratory shaft and then V-mole ES-2 to full size (Case 3a and 3b).

Method 4: Conventional construction of ES-1; drill-and-blast pilot exploratory shaft and then V-mole ES-2 to full size (Case 4a and 4b)

The exploratory shaft construction and many of the exploratory shaft tests are closely integrated; therefore, it was essential to consider the combination of both the exploratory shaft construction methods and the exploratory shaft testing program when evaluating the schedule and data quality aspects relative to the construction methods. Various combinations of exploratory shaft construction methods and testing sequences were therefore considered, as indicated in Table 2 (Ref: Table 4.1 of the Golder report). Two basic test sequences were considered for each of the four construction methods. The reason for two test sequences is related to various assumptions made concerning the need for and quality of transient excavation effects test data. Test sequence "a" represents the case where all thermomechanical testing planned for the Upper Demonstration Breakout Room (UDBR) is delayed until after the completion of exploratory shaft sinking, the short radial-borehole tests (SRBTs) are conducted in-line with sinking ES-1, and the long radial-borehole tests (LRBTs) are installed during exploratory shaft sinking but the majority of the testing at these locations is performed following exploratory shaft sinking. Test sequence "b" considers the case where both the thermomechanical testing and all radial borehole testing (RBT) are delayed until completion of exploratory shaft sinking. The following summarizes the results of the evaluation that was conducted for each of the construction method and testing sequence combinations indicated in Table 2:

- Test Data Quality - All construction methods and testing sequences considered in this study are capable of satisfying the testing data quality requirements within the exploratory shafts. The most significant discriminator among the methods is related to the timing of the performance of the RBTs and the ability to obtain transient hydrologic, hydrochemical, and rock characteristics data from these tests concurrent with exploratory shaft sinking. The test sequence "b" options (Table 2), which delay these tests until following completion of exploratory shaft sinking, were therefore rated lower in terms of the data quality criterion. In addition, the methods (Cases 3a and 4a) that employ the use of drill-and-blast techniques to construct ES-1 and V-mole techniques to construct ES-2, have been rated "Best" because they offer the best of all testing conditions including; timely access for mapping of the exploratory shaft walls constructed by two different mining methods; relatively undisturbed and uncontaminated exploratory shaft walls in ES-2; and the capacity for evaluating perched water conditions in both of the exploratory shafts.

- Exploratory Shaft Constructability - All construction methods evaluated are considered technically feasible for the anticipated geotechnical and ground-water conditions at the site. The single pass raise bore method has been rated lowest of the various methods, because of uncertainties related to the stability of the exploratory shaft walls in specific horizons and the inability of the raise bore methods to install support in a timely manner, lack of versatility of

TABLE 2

ALTERNATIVE ESF SHAFT CONSTRUCTION METHODS/TESTING SEQUENCES

ESF SHAFT CONSTRUCTION METHODS	TESTING SEQUENCE		
	All Testing In-Line	(a) Delay Thermo Tests, Partially Delay RB Tests[a]	(b) Delay Thermo Tests, Delay RB Tests[b]
(1) Drill-and-Blast Both Shafts	Case 0	Case 1a	Case 1b
(2) Drill-and-Blast Shaft 1, Raise Bore Shaft 2		Case 2a	Case 2b
(3) Drill-and-Blast Shaft 1, Raise Bore/V-Mole Shaft 2		Case 3a	Case 3b
(4) Drill-and-Blast Shaft 1, Drill-and-Blast/V-Mole Shaft 2		Case 4a	Case 4b

Notes: (a) Construct UDBR in-line with shaft construction, but delay thermomechanical testing in UDBR until after construction. Conduct Short Radial Borehole Tests and install long radial boreholes in-line with shaft construction, but delay re-testing of long radial boreholes until after construction.

(b) Construct UDBR in-line with shaft construction, but delay thermomechanical testing in UDBR until after construction. Delay both Short and Long Radial Boreholes Tests until after shaft construction.

(After Golder, 1989)

the method in accommodating unanticipated ground conditions, and difficulties associated with ensuring exploratory shaft verticality. By contrast, the conventional drill-and-blast method (including when used in conjunction with V-moling) is well suited to address the above concerns and has therefore been rated "Best" from a constructability viewpoint. The hybrid raise bore/V-mole method of construction has been rated intermediate for the constructability criterion.

- Health and Safety - The conventional drill-and-blast exploratory shaft method is rated as "Satisfactory" but lowest of the construction techniques because of the requirement for a virtually continuous manpower presence at the shaft bottom under relatively adverse conditions (heat, humidity, dust, exposure to rockfall), frequent transport of men within the exploratory shaft during construction, and the use of explosives. Raise boring is considered to be the best of the construction methods considered herein with respect to health and safety, with the V-mole method ranked slightly lower.

- Schedule - Compared with the current base case (Case 0) schedule (conventional exploratory shaft construction method with in-line testing), delaying all in-line testing for which transient data is not considered to be an issue could result in schedule savings of up to 25 percent. If all the RBTs could be delayed until the completion of exploratory shaft sinking, the current base case schedule could be reduced by as much as 50 percent. Although the raise boring method proceeds at a faster rate than conventional methods, for comparable testing sequences conventional sinking methods of both exploratory shafts results in substantially shorter elapsed time between the start of exploratory shaft sinking and the availability of the Main Test Level (MTL) for development and testing, primarily because the exploratory shafts can be constructed in parallel rather than sequentially and the exploratory shaft connection is not on the critical path. Further significant schedule savings could be achieved if an alternative location for the UDBR can be found (e.g., one accessible by ramp from the MTL).

- Cost - Estimated costs are highest for the current base case (because of substantial stand-by costs for the currently planned sequencing of in-line testing) and for the methods which include the use of a V-mole (due to the high capital cost associated with this equipment). Lowest estimated costs are associated with conventional exploratory shaft construction method and with raise boring method, with delayed testing where appropriate. The raise bore method is estimated to be of slightly lower cost than conventional sinking of both exploratory shafts because of manpower savings associated with raise boring.

Conclusions

- All construction methods and test sequences were considered to be acceptable with respect to each of the criteria used.

- All construction methods are considered technically feasible.

- All combinations of construction methods and testing sequences are considered capable of generating "Good" quality test data, with the primary discriminator for this criterion being the ability of the testing sequence to provide early-time transient effect test data (including the monitoring of construction fluid invasion) for the RBTs.

- Health and safety is not a very effective discriminator, since conventional exploratory shaft mining has a "Satisfactory" rating and every case considered includes at least one conventionally-mined exploratory shaft.

- Despite the faster advance rates of the raise boring method, conventional mining of both exploratory shafts in parallel results in a significantly shorter duration to reach the MTL compared with conventional and mechanical mining combinations where the exploratory shafts are mined in series.

- Final judgement as to the optimum construction method and testing sequence will depend upon the relative importance assigned to each criteria.

3.1.2 Testing Sequences

NWTRB Panel Suggestions

DOE should evaluate whether the schedule for exploratory shaft sinking to the MTL could be accelerated by deferring or relocating the planned ES-1 in-line tests.

Technical Evaluation

This suggestion was examined by identifying (from the SCP) the tests planned to be conducted during construction of ES-1 and the anticipated information to be obtained from such testing. The implications of modifying, deferring, or relocating each of the tests were then evaluated. The evaluation considered the identified requirements for exploratory shaft design and construction and the need for planned monitoring of exploratory shaft construction impacts. A summary of the results of the evaluation of deferral or relocation of each category of tests is presented in Table 3 (Ref: Table 3-1 of the Golder report).

Conclusions

- As shown on Table 3, it appears possible to defer or relocate some tests currently planned to be conducted in-line with exploratory shaft construction to achieve schedule benefits without significantly affecting the testing program.

- Delaying all in-line testing will result in a significant schedule savings but could impact test data quality. The issue of transient data requirements needs further evaluation by YMPO before the current testing program is modified.

- Compared to the current base case (conventional exploratory shaft construction method with in-line testing), delaying all in-line testing for which transient data is not considered to be an issue could result in schedule savings of up to 25 percent.

- If all the RBTs could be delayed until the completion of exploratory shaft sinking, the current base case schedule could be reduced by nearly 50 percent; however, YMPO believes that if the tests are

TABLE 3

SUMMARY OF TESTS IN THE ESF SHAFTS

TEST	IN BOTH SHAFTS?	AFFECTED BY CONSTRUCTION?	CAN MODIFY?	CAN DEFER?	CAN RELOCATE
Geologic Mapping	YES	SMALL	NO	YES[a]	NO
Rock Sampling	NO[b]	MODERATE[b]	YES[b]	YES[b]	NO
Vertical Seismic Profiling	YES	NO	NO	YES	NO
Shaft Convergence Test	NO[c]	SMALL	NO	NO	NO
UDBR	NO	NO	NO	YES	YES[d]
Thermomechanical Testing in UDBR	NO	NO	NO	YES	YES[d]
Excavation Effects Test	NO[c]	SMALL	YES[e]	POSSIBLE	YES[d]
SRBT	NO[c]	SMALL	NO	POSSIBLE[f]	NO
LRBT	NO	NO	NO	POSSIBLE	NO
Perched Water Tests	CONTINGENCY	MODERATE	NO	POSSIBLE[g]	NO

(After Golder, 1989)

Notes: See page 12 for explanation of superscripts.

TABLE 3
(Continued)

SUMMARY OF TESTS IN THE ESF SHAFTS

NOTES:

[a] Delays in mapping can result in some alteration in exposed rock and joint surface/infilling. Mapping must be done before exploratory shaft lining.

[b] Although not planned, samples could be obtained from both exploratory shafts. Blasting and construction fluids can contaminate samples. Delays may result in the alteration of specific features to be sampled. However, relatively undisturbed samples could be obtained at any time in air-drilled coreholes at a significant radial distance from the exploratory shaft wall.

[c] If different methods are used for constructing the two ESF shafts and they are both being considered for constructing the repository shafts, then these tests should be conducted in both exploratory shafts.

[d] The UDBR, and the associated testing (inluding the excavation effects test), could possibly be relocated to an area in a similar rock type which is accessed from a ramp from the MTL, if available. The Excavation Effects Test may have to be modified if the UDBR is relocated.

[e] In order to observe the transient hydrochemical response of the rock, the Excavation Effects Test could be conducted in a horizontal mode and combined with the UDBR and the MTLDBR, or it could be conducted in a trial shaft section from a relocated UDBR. In either case, however, it may be more appropriate to introduce construction fluids to the wall in a controlled manner..

[f] If the UDBR is relocated, then the Excavation Effects Test (modified) can be deferred. The SRBT's and LRBT's might be deferred until after exploratory shaft construction if the transient data (i.e., feature specific hydrochemical response and construction fluid invasion) are not critical or can be obtained in other ways (e.g., by the Excavation Effects Test).

[g] The Perched Water Test can be deferred in one exploratory shaft until after excavation, even though the data quality in that exploratory shaft may be reduced.

delayed the ability to obtain quality data on the transient hydrologic response of the rock due to exploratory shaft excavation would be affected.

- Significant schedule savings could be achieved if an alternative access location for the UDBR can be found (e.g., one accessible by ramp from the MTL).

3.2 Additional Exploratory Drifting

3.2.1 Additional Exploratory Drifting to the Ghost Dance Fault

NWTRB Panel Suggestions

Consider expanding the currently planned exploratory drifting to the Ghost Dance Fault to include an exploratory drift to the south to intersect the fault at additional locations where the offset appears to be significant.

Technical Evaluation

The principal purpose for drifting to the Ghost Dance fault (Figure 1) is to obtain hydrologic and structural data for performance assessment and repository design. The hydrologic characteristics of this major fault zone which transects the proposed repository block are particularly important to the modeling of site ground-water flow paths and travel times. Ground-water flux through the host rock is expected to be negligible and fault or fracture zones could represent preferential pathways for such flow. Although the currently planned intersection with the Ghost Dance fault is believed to offer a reasonable opportunity for obtaining representative hydrologic data for the fault zone, there is some indication on the surface that the Ghost Dance fault may be a hinged fault with increased displacement to the south. The magnitude of this offset, important for repository design, and potentially associated hydrologic variability have yet to be established.

Prior to obtaining new surface-based data, the evaluation of whether more than one exploratory drift intersection with the Ghost Dance fault is necessary is based on expert judgement as to what is adequate and reasonable. The following is a summary of the factors evaluated in the Weston report.

- Representativeness of Data - The Ghost Dance fault has been mapped on the surface as the most significant structure within the proposed repository block and it is a well-defined target for site characterization. The fault is thought to have variable displacement (a "hinge" or "scissors" fault) as compared to uniform normal or reverse displacement along its length. Fault characteristics such as dip and degree of deformation appear to vary along the length of the fault. Displacement appears to increase substantially to the south. Greater displacement toward the south may have resulted in a greater degree of brecciation and, therefore, the hydrologic characteristics of the fault may also vary from north to south.

  Since displacement apparently increases to the south, a southern intersection (e.g., approximately midway between the currently planned

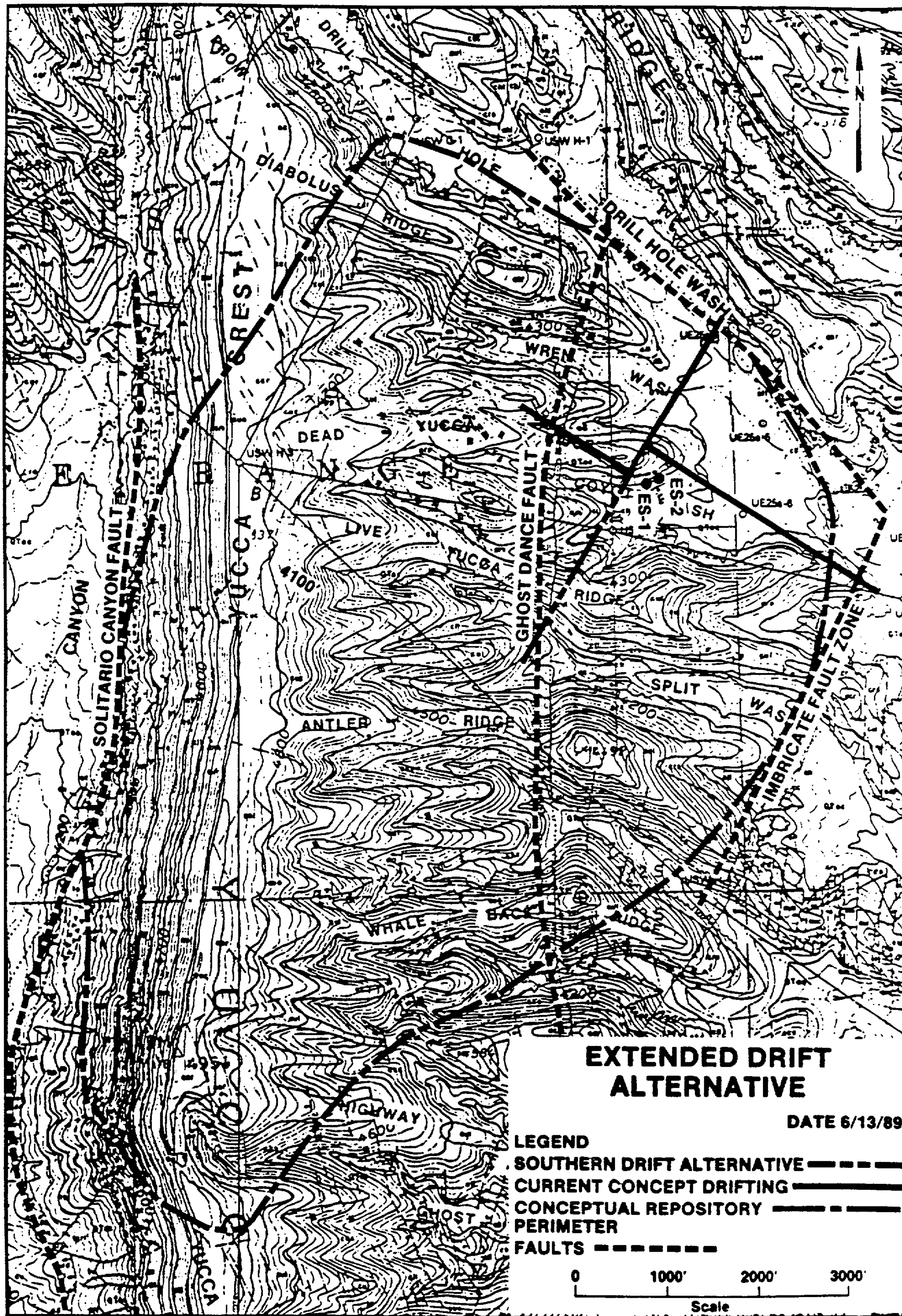
EXTENDED DRIFT ALTERNATIVE
DATE 6/13/89
LEGEND
SOUTHERN DRIFT ALTERNATIVE
CURRENT CONCEPT DRIFTING
CONCEPTUAL REPOSITORY PERIMETER
FAULTS
0
1000'
2000'
3000'
Scale
DIABOLUS RIDGE
DRILL HOLE WASH
WREN WASH
DEAD YUCCA
LIVE YUCCA RIDGE
GHOST DANCE FAULT
SOLITARIO CANYON FAULT
CANYON
YUCCA CREST
ES-1
ES-2
SPLIT WASH
IMBRICATE FAULT ZONE
ANTLER RIDGE
WHALE BACK RIDGE
HIGHWAY
GHOST
USW H-1
UE25a-6
4100
4300
4200

FIGURE 1

intersection and boreholes UZ-7 and UZ-8) may be more representative of the hydrologic and structural conditions at the MTL, and would provide added confidence to the characterization of this structure.

- Post-Closure Performance - Whereas SCP Section 8.4.3 discusses potential impacts from the construction of planned exploratory drifts, an analysis of possible effects of the additional exploratory drifting on post-closure performance has not been performed. Based on SCP Section 8.4.3, it can be inferred that the additional exploratory drifting is not likely to affect post-closure performance, because:

  - Any additional exploratory drifting would be planned to be coincident with the repository drift layout as currently conceptualized. Thus, it is highly unlikely that any new pathways for water would be created or that the host rock would be disturbed beyond the disturbance expected from development of the repository. However, an analysis of possible effects of additional drifting should be evaluated by YMPO using Subpart G procedures.

- Non-radiological Health and Safety - The potential for mine accidents is dependent on the amount of time spent underground by workers and the level of enforcement of worker safety requirements. In that sense, added exploratory drifting means added exposure to risks. However, the incremental addition in planned exploratory drifting should entail no substantial difference in risk to the underground workers. Also, taken from the perspective of repository development, there is no increased risk since the additional exploratory drift is expected to be coincident with the proposed repository main drift.

- Integration with Repository - Exploratory drifts and repository drifts can be laid out to be coincident. However, repository design is still in the conceptual phase and may change as in situ underground data are obtained.

- Information for Repository Design and Performance Assessment - The current testing plans will provide considerable information about the variation in rock properties across the site but little specific information on how geologic and hydrologic properties vary along the Ghost Dance fault, particularly lateral components of ground-water flow, and limited information about the way this feature could affect rock properties.

  The additional intersection to the south would provide added information useful to design in establishing constraints on repository layout due to fault offset. Additionally, the added hydrologic and geologic information obtained through in situ testing in a second exploratory drift to the Ghost Dance fault should substantially increase confidence in performance assessment modeling.

- Design Flexibility - Exploratory drifting constrains and may prematurely fix the elevation and orientation (trend and inclination) of the conceptual repository main drift. In that sense, additional drifting reduces flexibility. However, the plan to make exploratory drifts coincident with repository drifts can minimize the potential for subsequent constraints on repository layout.

- Cost - The estimated additional cost for conventionally mining the extended drift is $9.4 million, a 2.8 percent increase of the total cost for construction of the planned ESF and exploratory drifting ($332.6 million).

- Schedule - The schedule duration for the estimated 2000 feet of additional exploratory drifting to the south is eight (8) months. This drifting could be initiated concurrently with the other exploratory drifts and would therefore only increase the planned underground drifting time by four (4) months overall.

Conclusions

The following should be evaluated by YMPO using Subpart G procedures:

- Several lines of closely spaced surface-based boreholes across the Ghost Dance fault, which could include inclined boreholes, and detailed surface mapping along the fault, should be considered to obtain additional information on fault characteristics and stratigraphic offset.

- The addition of an exploratory drift to the south for a second intersect with the Ghost Dance fault offers sufficient additional benefits relative to costs to warrant its inclusion in the exploratory drifting plans.

- If only one exploratory drift is driven to the Ghost Dance fault, it should be an exploratory drift to the south rather than the currently planned exploratory drift to the northwest.

3.2.2 Additional Exploratory Drifting to the Western Boundary

NWTRB Panel Suggestion

Consider expanding the currently planned program to include an exploratory drift across the full east-west width of the proposed repository block to obtain a subsurface cross section of north-south trending features.

Technical Evaluation

The evaluation consisted first of a re-examination of the planned surface-based and underground testing programs to identify and characterize unknown north-trending features and then an evaluation of what added information might result from additional exploratory drifting as suggested by the NWTRB Panel. Information to be developed by these testing programs is intended to satisfy needs for repository design and performance assessments. In summary, the evaluation showed the following for each of the factors considered:

- Information on North-Trending Structural Features (Representativeness) Based on the extensive planned program of surface-based drilling, mapping, and geophysics, and the "exploratory" nature of investigating a large rock mass with no known major structural features, the planned surface-based testing program is considered to be sufficient to identify and initially characterize any major north-trending structural features in the western portion of the proposed repository block. The use of inclined boreholes should be considered as a means for enhancing the ability to characterize currently undiscovered near-vertical structures. Added confidence in the mapping program would be gained by mapping cleared-surface east-west oriented strips at selected locations across the proposed repository block.

If necessary later in the site characterization program, additional information from extended exploratory drifting to the west would increase confidence in data obtained from the surface-based testing program.

- Post-Closure Performance - Whereas SCP Section 8.4.3 discusses potential impacts from the construction of planned exploratory drifts, an analysis of possible effects of the additional exploratory drifting on post-closure performance has not been performed. Based on SCP Section 8.4.3, it can be inferred that additional exploratory drifting is not likely to affect post-closure performance, because:

  - Any additional exploratory drifting would be planned to be coincident with the repository drift layout as currently conceptualized. Thus, it is highly unlikely that any new pathways for water would be created or that the host rock would be disturbed beyond the disturbance expected from development of the repository. However, an analysis of possible effects of additional drifting should be evaluated by YMPO using Subpart G procedures.

- Non-radiological Health and Safety - The potential for mine accidents is dependent on the amount of time spent underground by workers and the level of enforcement of worker safety requirements. In that sense, added exploratory drifting means added exposure to risks. However, the incremental addition in planned exploratory drifting should entail no substantial difference in risk to the underground workers. Also, taken from the perspective of repository development, there is no increased risk since the additional exploratory drift is expected to be coincident with the proposed repository main drift.

- Integration with the Repository/Design Flexibility - The plan to make exploratory drifts coincident with repository drifts can minimize the potential for subsequent constraints on repository layout. Flexibility is decreased, however, when exploratory drifts are constructed before repository layout is firmly established.

- Information for Design and Performance Issues - Information obtained from the currently planned surface-based testing program, especially borehole data providing stratigraphic control, is expected to be adequate to support the repository design process with respect to identification of structural constraints on the repository layout west of the Ghost Dance fault without the need for additional exploratory drifting. Surface-based drilling, mapping, and geophysics are expected to identify any major structural features west of the Ghost Dance fault and determine the similarity of these features with known structural features. Thus, information for performance issues would largely be obtained from the existing (planned) program of surface-based and underground testing of known or suspected fault zones, and extrapolated to any new structures that might be discovered.

- Cost - The additional amount of exploratory drifting suggested by the NWTRB Panel is estimated at 4000 feet. Cost is estimated at $23 million.

- Schedule - The additional exploratory drifting would add approximately 16 months to the current ESF schedule.

Conclusions

- While extending the exploratory drifts westward would undoubtedly add valuable information regarding any significant north-trending features that might be found in that portion of the proposed repository block, the Weston report identified no compelling technical reason to supplement the planned exploratory drifting program at this time to include a exploratory drift to the western perimeter of the proposed repository block. Based on current knowledge of the site, and discussions in Section 4.2.1 of this report, Assessment of Technical Findings, the planned surface-based testing program appears adequate to identify and initially characterize any major north-trending features that may exist between the Ghost Dance and Solitario Canyon faults. The extensive surface mapping program, in conjunction with surface drilling, trenching and geophysics, is evaluated as capable of identifying structural offset on the order of approximately 10 feet. Also, the planned exploratory drifting will extend through over half the east-west expanse of the proposed repository block, providing opportunity to characterize the nature of north-trending features. However, the DOE will conduct an additional assessment, using Subpart G procedures, to determine whether additional activities are required.

- It is preferable to proceed with the currently planned surface-based testing program and exploratory drifting and then to re-evaluate the need for additional exploratory drifting when results become available. New data resulting from site characterization activities may show the need for additional exploratory drifting. The extent of the flexibility inherent in the current design to support expansion of the exploratory drifting program should be evaluated during the ESF Title II design process.

- Explicit decision points based on the results of surface-based and underground testing programs should be established to re-evaluate the advisability of additional exploratory drifting across the western portion of the proposed repository block.

- Consideration should be given to expanding the use of surface-based inclined boreholes and conducting detailed surface geologic mapping in the area of interest prior to any decision to initiate further exploratory drifting to the west.

4.0 DOE ASSESSMENT OF FEASIBILITY STUDIES

The NWTRB Panel's suggestions were directed primarily toward potential improvements in data quality, acceleration of the construction schedule for access to the MTL, and expanding the data base to assure representativeness concerning structural features within the proposed repository block. In this section, the NWTRB Panel's suggestions have been considered with respect to:

- Technical aspects, as discussed in the two feasibility studies summarized in Section 3.0; and

- Broader programmatic implications, such as the potential for impacts on ESF Title II design, ESF construction, SCP study plans, and external interactions.

4.1 Assessment of Report on Alternative Exploratory Shaft Construction Methods and Testing Sequences

4.1.1 Assessment of Technical Findings

The Golder evaluation of construction methods indicates that data quality is "Good" with all methods considered, but that it may be "Best" with a mechanically mined exploratory shaft, specifically Case 3a (drill-and-blast ES-1, raise bore/V-mole ES-2) and Case 4a (drill-and-blast ES-1, drill-and-blast/ V-mole ES-2). The evaluation also indicates that, depending on the tests, re-sequencing of in-line, in situ tests for schedule savings could affect data quality. The quality of the data would be adversely affected if tests related to collecting data on transient excavation-related effects were delayed until construction is complete. The specific tests of concern are the SRBTs. To maintain the best data quality, Golder suggests that tests such as the vertical seismic profiling (VSP), UDBR tests and LRBTs can be deferred, but the SRBTs should not be deferred.

The different construction and testing combinations evaluated in the Golder report indicate construction durations, shorter than the 26-month base case, result primarily from deferral or transferring of in-line tests currently planned for ES-1. Mechanical mining methods are faster for excavation, as NWTRB Panel members observed, but schedule analysis shows that sinking two exploratory shafts in parallel by conventional (drill-and-blast) methods and conducting the necessary in-line testing will provide more rapid access to the MTL than two exploratory shafts constructed sequentially, even though the second shaft is constructed by mechanical methods. Despite the faster rate of mechanical excavation methods, for comparable testing sequences, conventional sinking of both exploratory shafts results in the shortest duration between the start of exploratory shaft sinking and availability of the MTL for development and testing. Construction of ES-1 and the associated testing deemed necessary to characterize transient effects control the timing for connection of the two exploratory shafts and the completion of the MTL.

The schedule for development of the MTL can be accelerated by delaying the appropriate tests in ES-1 to shorten the time required to reach the MTL; however, considerable attention should be directed to what tests are delayed so as to not adversely affect data quality.

If the thermomechanical testing planned for the UDBR, the LRBTs and the UDBR excavation effects tests (delay of excavation effects tests was not explicity considered by Golder in schedule related conclusions) were all delayed until after completion of ES-1, a schedule savings of nearly ten months (or over 35 percent) could be achieved over the base case of 26 months for the current construction and testing schedule. This duration savings could be used to offset the schedule impact of mechanically mining one of the two exploratory shafts and would address the NWTRB Panel suggestion regarding the potential improvement in the quality of certain data that could be obtained from such an exploratory shaft. While all construction methods evaluated should enable "Good" quality data to be gathered, use of mechanical mining methods in the construction of the second exploratory shaft has the potential to enhance the quality of data from the testing program. A mechanically mined second exploratory shaft would allow mapping of exploratory shaft walls constructed by two different mining methods, one of which provides a smooth, relatively undisturbed and uncontaminated surface. This information could be used to assess the difference between the two construction methods and would provide input to decisions regarding the construction method for the repository shafts. The potential benefits and tradeoffs associated with the mechanical mining of one of the exploratory shafts, delaying or relocating some of the tests planned for ES-1, and considerations for transferring some tests to ES-2 are worthy of further evaluation, under appropriate Subpart G controls.

4.1.2 Assessment of Programmatic Impacts

The potential programmatic impacts associated with the Golder conclusions and any DOE decisions and follow-up actions are described below and summarized in Table 4. The potential impacts evaluated are: changes to SCP study plans; ESF Title II design changes; interactions with the NWTRB, NRC and the State; cost; and, schedule.

The studies completed with respect to the evaluation of construction methods do not completely address the method of mechanically reaming a small conventionally sunk (first) exploratory shaft to a larger diameter than currently planned. The limited consideration given in the Weston report to the feasibility of deploying a tunnel boring machine (TBM) for exploratory drifting suggests that a larger, reamed ES-1 or a larger, mechanically mined (V-moled) ES-2, together with a TBM for exploratory drifting, may be advantageous. This concept which was specifically suggested by the NWTRB chairman is believed to merit further consideration by Golder and also the YMPO as part of their Subpart G evaluation.

TABLE 4

Summary of Follow-up Actions, Technical Recommendations and Anticipated Programmatic Impacts: Golder Report

Recommendations		• Construct one conventionally mined shaft and one mechanically mined shaft. • Re-sequence ESF testing: - Delay VSP; - Delay non-transient effects UDBR tests; - Delay LRBTs; - Perform all other ES-1 testing as currently planned. • Additional Golder evaluation of conventionally mined small diameter shaft reamed to large diameter.
Follow-up Actions		• YMPO to conduct Subpart G evaluation of feasibility/advantages of one conventionally mined and one mechanically mined shaft: - waste isolation; - data quality; - cost/schedule; - design impacts. • YMPO to conduct Subpart G evaluation of test re-sequencing: - data quality; - construction-to-test interference. • YMPO to conduct Subpart G evaluation of larger diameter shaft(s) to accommodate TBM. • Golder to conduct additional evaluation of conventionally mined small diameter shaft (ES-1) reamed to larger diameter (i.e., mechanically mine both shafts). • These evaluations should be portions of a single integrated Subpart G evaluation.
Programmatic Impacts		
	• Study Plans	• VSP and DBR heater tests: - Plans not yet written; - Incorporate revisions during plan preparation; - No schedule impact anticipated. • UDBR ambient stress test and DBR experiment: - No study plan revisions required. • LRBTs: - Revise plans via change control procedures; - Estimate 3-6 months for HQ and PO approvals; - NRC review, no agreed timeframe; - Estimate no overall adverse schedule impact to start of LRB drilling.

TABLE 4 Cont'd

Summary of Follow-up Actions, Technical Recommendations and Anticipated Programmatic Impacts: Golder Report

Programmatic Impacts (Cont'd)

• Design Changes	• UDBR tests: - Protect installed UDBR facilities/instrumentation during delayed DBR construction/testing; - Alternative muck removal arrangements needed; - Construct muck loading pocket or retractable loader; - Incorporate a muck skip in cage design; - Modify surface muck disposal arrangements for skip discharge; - Mitigate risk of falling rock in shaft during muck loading; - Re-evaluate any changed UDBR ventilation needs; - Concurrently incorporate revisions into ESF Title II Design via change control process; - No appreciable schedule impact on design completion anticipated. • LRBTs: - Changes to testing procedures can be accommodated in ESF Title II Design with no significant schedule impacts.
• Cost	• Costs for preferred methods (one conventionally mined shaft and one mechanically mined shaft) range from $20.7 million to $27.1 million; compared with $25.6 million for the base case (two conventionally mined shafts). • No significant cost impacts anticipated. • Costs impacts for re-sequencing tests not yet determined.
• Schedule	• Schedule savings by delaying non-transient effects tests about the same as schedule increase to perform mechanically mined shaft in series with conventionally mined shaft. • Revised shaft construction method/testing sequence gives no appreciable overall schedule difference from current ESF plans.
• Interactions	• NWTRB: Additional interaction is anticipated to discuss DOE Management recommendations. • NRC: Additional interaction is anticipated to provide assurance that test re-sequencing will not adversely affect test data quality or cause test interference effects. • State: Similar to NRC.

The Golder evaluation indicates that the greatest potential time savings from re-sequencing or relocating the testing planned for ES-1 would be achieved by delaying all testing other than those tests for which data on transient conditions are expected, or alternatively, delaying all RBTs (both the SRBTs and LRBTs) until after exploratory shaft completion and relocating the UDBR and the associated testing so that the shaft could be constructed and the tests performed following exploratory shaft completion. The delay in SRBTs has the potential to compromise the quality of the data base for evaluating the transient effects of exploratory shaft construction. The relocation of the UDBR would necessitate major design changes for both ES-1 and the MTL.

It is concluded that re-sequencing of certain in-line testing is reasonable; however, the re-sequencing needs to be evaluated with respect to data quality and test interference. This should be conducted by the YMPO as a Subpart G evaluation. The tests that should be evaluated for re-sequencing in the ES-1 testing schedule are the following:

- Delay vertical seismic profiling (VSP) until after completion of exploratory shaft construction.

- Construct the UDBR in-line with exploratory shaft construction but delay all tests not providing data on transient effects of exploratory shaft construction (e.g., the ambient stress test, the construction of the rooms for the UDBR experiment, and the heater test). The potential schedule savings is almost four (4) months.

- Drill the LRBs but delay long term tests until after exploratory shaft construction is complete (potential schedule savings of four (4) months). Significant technical difficulties could result in attempting to drill the LRBs after the completion of the exploratory shaft due to the possible lack of a stable drilling platform within the exploratory shaft.

- Conduct all other testing in ES-1 as currently planned.

The evaluation performed by Golder indicates that deferring and/or relocating some planned in-line testing in ES-1 could accelerate the exploratory shaft sinking and the ESF testing program by as much as 8 to 13 months if both exploratory shafts are constructed by the conventional drill-and-blast method. The recommended re-sequencing of tests would not impact data quality. However, the schedule advantages from re-sequencing testing would be offset by the delay in completing ES-2 if this exploratory shaft was to be constructed by mechanical mining methods after sinking ES-1 and drifting across at the MTL.

Study Plan Revisions

- VSP -- Since VSP surveys are not scheduled during exploratory shaft construction, the study plan (SCP Study 8.3.1.4.2.2) submitted to the NRC does not currently contain the description of this activity (study plan activity 8.3.1.4.2.2.5); no impact on schedule is anticipated since the activity description has to be developed and incorporated as an approved revision to the existing study plan. However, no agreement exists at this time regarding the length of time required for NRC reviews of study plan revisions.

- UDBR Testing -- Activity descriptions for the ambient stress test (study plan activity 8.3.1.15.2.1.2) and DBR experiment (study plan activity 8.3.1.15.1.5.2) are written and the study plans have been submitted to the NRC, but these study plans should not require revision if the tests are delayed; the activity description for the DBR heater test (study plan activity 8.3.1.15.1.6.1) has yet to be written and hence any change in test sequence should be accommodated during the development of the study plan, under existing DOE/HQ and YMPO control procedures. The YMPO will need to perform a Subpart G evaluation of the impacts of re-sequencing these tests.

- LRB Tests -- The activity description (study plan activity 8.3.1.2.2.4.4) has been written and the study plan issued to the NRC. This study plan would need to be revised to accommodate the delay in testing planned for the long radial boreholes. Any proposed change in the LRBTs would have to be accepted under the DOE/HQ and YMPO change control procedures and the revised study plan approved according to DOE/HQ and YMPO procedures, a process that should take between three and six months. As stated above, no agreement exists regarding the length of time required by NRC to review revisions to study plans. Depending on the duration of these activities and the actual date for the start of ES-1 construction, there should be no appreciable impact on the initial schedule for the first set of long radial boreholes.

Design Changes

- UDBR -- The only potential design impact of delaying certain tests in the UDBR would appear to be on the UDBR and the construction of the repository-sized room for the DBR experiment. If the DBR experiment and the other tests planned for the UDBR were delayed until after exploratory shaft construction, the appropriate design changes would have to be made to permit such construction and testing from within the completed exploratory shaft. Such changes should consider:

  - Provisions for protecting any installed UDBR utilities and instrumentation (e.g., in vertical stress relief boreholes and angled extensometer boreholes) from damage due to blasting and mucking operations to construct the DBR. Potential mitigative measures for such concerns could include the use of bulkheads and false floors to protect installed facilities.

  - Provisions for alternative muck removal arrangements, including:

    -- Construction of a loading pocket (or retractable loader) for directing muck into the exploratory shaft mucking conveyance;

    -- Modification of the cage design to incorporate a skip for handling the muck;

    -- Modification of surface muck arrangements to provide for skip discharge, in lieu of sinking bucket discharge; and

    -- Providing protection in the exploratory shaft to mitigate the risk of falling rock when loading muck at the UDBR-level.

- Provisions for re-evaluating any changed UDBR ventilation needs after exploratory shaft connection.

- The test re-sequencing discussed above would have to be incorporated into the ESF Title II design process, through the change control procedure. Such changes could be evaluated and processed concurrently with ESF Title II design. They have some effect on the schedule for the completion of the design; however, the impact of the change will be dependent on the extent of all changes to ESF Title II design.

- LRBTs -- If the LRBs are drilled but testing is deferred until after exploratory shaft construction, a majority of the potential changes which may be required would be those associated with the testing and operations.

  - The above provisions need to be factored into the ESF Title II design. However, since they relate to testing rather than drilling the LRBs, the impact on the ESF Title II design process will be minimal.

Cost and Schedule

- The cost of the construction method actually selected after a Subpart G evaluation is completed by YMPO is estimated to range from slightly higher to slightly lower than the base case cost. For the preferred cases involving a conventionally mined exploratory shaft and a mechanically mined exploratory shaft, estimated construction costs for case 2a, 3a, and 4a are $20.7 million, $24.4 million, and $27.1 million, respectively. Such costs compare favorably with the base case cost of $25.6 million. Consequently, the closeness of such estimated costs, which consider construction costs, costs for standby during in-line testing, but not actual testing costs, indicates little or no cost impact associated with selecting a different or modified exploratory shaft construction method/testing sequence combination.

- Similarly, the estimated schedules for the preferred exploratory shaft construction method and test sequence combinations (case 2a, 3a, and 4a) are 27, 29 and 26 months, respectively. These schedules reflect an increase resulting from performing conventional and mechanical mining in series, which is offset by a schedule duration savings from delaying non-transient effects tests until after exploratory shaft construction. Thus, the schedules for preferred cases compare favorably to the base case schedule of 26 months to conventionally sink two exploratory shafts in parallel and perform all testing in-line. On this basis none of the preferred combinations will cause a significant schedule impact to the ESF program.

Interactions as a Consequence of Proposed Changes

- NWTRB -- Additional interactions are anticipated to discuss DOE Management recommendations.

- NRC -- Additional interactions are anticipated to provide reasonable assurances to the NRC that the re-sequencing of tests would not adversely affect data quality or result in test interference.

- State -- similar to NRC.

4.2 Assessment of Report on Additional Exploratory Drifting

4.2.1 Assessment of Technical Findings

The current plan for exploratory drifting, as described in the SCP, calls for one intersection of the Ghost Dance Fault and no exploratory drifting to the west of this fault. The question posed by the NWTRB Panel and the subject of the Weston feasibility study was whether this was sufficient.

The question of sufficiency has been a fundamental consideration in the development of the SCP and will continue to be a consideration in the development or revision of the study plans that provide more detailed description of site characterization activities. The SCP is a comprehensive plan that the DOE considers to be adequate to initiate site characterization.

Additional Exploratory Drifting to the Ghost Dance Fault

Based upon a qualitative analysis of the planned site characterization testing program and the results of the technical evaluation of the additional information that could be gained for performance assessment and repository design (see Section 3.2.1), it appears advantageous for YMPO to evaluate, using Subpart G procedures, the recommendations in the Weston report to include several lines of closely spaced boreholes across the Ghost Dance fault and to consider the addition of inclined boreholes in the surface-based testing program as a means to supplement the data-base expected from the planned drilling program and the proposed modification to the underground testing program. YMPO will also evaluate using Subpart G procedures the Weston recommendation to plan now for an additional exploratory drift to the south to intersect the Ghost Dance fault at a second location. The relative advantages for potentially obtaining more useful site characterization data at a second, more southerly intersection of the Ghost Dance fault (where fault offset is likely to be greater), compared with current plans for a single intersection of the northern portion of the fault, indicate that if project limitations permit funding only one exploratory drift to the Ghost Dance fault, the southern drift intersection would be preferred. This conclusion should also be evaluated by the YMPO as part of an integrated effort using Subpart G procedures.

Additional Exploratory Drifting to the Western Boundary

With respect to characterization of the north-south trending features in the western portion of the proposed repository block, the current plan calls for an extensive surface-based testing program. While recognizing that results of such testing may eventually show the desirability of additional exploratory drifting, the resolution achievable by the planned surface-based testing (i.e., mapping, correlation between boreholes, and geophysics) is considered to be sufficient to identify and initially characterize any major north-trending features that may exist between the Ghost Dance and Solitario Canyon faults. In addition, the planned drifting to the imbricate fault zone and Ghost Dance fault provides exploratory drifting across the eastern portion of the proposed repository block. This should provide a representative section of what may be expected in the western portion of the proposed repository block. Major structural features are not currently identified in the western portion of the proposed repository block, and the planned surface-based investigations are expected to identify any features that may exist. Therefore, as part of an integrated evaluation the YMPO will conduct a Subpart G evaluation of the Weston recommendation: to proceed with the program currently as described in the SCP; evaluate data as they are obtained relative to the information needed for performance assessment and repository design; and then evaluate whether and when more surface-based testing or additional exploratory drifting should be done.

The Weston recommendation is to establish decision points (and criteria) for re-evaluating and possibly expanding the planned surface-based testing activities to include: detailed geologic mapping (e.g., in east-west strips that would cross-cut potential north-south features); and, the use of inclined boreholes to intersect any steeply dipping structures. This recommendation will be evaluated by the YMPO using Subpart G procedures as a means to supplement the data base from surface-based exploration. The potential impacts of such additions or revisions to the planned surface-based program should be assessed as part of this evaluation. This approach is consistent with the objective of adequately characterizing the site while maintaining repository design flexibility and minimizing the potential for impacts on waste isolation. This preference is also influenced by the estimate of 16 months to construct the western exploratory drift at an estimated additional cost of $23 million. Although alternate construction methods, such as the use of a TBM, could reduce the drifting duration, the present exploratory shaft design will not readily accommodate a TBM operation because of the limited access, ventilation, and muck haulage imposed by the current exploratory shaft design. An evaluation, using Subpart G procedures, of the advantages of a TBM and modifications necessary for its use will be conducted by the YMPO.

Based on these technical considerations, together with the cost and schedule implications of the additional exploratory drifting, it is concluded that any decision on the need for additional exploratory drifting to the west should be deferred pending evaluation of the results from the currently planned surface-based tests.

In response to the NWTRB Panel assertion that no additional surface-based data are needed to determine that additional exploratory drifting is warranted, the DOE feels that while planning for additional drifting to the Ghost Dance fault is appropriate at this time, the decision to drift to the western boundary should be based on the results of surface-based testing. This position is based on several factors. First, the Ghost Dance fault is known to be a significant structural feature with structural and hydrologic characteristics that could impact the design and performance of the proposed repository. Thus, it warrants detailed characterization plans incorporated in the initial ESF construction and testing programs. Also, the proposed (second) exploratory drift to the Ghost Dance fault is coincident with the conceptual repository main drift and is subparallel to the strike of the rock units. This minimizes the impacts on design flexibility and postclosure performance.

On the other hand, there are no major structural features currently recognized in the repository block between the Ghost Dance fault and the Solitario Canyon fault. In this case the DOE will be characterizing a large volume of rock rather than a specific target. Thus, an exploratory drift to the western boundary planned before the benefits of surface-based testing results are available could be inappropriately located both in terms of intersecting features of interest and in respect to reducing design flexibility for the final grade and orientation of the proposed repository.

4.2.2 Assessment of Programmatic Impacts

Additional Exploratory Drifting to the Ghost Dance Fault

The programmatic actions required to implement this recommendation (Table 5) as part of the site characterization program will include the following and should be evaluated using Subpart G procedures:

- Technical assessments by the YMPO of the recommended addition to the exploratory drifting program and additional surface-based drilling;
- Assessment of potential impacts of the additional exploratory drift on site performance;
- Revision of ESF Subsystems Design Requirements Document;
- Modifications to the basis for ESF Title II design;
- Analysis of adequacy of ventilation and muck handling systems to accommodate additional exploratory drifting;
- Development of study plans that include plans for testing in the second drift to the Ghost Dance fault and for surface-based drilling in the vicinity of the fault;
- Management approvals for cost impacts, schedule changes for exploratory drifting, and changes to the site characterization and design baselines;
- NWTRB, NRC, and the State interactions to present the basis for the revised plans, including input to Semi-annual Progress Reports after changes are approved.

Study Plan Revisions

The potential impacts are summarized in Table 5. The following is a discussion of the potential impacts.

- The mechanical and hydrologic testing as well as subsurface geologic mapping proposed for the currently planned intersection of the Ghost Dance fault would be repeated at the second intersection. Therefore, no impact to testing strategy is anticipated.

TABLE 5

Summary of Follow-up Actions, Technical Recommendations and Anticipated Programmatic Impacts: Weston Report

Recommendations	• Additional exploratory drift south to Ghost Dance fault
	- Additional exploratory drift to be executed simultaneously with planned exploratory drifts;
	- Expand surface-based drilling program to include:
	  - Several lines of boreholes transecting the Ghost Dance fault;
	  - Inclined boreholes to intersect the fault;
	  - More detailed surface-based mapping along the fault trace.
	- Incorporate additional exploratory drift into the ESF Title II design process.
	• Additional exploratory drifting to the western boundary
	- Present surface-based testing program adequate to initiate new site characterization activities;
	- Include inclined boreholes in the systematic drilling program;
	- Exploratory drifting to the west should be limited at this stage, to currently planned drifts;
	- Flexibility to expand exploratory drifting to the west should be evaluated in ESF Title II design process;
	- Decision points should be established in planning networks to reevaluate decision not to extend exploratory drifts to western boundary.
	• Expand surface-based testing program to include inclined boreholes.
	• Conduct detailed geologic mapping (e.g., in east-west strips) to detect north-trending features.

Follow-up Actions	• Additional drifting to the Ghost Dance fault: - YMPO to conduct Subpart G evaluation of drift southward to a second intersect; - YMPO to conduct Subpart G evaluation of several lines of closely spaced boreholes across fault; - YMPO to conduct Subpart G evaluation of drilling inclined boreholes to intersect fault. • Additional drifting to the Western Boundary: - YMPO to conduct Subpart G evaluation of decision not to drift to west; - Conduct detailed geologic mapping (in east-west strips) to detect north-trending features; - YMPO to conduct Subpart G evaluation of drilling inclined boreholes to intersect fault. • These evaluations should be portions of a single integrated Subpart G evaluation.

TABLE 5 Cont'd

Summary of Follow-up Actions, Technical Recommendations and Anticipated Programmatic Impacts: Weston Report

Programmatic Impacts

• Study Plans	• Underground testing in exploratory drifts: - Study plans not yet developed; when developed, can easily accommodate both fault intersects; - No impact to testing strategy anticipated; - No schedule impacts anticipated for study plan development.
• Design Changes	• Incorporate second Ghost Dance fault drift into ESF Title II Design: - 4-8 weeks of engineering analysis performed concurrently to address design changes; - 2-3 months of concurrent Subpart G analysis of impacts of additional drifting. • Decision to not perform drifting to western boundary at the present time has no impact on design. Decision will be evaluated by YMPO using Subpart G procedures.
• Cost	• Second intersect to Ghost Dance fault: - Estimated cost $9.4 million; - Additional testing costs not yet determined. • No additional drifting to western boundary at present time: - No additional cost now. If needed, estimated cost is $23 million.
• Schedule	• Additional drifting to Ghost Dance Fault extends overall ESF schedule about four months.
• Interactions	• NWTRB: Additional interactions are anticipated to discuss DOE Management recommendations. • NRC: Anticipated interaction with the NRC regarding decision for second intersect with Ghost Dance fault and to provide analysis of impacts of additional drifting on waste isolation. • State: Similar to NRC.

- Since study plans for underground testing in exploratory drifts have not yet been prepared, any revision to planned activities can be accommodated during the initial development of the applicable study plans under the appropriate DOE/HQ and YMPO control procedures.

Design Changes

- The additional exploratory drift would need to be incorporated as a proposed change to the ESF Title II design. On the basis of incorporating other changes through the change control process, it is estimated that this would require four to eight weeks of engineering analysis concurrent with ESF Title II design.

- Based upon existing analyses of the potential impacts of planned exploratory drifts on the waste isolation capabilities of the site (SCP Section 8.4; Design Acceptability Analysis), no adverse effects on site performance are expected from the extended exploratory drifting. However, analyses of the effects of all planned excavations on waste isolation and test interference will need to be completed using Subpart G procedures as part of ESF Title II design. The analyses would require two to three months concurrent with ESF Title II design.

- Based upon the use of conventional mining methods and analyses by Fenix and Scission (1988) of the capability of the current ESF design to support additional exploratory drifting, the design appears sufficient to accommodate the muck hauling and ventilation requirements for the relatively short, second exploratory drift to the Ghost Dance fault. However, a documented analysis of ventilation and excavation requirements should be done as part of ESF Title II design for all the planned drifts. These analyses should include consideration of a TBM and would be completed concurrently with ESF Title II design.

Cost and Schedule

- These changes will result in increased costs and prolong the duration for completion of the exploratory drifting program by an estimated four months if the additional exploratory drift can be constructed in parallel with the other exploratory drifts. The cost increase, $9.4 million, has the potential to require trade-off decisions due to budget constraints at the time the work is to be accomplished.

Interactions as a Consequence of Proposed Changes

- The proposed additional exploratory drift supplements the current plans for site characterization. Therefore, it is anticipated that the DOE interactions with the NRC and the State will consist primarily of providing appropriate analyses of the potential for impacts on waste isolation and technical meetings, as requested, to discuss these analyses. The action would implement NWTRB Panel suggestions, and it may be necessary to conduct other interactions to inform the NWTRB of the DOE management recommendations.

- Adding a second exploratory drift to intersect the Ghost Dance fault further to the south would respond, in part, to an NRC Site Characterization Analysis (SCA) comment on the SCP, suggesting that the DOE consider exploratory drifting to the southern part of the proposed repository block.

In summary, it appears that efforts required to incorporate plans for the additional exploratory drift to the Ghost Dance fault could be accommodated as part of the scheduled ESF Title II design effort and study plan development process. This matter requires more detailed evaluation and planning by the YMPO.

Additional Exploratory Drifting to the Western Boundary

The decision not to modify current plans to include an exploratory drift to the western boundary of the proposed repository block to characterize potential north-trending features has no impact on ESF Title II design or study plan development. This decision, runs counter to the suggestion by the NWTRB Panel and may require further interactions. The YMPO will conduct a Subpart G evaluation of the decision not to drift to the western boundary of the proposed repository block.

5.0 FOLLOW-UP ACTIONS TO FEASIBILITY STUDIES

The following section describes DOE actions based on the appraisal of the Golder and Weston reports. Such actions are directed at either implementing certain of the report recommendations or performing an integrated Subpart G evaluation comprised of several components described below to assess issues which were not fully addressed in the feasibility studies.

5.1. Alternative Exploratory Shaft Construction Methods and Testing Sequences

The following actions related to the NWTRB Panel suggestions to consider alternative ESF Shaft construction methods and testing sequences are derived from assessment of the information presented in the Golder report (Section 3.1), and the DOE assessment of the Golder conclusions and recommendations (Section 4.1).

- Assessment of the information presented in the Golder report concludes that there may be an overall advantage to have both a mechanically mined shaft and a conventionally mined shaft. This will provide two exploratory shaft construction methods that can be compared, and will also provide enhanced data quality beyond that which could be obtained from only conventionally mined shafts. On this basis, YMPO should conduct a Subpart G evaluation of one mechanically mined shaft and one conventionally mined exploratory shaft. The results of the additional Golder evaluation (described below) will be included in this YMPO evaluation.

- The information provided in the Golder report indicates that constructing a conventionally mined exploratory shaft sequentially with a mechanically mined exploratory shaft will extend the ESF schedule beyond that which could be achieved by constructing two conventionally mined exploratory shafts concurrently. However, the information in the Golder report further indicates that such an extension in duration could be offset by a selective rescheduling of portions of the testing program, such that data quality requirements are not impaired. On this basis, the following re-sequencing of the ES-1 testing activities will be evaluated using Subpart G procedures by the YMPO, including appropriate treatment of design, schedule and cost aspects.

    - Delay VSP until after completion of exploratory shaft construction.

    - Construct the UDBR in-line with exploratory shaft construction but delay all tests not providing data on transient effects of exploratory shaft construction (e.g., the ambient stress test, the construction of the rooms for the DBR experiment, the heater test).

    - Drill the LRBs but delay the tests until after exploratory shaft construction is complete.

    - All other testing in ES-1 should proceed as currently planned.

- In the interest of improving ESF data quality, the NWTRB Panel addressed the use of mechanical mining methods in both exploratory shafts. More specifically, conventionally mine ES-1 to a 8 to 10 foot diameter, performing only required in-line testing, then raise bore ES-2 and finally mechanically ream ES-1 to full diameter. Golder's report (Section 4.7) discussed this approach briefly, but did not perform a complete analysis. Golder will be directed to:

  - Expand the scope of their previous study, such that the construction method and testing sequence involving mechanical mining of both exploratory shafts, as suggested by the NWTRB Panel, is evaluated at the same level of detail as the other case studies;

  - Evaluate various reaming techniques (i.e., raise boring, V-mole, etc.) which would yield improved and/or optimized results for this case, especially from a schedule viewpoint, consistent with the ESF Title II Design requirements.

- A Subpart G evaluation shall be conducted by the YMPO for constructing larger diameter exploratory shafts which may be sufficiently large enough to facilitate TBM access and enhance overall ESF efficiency (muck handling and ventilation).

5.2 Additional Exploratory Drifting

The following actions related to additional exploratory drifting are derived from the evaluation of the information presented in the Weston feasibility studies prepared in response to the NWTRB Panel's suggestions regarding the possible need for additional exploratory drifting (Section 3.2) and the DOE evaluation of the Weston conclusions and recommendations (Section 4.2).

- The feasibility, usefulness, schedule, and cost of augmenting the planned surface-based testing program by adding the following activities will be evaluated by the YMPO using Subpart G procedures.

  - Drill several closely-spaced lines of boreholes across the Ghost Dance fault.

  - Conduct detailed surface geologic mapping along the surface trace of the Ghost Dance fault and in east-west strips between the Ghost Dance and Solitario Canyon faults, across the trend of structural features identified on the basis of currently planned surface-based studies.

  - Drill inclined boreholes to intersect the Ghost Dance fault and other steeply-dipping structural features detected through surface-based studies.

  - Evaluate the technology and methodology for dry-drilling and coring of inclined boreholes by a prototype testing activity.

- A Subpart G evaluation of the proposed exploratory drift to the Ghost Dance fault will be conducted by the YMPO and, if appropriate, an action plan will be developed for implementation of this exploratory drift that will include appropriate treatment of design, schedule, and cost aspects. The evaluation will also include an assessment of potential impacts to waste isolation and interferences from construction and testing.

- A Subpart G evaluation of the adequacy of the current plan to defer exploratory drifting to the western boundary of the proposed repository until data from new site characterization activities are available will be conducted by the YMPO.

REFERENCES

Fenix & Scisson, Inc., 1988, "Impact Analysis of ESF Design for Calico Hills Penetration and Exploratory Drift and Tuff Main Extension to Limits of the Repository Block," DOE/NV/10322-35, Prepared by Fenix & Scisson, Inc., Las Vegas, NV.

Golder Associates Inc., June 22, 1989, "Evaluation of Alternative ESF Shaft Construction Methods and Test Sequences", Draft, Seattle, WA

Roy F. Weston, Inc., July 14, 1989, "Evaluation of Additional Drifting for Site Characterization at Yucca Mountain", Washington, D.C.

Sandia National Laboratories, 1987, "Site Characterization Plan Conceptual Design Report", SAND84-2641, 6 Vol., Sandia National Laboratories, Albuquerque, NM.

U.S. Department of Energy, 1986, "Generic Requirements for a Mined Geologic Disposal System", OGR/B-2, Washington, D.C.

U.S. Department of Energy, 1988a, "Site Characterization Plan", DOE/RW-0199, Washington, D.C.

U.S. Department of Energy, 1988b, "Surface-based Investigation Plan", YMP/88-25, Las Vegas, NV.

Yucca Mountain Project/88-02, Nov. 8, 1988, "Yucca Mountain Project Exploratory Shaft Facility Title I Design Summary Report", Final Draft, Yucca Mountain Project Office, Las Vegas, NV.

Yucca Mountain Project, 1988, "Yucca Mountain Project Exploratory Shaft Facility Subsystem Design Requirements Document (SDRD)", NVO-309, Las Vegas, NV.

Yucca Mountain Project/89-3, Feb. 3, 1989, "ESF Title I Design Acceptability Analysis and Comparative Evaluation of Alternative ESF Locations", Yucca Mountain Project Office, Las Vegas, NV.

Evaluation of Additional Drifting for Site Characterization at Yucca Mountain

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Prepared by
Roy F. Weston, Inc.
Washington, D.C.
for
U.S. Department of Energy
Office of Civilian Radioactive Waste Management

WESTON
MANAGERS DESIGNERS/CONSULTANTS

102.3

EVALUATION OF ADDITIONAL DRIFTING FOR SITE CHARACTERIZATION AT YUCCA MOUNTAIN

JULY 14, 1989

PREPARED BY
ROY F. WESTON, INC.
WASHINGTON, D.C.

FOR
U.S. DEPARTMENT OF ENERGY
OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT

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EXECUTIVE SUMMARY

At a meeting with the Department of Energy (DOE) on April 11-12, 1989, the Structural Geology and Geoengineering Panel of the Nuclear Waste Technical Review Board (the NWTRB Panel) raised concerns regarding the ability to fully characterize the proposed repository block at Yucca Mountain, Nevada, through the planned exploratory drifting from the exploratory shaft facility (ESF). The NWTRB Panel suggested that the DOE consider expanding the currently planned drifting program (see Figure 3-1) to intersect the Ghost Dance fault at more than one location, and to characterize the western part of the repository block so as to obtain more information and reduce uncertainty related to the representativeness of data collected. Specifically, the NWTRB Panel suggested the following:

- Conduct additional exploratory drifting to intersect the Ghost Dance fault at one or more other locations, preferably to the south.
- Extend the planned exploratory drift to the northwest through the Ghost Dance fault to intersect the western perimeter of the proposed repository block and explore for north-trending structural features.

The purpose of this report is to evaluate and respond to the suggestions made by the NWTRB Panel regarding the adequacy of the planned exploratory drifting in the Yucca Mountain ESF. The suggestions of the NWTRB Panel were evaluated by:

- Examining the planned SCP surface-based and underground testing activities;
- Evaluating the adequacy of the data expected to be obtained from tests in these activities with respect to characterizing the Ghost Dance fault and any currently unknown north-trending features in the western portion of the proposed repository block between the Ghost Dance and Solitario Canyon faults;
- Determining the need for extending the exploratory drifting program to supplement the current plan and identifying alternatives for extended exploratory drifting; and,
- Evaluating these alternatives in terms of the various factors on which the current plans for exploratory drifting were based.

In planning a site characterization program, the DOE has adopted an approach that begins with the evaluation of regulatory requirements promulgated by the Nuclear Regulatory Commission (NRC) in 10 CFR Part 60, and that must be satisfied in siting and licensing a repository; identifies the performance and design information needed to address those requirements; and then develops specific investigations to obtain the needed information.

The DOE's site characterization program consists, essentially, of surface-based and underground testing, associated laboratory tests, and analyses of data including performance assessments. The extensive surface-based and underground tests are designed to complement each other so that the information gathered during site characterization can be integrated and projected confidently across the entire proposed repository block. Results from the planned surface-based and underground testing will be evaluated to determine whether additional data are required to reduce uncertainty for performance assessments and repository design.

In the SCP, the DOE described investigations designed to reduce uncertainty in geologic models of the Yucca Mountain area. As these investigations proceed, the integrated results from planned surface-based mapping, geophysics and drilling activities and tests performed in the ESF will be used to;

- Refine the geologic models;
- Provide input to repository and waste package design;
- Provide input to performance assessment calculations; and
- Reevaluate performance allocations.

This will be an iterative process, based on the results of site characterization investigations. This iterative process will reduce uncertainty in the estimates of geologic features and processes, and it will provide a basis to reevaluate the adequacy of the site characterization program.

The NRC's siting criteria (10 CFR 60.122) states that it must be demonstrated that "the potentially adverse human activity or natural condition has been adequately investigated, including the extent to which the condition may be present and still be undetected taking into account the degree of resolution achieved by the investigations." One of the many aspects of this issue that will be addressed during site characterization is the minimum vertical offset of a fault that can be recognized by surface mapping techniques. As described in the SCP (Section 8.3.1.4.2.2.1 - Geologic mapping of zonal features in the Paintbrush Tuff), vertical offsets of 35 feet (10 meters) or less due to displacement along faults should be recognized by geological mapping of bedrock exposures. Because of the gradational nature of contacts (zonal features) within the Tiva Canyon Member and the degree of exposure, the level of confidence or accuracy in locating these contacts varies across the site. Based on project experience, zonal contacts can be located with a vertical error of plus or minus approximately 1.5 feet (0.5 meters) with high confidence. At locations with greater colluvial cover and less frequent outcrops, the possible error is somewhat greater. In general, it appears that dip-slip offsets greater than 7 to 10 feet (2 to 3 meters) would be detected by surface mapping of bedrock outcrops. Since the Ghost Dance fault is visible on air photos, and at the surface in Coyote Wash, where the offset is only 3-4 meters, it is assumed that mapping faults with this degree of near-vertical displacement would provide adequate stratigraphic and structural input for repository design.

In complying with the aforementioned regulation, it may become obvious, at some point in the site characterization program, that uncertainty in the geologic models cannot be reduced sufficiently by planned surface-based testing (e.g., fault offset cannot be resolved within less than 35 feet). If this is the case, based on the available (integrated) results of planned surface-based mapping, geophysics and drilling, then the DOE could consider expanding the planned surface-based testing program to include additional activities or boreholes to either investigate specific features of interest or to increase confidence in the ability to make predictions of performance assessments or to refine repository design. An expanded surface-based program could include additional investigations such as detailed geologic strip-maps, additional geophysical surveys and vertical and inclined boreholes. If an expanded surface-based program could not provide the necessary reduction in uncertainty (or if the results of an expanded surface-based program do not sufficiently reduce uncertainty), then an additional means of reducing uncertainty could be to expand the exploratory drifting program beyond what is currently planned. This decision may be better accomplished at some time in the future (as opposed to expanding the program now) when surface-based testing and integrated data analysis will have provided better stratigraphic control across the proposed repository block. Deferring this decision would have the advantage of permitting the expanded drifting to be located to investigate the features of interest and to be better integrated with the proposed repository, as the elevation, grade, and orientation of the conceptual repository design may change.

An illustration of the process described above is the recommendation, presented below, to include an additional exploratory drift to the Ghost Dance fault. This recommendation is based on the conclusion that uncertainty in characterizing this specific feature will not be sufficiently reduced by the planned surface-based and underground testing.

Based on the integration and interpretation of early results of the planned surface-based and underground testing, the DOE should decide whether additional exploratory drifting to the west should be conducted during site characterization (and before a license application is submitted) or could be conducted during the performance confirmation phase of the repository program as is currently planned.

Ghost Dance Fault

Planned testing related to characterizing the Ghost Dance fault was evaluated based on the level of detail contained in the SCP. Planned activities were grouped into five categories (surface mapping, geophysics, drilling, underground mapping, and other underground tests) to characterize the Ghost Dance fault, and in particular the hydrologic properties associated with the fault. The criteria used for this evaluation are listed below:

- Nature of fractures in the Ghost Dance fault;
- Location and geometry of lithostratigraphic features bounding the Ghost Dance fault;
- Displacement across the Ghost Dance fault;
- Variability in rock properties across the Ghost Dance fault;
- Effects of the Ghost Dance fault on flow mechanisms; and,
- Gas flow permeabilities of the Ghost Dance fault.

The evaluation using these criteria indicates that whereas the planned surface-based and underground investigations appear adequate to initiate new site characterization activities, valuable hydrologic and structural information useful for performance assessments and repository design would be obtained by extending the Drill Hole Wash exploratory drift (conceptual repository main drift) southwest from the dedicated testing area approximately 2,000 feet to intersect the Ghost Dance fault at a location where the displacement across the fault may be greater than at the planned intersection. This proposed alternative, discussed in Section 6.0 of this report, would provide access to the Ghost Dance fault at a location approximately 1/2 mile south of the currently planned intercept and approximately 1/2 mile north of boreholes UZ-7 and UZ-8. In addition, the DOE should consider including several lines of boreholes transecting the Ghost Dance fault, and should consider expanding it's surface-based drilling program to include inclined boreholes. These additional boreholes will help define stratigraphic offset across the Ghost Dance fault and provide information for repository design.

To evaluate the alternative approach against the planned exploratory drifting to the Ghost Dance fault, eight evaluation factors have been identified. The following is a summary of the qualitative evaluation of the alternative approach (extended exploratory drifting to the Ghost Dance fault) taking the eight factors into consideration:

Factors	Summary of Evaluation
Information for Characterization of the Ghost Dance fault (Representativeness of Data)	Geologic and hydrologic conditions may vary along length - extended drifting is preferred for direct observation
Information for Design and Performance Issues	Design issues - additional testing is helpful to determine amount of offset across the Ghost Dance fault and its effect on the planned repository horizon. An expanded surface-based testing program may be more applicable
	Performance issues - additional information from drifting is preferred to reduce the uncertainty of the parameters used in the performance assessment models.
Postclosure Performance	Additional exploratory drifts consistent with conceptual repository layout do not adversely impact site performance.
Non-radiological Health and Safety	Relative to repository development, impact is negligible.
Integration with the Repository	Additional drift is an integral part of the conceptual repository layout.

Factors	Summary of Evaluation
Design Flexibility	No additional impact on flexibility; proposed drift would be perpendicular to dip of tuffaceous units and consistent with conceptual repository layout.
Cost	Approximately $9.4 million, a 2.8% increase.
Schedule	Increase of 4 months over planned exploratory drifting if excavated concurrently.

Drifting to Characterize North-trending Features

Planned testing related to characterizing the proposed repository block west of the Ghost Dance fault to detect any currently unknown, major north-trending features was evaluated based on the level of detail in the SCP. Planned activities were grouped into the following categories: surface-based tests (surface mapping, geophysics, and drilling); and underground tests expected to identify and characterize any currently undiscovered major north-trending features in the western portion of the proposed repository block.

Sections 7.1 and 7.2 provide a general discussion of the adequacy of the planned tests to identify and characterize major north-trending features, including brief descriptions of the corroborative relation between the types of tests (e.g., boreholes provide control for geophysical surveys, mapping helps determine trench locations, etc.). Section 7.3 provides a summary evaluation of the planned testing categories against specific criteria. These criteria are:

- Identification of major north-trending features;
- Nature of fractures in fault zones;
- Extent and variability of fracture networks in the host rock;
- Location and geometry of lithostratigraphic features;
- Nature of hydrologic properties;
- Fault offsets;
- Rock strength properties;
- Variability in properties across the proposed repository block;
- Effect of major features on flow mechanisms; and,
- Gas flow permeabilities of fault zones.

On the basis of this evaluation and the discussions in Section 7.1. and 7.2, there is not a compelling need to augment the planned programs of exploratory drifting or underground testing by extending the exploratory drifts to the west of the Ghost Dance fault. The present plans are sufficient to identify any major unknown north-trending structural features and to initially characterize any features that may be identified.

To evaluate the alternative of drifting to the west against the planned site characterization activities, eight evaluation factors have been considered. The following is a summary of the qualitative evaluation of exploratory drifting to characterize north-trending structural features:

Factors	Summary of Evaluation
Information for Characterization of the North-trending Structural Features	Not necessary now, but would increase confidence.
Postclosure Performance	No adverse effects expected if drift is coincident with conceptual repository layout.
Non-radiological Health and Safety	Relative to repository development, no additional effect on worker safety if exploratory drift is coincident with a conceptual repository panel access drift.
Integration with the Conceptual Repository Design	No effects on conceptual repository layout, however, may not be coincident with final layout.
Design Flexibility	Design becomes less flexible as additional drift subparallel to dip of tuff units is constructed because it may impact the plane of the repository horizon; drift orientation may not be coincident with final repository layout.
Information for Design and Performance Issues	Not necessary at present, but may be necessary to reevaluate later in planned program.
Cost	Increased cost of approximately $23 million.
Schedule	Based on conventional drill and blast methods, an additional 16 months for exploratory drifting; it will not provide data for early input to a determination of site suitability.

Conclusions and Recommendations

Conclusions (Ghost Dance fault)

The evaluations described above indicated that an additional drift that would intersect the Ghost Dance fault, south of the currently planned intercept, would provide access for direct observation and testing of geologic and hydrologic parameters and, therefore, the additional data is preferred for performance assessments and for input to repository design. Specifically, an extended exploratory drift should be driven to the southwest along the conceptual repository main drift to intersect the Ghost Dance fault. This alternative is preferred in addition to the currently planned exploratory drift which will be driven northwest to intersect the Ghost Dance fault. The factors leading to this conclusion are:

- The Ghost Dance fault appears to be a significant structural feature within the proposed repository block. The ability to adequately characterize this structural feature is important in reducing the uncertainty of performance assessment calculations;
- The Ghost Dance fault is thought to have variable displacement (a "hinge" or "scissors" fault) as compared to typical normal or reverse displacement. Fault characteristics such as dip and degree of deformation may vary along the length of the fault and with depth;
- Based on existing information from surface mapping, displacement along the Ghost Dance fault appears to substantially increase to the south and therefore, the planned repository horizon may be effected;
- Greater displacement toward the south may have resulted in a greater degree of fracturing and brecciation, and therefore hydrologic characteristics of the fault and across the fault may vary from north to south;
- Characteristics of the fault appear to vary at the surface but are not known at depth;
- The intersection of the planned exploratory drift with the Ghost Dance fault toward the north will provide direct observation of the fault at only one location;
- Extended exploratory drifting to the Ghost Dance fault supplemented by an expanded drilling program would provide access for direct and indirect observation and testing, and would aid in refining the location and orientation of the proposed repository horizon;
- It appears that an extended exploratory drift can be excavated without a significant adverse impact to the program schedule;
- The extended exploratory drift to the Ghost Dance fault (Figure 6-1) will reduce uncertainty regarding structural and hydrologic characteristics along the southern portion of the fault;

- The additional data obtained would further reduce uncertainty in lateral and vertical variabilities for purposes of performance assessment and repository design; and,

- This extended exploratory drift would provide access to directly observe and test the fault zone at a location of potentially greater deformation which may have hydrologic characteristics different from those to the north.

Recommendations (Ghost Dance fault)

The recommendations for the extended exploratory drift to the Ghost Dance fault are presented below. These recommendations are based on the conclusions discussed above.

- It is recommended that an additional (extended) exploratory drift should be driven to the southwest coincident with the conceptual repository main drift, approximately 2,000 feet, to intersect the Ghost Dance fault. This intersection would be near a mid-point between the planned drift to the north and the boreholes (UZ-7 and UZ-8) to the south.

- The extended exploratory drift should be excavated simultaneously with the excavation of the other three exploratory drifts (e.g. four concurrent headings) to minimize schedule impacts.

- The extended exploratory drift, as described in this report, should be incorporated as a proposed change in the Title II design.

- If only one exploratory drift is driven to the Ghost Dance fault, it should be the extended exploratory drift to the south where offset and deformation may be greater, rather than the currently planned drift to the northwest.

- In addition to the extended exploratory drift, the DOE should consider expanding its drilling program to include several lines of boreholes transecting the Ghost Dance fault, and possibly inclined boreholes to intersect the fault. These additional boreholes will help define stratigraphic offset across the Ghost Dance fault and provide information for repository design. In addition, the DOE should consider more detailed surface mapping along the fault trace.

Conclusions (North-trending Features)

There is not a compelling need to augment the planned exploratory drifting program with a drift to the western perimeter of the proposed repository at this time; however, new data from site characterization activities may require reevaluation of this conclusion. The factors contributing to this conclusion are listed below:

- Based on what is presently known about the hydrologic and geologic conditions of the proposed repository block, the planned surface-based testing will be sufficient to identify and initially characterize any major north-trending features that may exist between the Ghost Dance and Solitario Canyon faults.

- The information obtained from the surface-based and underground testing is expected, at this time, to be adequate to support the repository design process with respect to identification of constraints on the repository layout west of the Ghost Dance fault, without the need for additional information from exploratory drifting.

- Evaluations of the results of early site characterization testing activities may indicate a need to more thoroughly characterize the hydrologic and geologic conditions of the western portion and boundary of the proposed repository block. This may include additional drilling, mapping, or exploratory drifting.

- Depending on the location of the feature(s) of concern, an additional exploratory drift approximately 4,100 feet long could be located coincident with one of several proposed panel access drifts (Fig. 8-1) in the conceptual underground repository layout. The location and grade of an appropriate panel access drift is less likely to change after new site data have been incorporated into repository design.

- If it is determined that a drift to the northwest is necessary based on an evaluation of the information from the planned surface-based and underground testing, the additional drift should be driven to the northwest from a point near the intersection of the recommended additional exploratory drift to the southwest with the Ghost Dance fault. The northwest drift would then pass through the central portion of the proposed repository block to a point where the Solitario Canyon fault is nearest to the proposed repository block.

- The current ESF program is considered flexible enough to allow for an exploratory drift to the western perimeter of the proposed repository block at some later time, if required.

- The planned exploratory drifting to the imbricate normal fault zone and the Ghost Dance fault cover approximately 50 percent of the east-west width of the proposed repository block. The western portion of the proposed block has exposures at the surface in outcrop that will help provide controls for mapping. Therefore, the combination of the planned exploratory drifting and the surface-based testing program should identify any significant north-trending structural features within the western part of the proposed repository block.

<u>Recommendations (North-trending Features)</u>

The recommendations for exploratory drifting to the western portion of the proposed repository block are presented below. These recommendations are based on the conclusions reached above.

- Although the present surface-based testing program has been evaluated as being adequate to initiate new site characterization activities, the DOE should consider including inclined boreholes in the systematic drilling program. This would enhance the ability to characterize any near vertical features (e.g., fractures) encountered in the proposed repository block.

- Exploratory drifting to the northwest should be limited, at this stage, to that which is currently planned. However the flexibility to expand the exploratory drifting to the northwest should be evaluated in the Title II design process to assure the capabilities of the underground support systems are adequate to support extended exploratory drifting.

- Decision points based on the results of surface-based and underground testing should be established to reevaluate the decision not to extend northwest exploratory drifting. Suggested decision points are as follows:

  - Periodically during site characterization;
  - After completion of the detailed surface mapping of Yucca Mountain;
  - After completion of the systematic drilling program; or
  - After completion of planned exploratory drifting.

- The DOE should consider expanding the use of inclined boreholes and conducting detailed geologic mapping in an area or direction of interest (e.g., east-west strip maps across the central portion of the proposed repository block) during early surface-based testing and prior to initiating the excavation of a long drift to the northwest.

1.0 INTRODUCTION

1.1 Purpose

The purpose of this report is to evaluate and respond to the suggestions made by the Structural Geology and Geoengineering Panel of the Nuclear Waste Technical Review Board (the NWTRB Panel) regarding the adequacy of the planned exploratory drifting in the Yucca Mountain Exploratory Shaft Facility (ESF). The Department of Energy, Office of Facilities, Siting and Development (DOE-OFSD) assigned Roy F. Weston, Incorporated (WESTON) to evaluate the NWTRB Panel's suggestions. In this report WESTON has evaluated the NWTRB Panel's technical suggestions in a manner consistent with the May 2, 1989 "Action Plan For The Development Of Report On NWTRB Suggestions Related To Additional Drifting In The ESF" (Appendix A) which was developed, concurred on and approved by the DOE.

1.2 Background

At a meeting with the Department of Energy (DOE) on April 11-12, 1989, the NWTRB Panel suggested that the DOE consider expanding the currently planned exploratory drifting program, described in the Site Characterization Plan for the Yucca Mountain Site (SCP; DOE, 1988a), to intersect the Ghost Dance fault at two or more locations (rather than the single intercept currently planned) in order to obtain additional information on the characteristics of the fault and the underground conditions. The NWTRB Panel would like additional data collected on the sense and magnitude of the offset of faults, and hydrologic characteristics of the faults. Specifically, the NWTRB Panel suggested the following:

- Conduct additional exploratory drifting to intersect the Ghost Dance fault at one or more other locations, preferably to the south.

- Extend the planned exploratory drift to the northwest through the Ghost Dance fault to intersect the western perimeter of the proposed repository block and explore for north-trending structural features.

The suggestions of the NWTRB Panel were evaluated by (1) examining the planned SCP surface-based and underground testing activities, (2) evaluating the data expected to be obtained from tests in these activities with respect to characterizing the Ghost Dance fault and any unknown north-trending features in the western portion of the repository block, (3) assessing the value/impacts of extending the exploratory drifting program in terms of the various factors on which the current plans for exploratory drifting were based.

1.3 Organization of Report

The remainder of the report is divided into the following sections and appendices. Section 2.0 summarizes the NWTRB Panel suggestions on extended exploratory drifting. Section 3.0 provides a summary description of the Ghost Dance fault and other north-trending features in the proposed repository block. Section 4.0 summarizes the planned surface-based and underground testing activities related to characterization of the Ghost Dance fault and north-trending structural features. Sections 5.0 and 6.0 provide qualitative evaluations of the planned testing program and extended exploratory drifting relative to the Ghost Dance fault. Sections 7.0 and 8.0 provide qualitative evaluations of the planned testing program and extended exploratory drifting relative to north-trending structural features, and Section 9.0 presents conclusions and recommendations.

Appendix A contains the DOE approved action plan for the development of this report. Appendix B lists selected relevant excerpts from the transcripts of the April 12, 1989, NWTRB Panel meeting. Appendix C discusses alternative drift excavation techniques (e.g., tunnel boring machines) and general specifications for the support of exploratory drifting.

2.0 SUMMARY OF NWTRB SUGGESTIONS ON EXTENDED EXPLORATORY DRIFTING

The NWTRB Panel has suggested that the currently planned surface-based testing and exploratory drifting program, as described in the SCP, may not be sufficient to characterize the Ghost Dance fault and the area of the proposed repository bounded by the Solitario Canyon fault on the west and the Ghost Dance fault on the east. The NWTRB Panel suggested that it would be prudent to plan now for additional exploratory drifting, rather than formulate generic contingency plans, as indicated in the Site Characterization Plan (DOE, 1988a).

2.1 Exploratory Drifting to the Ghost Dance Fault

The NWTRB Panel has suggested that the currently planned surface-based testing and exploratory drifting program in the SCP may not sufficiently characterize the repository horizon or the hydrologic characteristics of the Ghost Dance fault. If, for example, the amount of displacement is ten feet near the northern portion of the fault, then the repository horizon and fault zone characteristics could be different from the repository horizon and fault zone characteristics where the displacement has been postulated to be 125 feet, such as at the southern part of the fault (DOE, 1988a; and Figure 2-1). However, the NWTRB Panel concluded that, based on their experience, the structural stability and the ability to mine drifts through the Ghost Dance fault are not significant concerns. The NWTRB Panel is concerned that the currently planned surface-based testing program and the exploratory drifts, as presently laid out near the north end of the proposed repository boundary, may not provide sufficient representative data on the Ghost Dance fault or stratigraphic control along its length as input for repository design. The NWTRB Panel suggested that an extended exploratory drifting program should intersect the Ghost Dance fault in at least two points, one of which should be farther to the south to take into consideration the possible greater displacement along the fault.

2.2 Exploratory Drifting to the Western Perimeter of the Conceptual Repository Boundary

The NWTRB Panel suggested that the currently planned surface-based testing and exploratory drifting program, as described in the SCP, may not provide sufficient exploration to detect any unknown north-trending near-vertical features. The planned surface-based activities appear to be focused on vertical boreholes and characterizing stratigraphy and rock properties. The NWTRB noted that the currently planned surface-based activities may only characterize known near-vertical structural features and may not detect unknown near-vertical structural features that may offshoot from the Solitario Canyon and the Ghost Dance faults. The NWTRB Panel suggested that extended exploratory drifting, normal to the predominant and regional north-trending structures, may be necessary to sufficiently characterize the area of the proposed repository block.

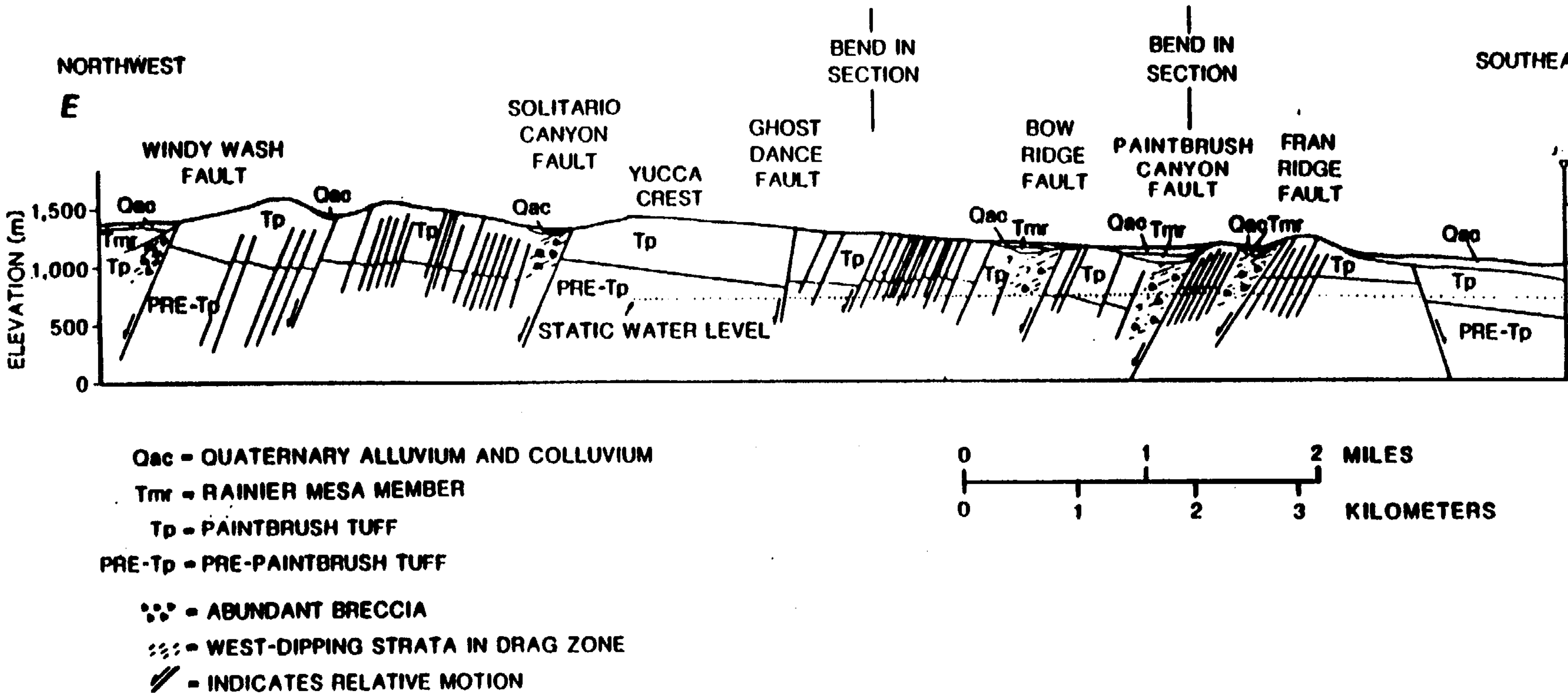

Figure 2-1. Schematic geologic cross section E-E' at Yucca Mountain. See Figure 1-17. of the SCP (section 1.2.2) for location of cross section E—E'. Modified in SCP from Scott and Bonk, 1984.

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3.0 SUMMARY DESCRIPTION OF THE GHOST DANCE FAULT AND OTHER NORTH-TRENDING FEATURES IN THE PROPOSED REPOSITORY BLOCK

The proposed repository block is bounded on the west by the Solitario Canyon fault zone, on the northeast by Drill Hole Wash (possibly underlain by a fault), and on the east and southeast by an imbricate fault zone. The Ghost Dance fault trends north through the northeastern area of the proposed repository block (Figure 3-1). At Yucca Mountain, the structural block and the west-dipping normal faults that define it have been delineated by surface mapping and geophysical surveys (DOE, 1988a). Major normal faults such as the Solitario Canyon and the Ghost Dance faults, generally strike north and dip steeply west. Offset along both of these faults appears to decrease northward through Yucca Mountain (DOE, 1988a). As currently conceived, the proposed repository block would be excavated mainly in the relatively unfaulted western part of the structural block.

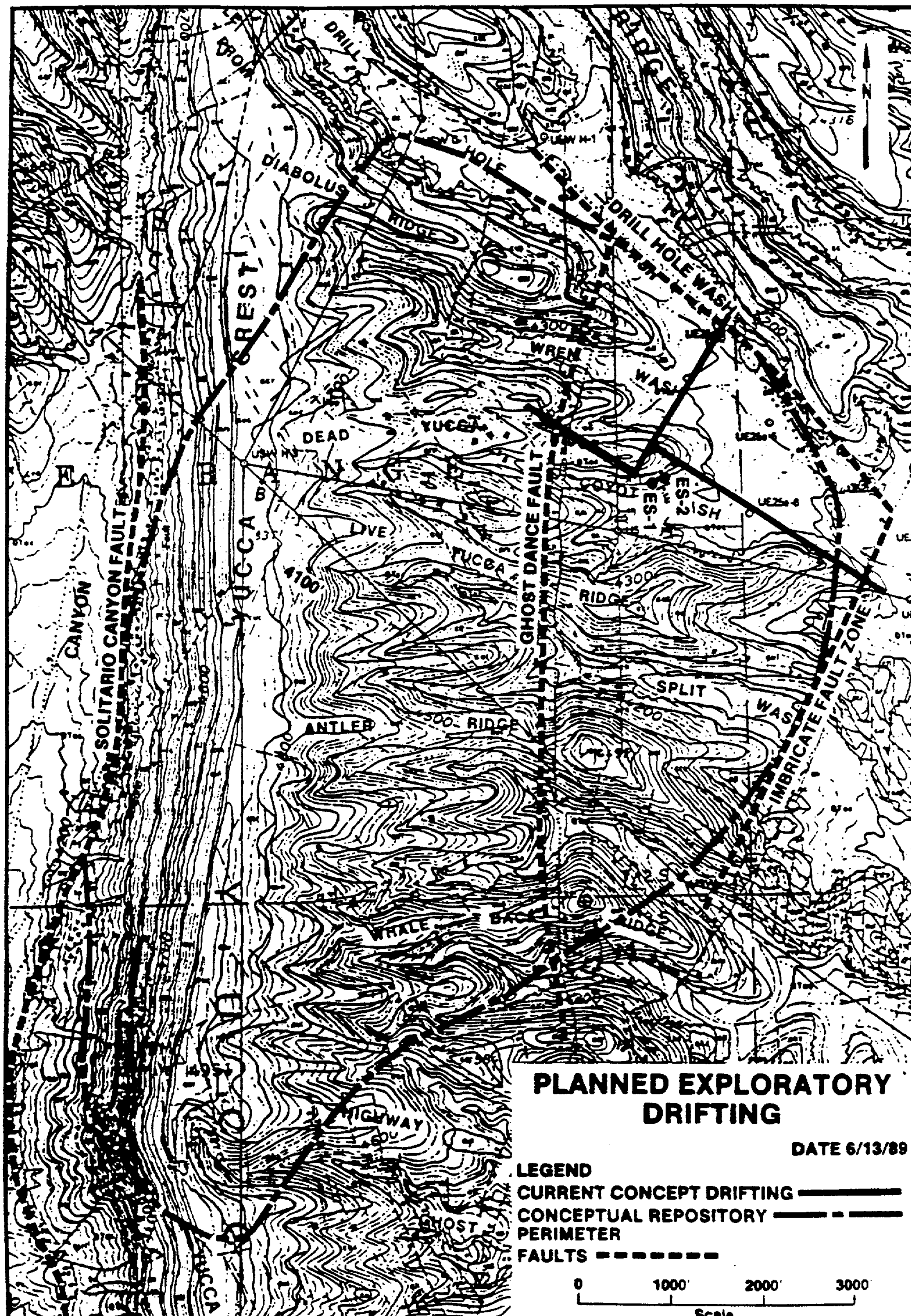
3.1 Ghost Dance Fault

The Ghost Dance fault has been mapped as a north-striking normal fault in the northeastern area of the proposed repository block. It appears to have 125 feet of vertical offset at the southeastern margin of the conceptual repository. Displacement appears to decrease northward and is not easily recognized at Drill Hole Wash. The apparent increase in displacement to the south indicates that this may be a "hinge" fault. The fault dips very steeply (80 to 90 degrees) to the west at the surface, and the western side is down-dropped. Breccia zones, as much as 66 feet wide, have been mapped at the surface (DOE, 1988a).

Due to brecciation the fault may be a more transmissive zone than the surrounding rock matrix and may provide a potentially large flux pathway for water infiltrating from the ground surface to the saturated zone. It may therefore represent a preferred pathway for gases to vent to the accessible environment at the ground surface or a ground-water pathway for radionuclides to reach the saturated zone below the proposed repository horizon. Alternatively, the fault may be a more impermeable zone than the surrounding rock matrix and may act as a dam to impede or stop the flow of water across it thus providing the potential for water to be impounded or trapped (perched water).

3.2 North-trending Structural Features

Within the proposed repository boundary, recognized offset on faults is 16 feet or less, except for the Ghost Dance fault, which appears to have 125 feet of vertical offset at the southeastern margin of the perimeter boundary. North to north-northwest striking west-dipping normal faults with small (less than 16 feet) vertical offsets are present, particularly near the southern and eastern edges of the proposed repository. These small faults can be readily identified at the surface only where stratigraphic boundaries are distinct and exposures are good. Elsewhere, particularly north and west of Abandoned Wash (Figure 3-1), the presence of these faults between exposures has been inferred from observed offsets in the projections of recognizable stratigraphic horizons (USGS, 1984); however there appear to be no major faults within the proposed repository boundary.


PLANNED EXPLORATORY DRIFTING
DATE 6/13/89
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CONCEPTUAL REPOSITORY PERIMETER
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DIABOLUS RIDGE
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WREN WASH
DEAD YUCCA
LIVE YUCCA RIDGE
GHOST DANCE FAULT
ES-1
ES-2
COYOTE WASH
SPLIT WASH
ANTLER RIDGE
WHALE BACK RIDGE
IMBRICATE FAULT ZONE
SOLITARIO CANYON FAULT
CANYON
YUCCA CREST
HIGHWAY
GHOST
USW H-1
UE25a-6

FIGURE 3-1

4.0 SUMMARY OF PLANNED SCP SURFACE-BASED AND UNDERGROUND ACTIVITIES

The DOE's general plans for site characterization include a subset of the surface-based tests and exploratory drifting from the ESF relevant to the NWTRB Panel suggestions. Since much of the existing site-specific information is limited due to the absence of underground geologic information, the overall testing program has been developed to permit flexibility to adapt to and characterize geologic features and any unexpected conditions that may be encountered during the site characterization program. The extensive surface-based tests and underground tests are designed to complement each other so that the information gathered during site characterization can be projected confidently across the entire proposed repository block. Results from the planned surface-based and underground investigations will be integrated and evaluated to determine whether additional data are required to reduce uncertainty for performance assessments and repository design.

It is highly unlikely that major geologic features would not be detected by this iterative process. This section describes the planned site characterization activities relevant to characterizing the Ghost Dance fault and other potential north-trending features in the proposed repository block. Sections 5.0 and 7.0 evaluate the adequacy of these activities to characterize these features.

4.1 Rationale for Planned Testing

The site characterization program has three principal purposes:

- To provide the data to be used to evaluate the suitability of a site;
- To provide the data needed for licensing; and
- To provide the data for design of the proposed repository and the waste package.

In planning a site characterization program to achieve these purposes, the DOE has adopted an approach that starts with the evaluation of regulatory requirements that must be satisfied in siting and licensing the proposed repository, identifies the performance and design information needed to address those requirements, and then develops specific investigations to obtain the needed information. This approach is embodied in an issue resolution strategy. An important part of this strategy is an issues hierarchy that consists of key issues, issues, and information needs. The key issues and issues are based on the regulatory requirements that govern the siting and design of a repository. The information needs define the data and analytical techniques that are needed to resolve each issue. Issue resolution is not likely to provide complete assurance that performance of the proposed repository system will be acceptable. A reasonable assurance of acceptable performance is the general standard that will be met.

The general objectives of site characterization are compatible with the regulations promulgated by the Nuclear Regulatory Commission (NRC) in 10 CFR Part 60. In these regulations, the NRC specifies postclosure performance objectives, including the environmental standards anticipated to be set by the Environmental Protection Agency for radionuclide releases to the accessible environment, individual protection, and ground-water protection; requirements on the containment to be provided by the set of waste packages and on the rate of release of radionuclides from the engineered-barrier system; and an objective for the pre-waste-emplacement ground-water travel time. The regulations also specify design criteria for the disposal system related to the postclosure performance objectives, and identify preclosure objectives for radiation protection.

The characterization of faults, fault zones, and their hydrology is an important aspect of the DOE's program. Faults are geologic features that must be incorporated into three-dimensional models of the geology, as well as repository design and ground-water flow and transport. The geology of Yucca Mountain (e.g., structure, stratigraphy, lithology, etc.) must be characterized to aid in assessing the performance of the site and designing the layout of the proposed repository (e.g., distance from emplacement panels to faults, conceptual repository layout and grades, etc.). Faults can affect the hydrologic behavior of the ground-water flow system and consequently the time of ground-water travel as well as transport of radionuclides to the accessible environment. Faults could provide vertical conduits for flow, or they could act as flow boundaries in the unsaturated zone.

Site characterization (both surface-based and underground) will investigate and describe the current state of fault zones in and around the proposed repository site. Information resulting from these investigations will be used as input to models for predicting the impacts of fault zones on site performance as well as the potential impacts of temporal changes within those zones. As summarized very briefly below, hydrologic parameters whose values may be affected by natural processes over a period of time (e.g., fault movement) include the percolation flux, the elevation of the water table, permeability and porosity, and pathways for travel to the accessible environment.

Percolation flux. The creation of scarps, the diversion of drainage, the change in the dip of beds, or the juxtaposition or tilting of beds due to fault offset could affect the average percolation flux at the top of the Topopah Spring welded unit. Various amounts and locations of offsets will be modeled to determine the point at which fault offset could become a significant factor in controlling the ground-water flux.

Water-table elevation. Fault offsets can change the elevation of the water-table or potentiometric surface, change the hydraulic gradient, or create discharge points or perched aquifers in the controlled area.

Permeability and porosity. The movement along faults could result in significant local changes in the permeability of saturated fractures--the effective fracture porosity along the fault could affect the regional ground-water flow system.

Travel pathway. Offsets occurring on faults in the controlled area in the 10,000 years after waste emplacement may divert radionuclides to travel pathways with significantly different distribution coefficients or water chemistry. Preliminary evidence suggests that the downward movement of water in the unsaturated zone will not be diverted completely beyond the limits of the proposed underground portion of the repository by the heat generated by the waste (SCP Section 8.3.5.17). It is expected, however, that lateral diversion could occur to some extent, thus reducing the overall downward flux through the proposed repository. However, structural features of high permeability could disrupt this lateral water movement. For example, the

Ghost Dance fault could act as a conduit for downward vertical flow through the proposed repository horizon. The extent and effects of these conditions need further investigation to determine their likelihood and significance.

4.2 Surface-based Activities

The SCP describes an extensive surface-based investigation program which includes both regional and site-scale activities. This section describes the main site-scale activities relevant to the NWTRB Panel suggestions. For the purposes of this evaluation, these activities have been grouped into three broad categories:

- Surface mapping;
- Geophysics; and
- Drilling.

4.2.1 Surface Mapping

Several SCP activities are directly or indirectly intended to collect information on the surface expression of geologic structures and potentially related landforms or deposits.

Geologic mapping of zonal features in the Paintbrush Tuff (Activity 8.3.1.4.2.2.1) will provide more detailed mapping to complement published geologic maps. The objectives of this activity are (1) to map zonal variations within exposed tuffs that will aid in the identification of structural displacements at a scale of 35 feet (10 meters) or less, and (2) to detect subtle changes in structural styles.

Surficial deposits mapping of the Yucca Mountain area (Activity 8.3.1.5.1.4.2) will provide a map of surficial deposits for facility placement planning, geomorphic studies, engineering property studies, and surface infiltration studies. The distribution of surficial deposits will be determined by mapping the deposits on aerial photographs and possibly on satellite imagery. The contacts of the deposits will be verified in the field by examining trenches and natural exposures. This activity will also determine the distribution of major concentrations of calcite-silica vein deposits at or near the ground surface at Yucca Mountain. The alternative conceptual models concerning the origin of these deposits within faults and fracture systems may have significant hydrologic implications.

Development of a geomorphic map of Yucca Mountain (Activity 8.3.1.6.1.1.1) will help determine the areal distribution of active erosional areas and geomorphically stable areas. This map may help determine the role of erosion (as opposed to fault displacement) in the formation of the Ghost Dance fault's surface expression, and thus refine estimates of displacement on this fault.

Evaluate Quaternary geology and potential Quaternary faults at Yucca Mountain (Activity 8.3.1.17.4.6.1) will map faults in the site area at a scale of 1:24,000. Information will be compiled from existing geologic mapping (USGS, 1984) and all site area faults will be examined in the field to determine the age of youngest offset deposits. Information on the age and recurrence intervals of individual faults (including the Ghost Dance fault) will be added to the map from detailed trench studies described in Activity

8.3.1.17.4.6.2 (Evaluate age and recurrence of movement on suspected and known Quaternary faults). The map will be periodically updated as other studies of faults are completed and released in final form when site characterization is completed.

Characterization of the vertical and lateral distribution of stratigraphic units within the site area (Study 8.3.1.4.2.1) will use geologic mapping, geophysical surveys, borehole evaluations, and geologic sampling, testing, and analysis to gather pertinent geologic data, develop lithologic correlations, and describe the geologic stratigraphy of the site area. Surface-based mapping and borehole activities will be complemented by geologic mapping and testing in the exploratory shafts and drifts (Activity 8.3.1.4.2.2.4).

Surface-fracture network studies (Activity 8.3.1.4.2.2.2) is expected to provide measurements and analyses of fracture networks to support modeling of potential hydrologic flowpaths, particularly in the unsaturated zone. Applications are also expected to aid development of tectonic models and determination of the mechanical response of fractured rock to excavation and thermal loading. The analyses will provide quantitative data for determining spatial distribution of fractures, chronology of fracture development, and parametric characteristics of fractures. The results of this activity, Activity 8.3.1.4.2.2.3 (Borehole evaluation of faults and fractures), Activity 8.3.1.4.2.2.4 (Geologic mapping of the exploratory shaft and drifts), and 8.3.1.4.2.2.5 (Seismic tomography/vertical seismic profiling) will provide input to Study 8.3.1.4.2.3 (Three-dimensional geologic model) concerning the fractures and faults in the site area.

4.2.2 Geophysics

Numerous geophysical activities described in the SCP are designed to collect information to help reduce uncertainty regarding the structures and stratigraphy at the Yucca Mountain site. The following list contains site scale geophysical methods which are expected to increase DOE's understanding of the site geology, including faults within the proposed repository block.

Activity Title	Activity Number
Seismic tomography/vertical seismic profiling	8.3.1.4.2.2.5
Monitor current seismicity	8.3.1.17.4.1.2
Conduct and evaluate deep geophysical surveys in an east-west transect crossing the Furnace Creek fault zone, Yucca Mountain, and the Walker Lane	8.3.1.17.4.3.1
Evaluate intermediate depth (2 to 3 kilometer) reflection and refraction methods and plan potential application of these methods within the site area	8.3.1.17.4.7.1
Detailed gravity survey of the site area	8.3.1.17.4.7.2
Detailed aeromagnetic survey of the site area	8.3.1.17.4.7.3
Detailed ground magnetic survey of specific features within the site area	8.3.1.17.4.7.4

Evaluate surface geoelectric methods and plan potential applications of these methods within the site area	8.3.1.17.4.7.5
Evaluate methods to detect buried faults using gamma-ray measurements, and plan potential application of these methods within the site area	8.3.1.17.4.7.6
Evaluate thermal infrared methods and plan potential application of these methods within the site area	8.3.1.17.4.7.7
Evaluate shallow seismic reflection (mini-Sosie) methods and, if appropriate, conduct surveys of selected structures at and proximal to the site area	8.3.1.17.4.7.8

The results of these activities as well as the surface mapping, drilling, exploratory drifting, and numerous other SCP site and regional investigations will provide input to Study 8.3.1.4.2.3 (Three-dimensional geologic model) which will develop a three-dimensional geologic model of the site area. The early results of site characterization investigations and the geologic model will be used to guide further site characterization, repository design (advanced conceptual design and license application design), and performance assessments.

4.2.3 Drilling

The DOE has developed a comprehensive drilling program that includes initial plans for the number and location of boreholes and drilling methods to be used. The initial plans are intended to be responsive to information needs identified as site characterization proceeds. Since the drilling of some boreholes is dependent on the results of other investigations such as surface mapping and geophysical surveys, the SCP presents plans for a specific number of boreholes, but maintains flexibility to expand the drilling program. The samples and information collected in the drilling program are planned to be spatially distributed and of sufficient quality to characterize the lateral and vertical variability of the lithologic, hydrologic, mechanical and thermo-mechanical properties across the site. Information obtained from boreholes will be evaluated using geostatistical techniques to assure that the data collected are representative of site conditions (SCP Section 8.3.1.4.3.1).

The drilling information is also planned to be sufficient to provide lithostratigraphic data across the site. This control is needed to help understand the hydrostratigraphy (hydrology) of the site and to determine the potential constraints on conceptual repository design and layout. For example, one constraint on conceptual repository design is the geometric relation between the repository grade and the orientation (strike and dip) of the rock units including the lithophysal zone (upper bound of the proposed repository horizon) and the vitrophyre unit (lower bound of the proposed repository horizon) of the Topopah Spring Member. There is currently some uncertainty regarding the position and orientation of these lithologic units. This uncertainty will be reduced by the drilling program. Another design constraint that will be defined by the drilling program (and other investigations) is the effect of fault displacement (offset of the proposed repository horizon across a fault) on conceptual repository grades, orientation, and general layout.

The surface-based drilling program is divided into two major parts: the features drilling program and the systematic drilling program. These drilling programs involve similar drilling methods, sampling requirements, and technical objectives.

Features Drilling Program

This program partially overlaps and complements the systematic drilling program (SCP Activity 8.3.1.4.3.1.1). It includes the drilling of vertical boreholes into the unsaturated zone at the site (SCP Activity 8.3.1.2.2.3.2), multipurpose-borehole testing (SCP Activity 8.3.1.2.2.4.9), and the Solitario Canyon horizontal borehole (SCP Activity 8.3.1.2.2.3.3). Each of the activities in this program will provide detailed information on hydrologic properties, moisture content, and matric potential in the unsaturated zone.

Site Vertical Boreholes

This activity is confined to the area of Yucca Mountain that is immediately above and adjacent to the conceptual repository boundary. Vertically, the study area extends from near the surface of Yucca Mountain to the underlying water table.

This activity involves dry drilling and coring 17 vertical boreholes ranging in depth from 200 to 2000 feet. Nine of the proposed boreholes will range in depth from 200 to 500 feet and will be terminated before penetrating the proposed repository horizon. The remaining boreholes will be drilled to depths ranging from 1200 to 2000 feet and will penetrate the unsaturated zone below the proposed repository horizon.

Multipurpose Boreholes (MPBH)

Before starting to construct the exploratory shafts, the DOE plans to drill a vertical multipurpose borehole near the location of each shaft to detect and characterize any water-saturated rock layers (perched-water zones) that may be present and to characterize the lithologic and hydrologic conditions existing before the construction of the exploratory shafts. In addition, the data collected from monitoring these planned boreholes before and during shaft construction will allow the DOE to evaluate whether the construction of the shafts and the underground drifts could affect the subsequent testing. If necessary, a third MPBH will be drilled halfway between the two shafts.

Each of the proposed MPBHs will be drilled to the maximum depth of the respective shaft. The specific location of each hole will be selected to meet the requirements for long-term surface access for monitoring and the requirement to locate the boreholes at least two drift diameters away from any underground openings, which is the expected zone of mechanical influence expected to occur around such penetrations.

Solitario Canyon Horizontal Borehole

The Solitario Canyon fault has formed a steep escarpment on the west side of Yucca Mountain with approximately 900 feet of topographic relief. This fault is a hinge-type fault (as the Ghost Dance fault is postulated to be) that has more offset to the south than it does near the northern perimeter of the proposed repository block. This fault is important because it defines the western boundary of the proposed repository block and could affect the hydrologic system encompassing the proposed repository.

A long borehole, subhorizontally drilled from the surface, will be used to investigate this fault. This borehole will be drilled laterally into the Topopah Spring welded unit across the Solitario Canyon scarp, where the upper part of this unit is exposed at the site. The location of this borehole has been tentatively identified near the northwestern end of the block (DOE, 1986, Vol. 4, Map 8; Fig. 4-1 of this report). The borehole will be drilled dry to attempt to provide representative information on in situ moisture conditions. The length of the borehole will be sufficient to penetrate the zone of fracturing or alteration associated with the fault; this could require a borehole up to 1000 feet long.

Drilling Activities Related to Features Drilling Program

Numerous activities in the SCP are intended to characterize the hydrologic system (both unsaturated and saturated) of the site area (and region). Following is a description of several of these activities that investigate the unsaturated hydrologic characteristics of the proposed repository block including fracture and fault zones.

Studies to provide a description of the unsaturated zone hydrologic system at the site (Investigation 8.3.1.2.2) contains several activities to address unsaturated zone hydrology. The following parameters will be measured or calculated as a result of the site studies planned to satisfy this investigation:

- Infiltration characteristics and spatial distribution of the physical and hydraulic properties of the surficial hydrogeologic units at Yucca Mountain;

- Unsaturated zone percolation characteristics and spatial distribution of the physical and hydraulic properties of the proposed repository host rock and surrounding hydrogeologic units;

- Unsaturated zone gas-phase movement characteristics and gas phase (pneumatic) properties of the proposed repository host rock and surrounding units;

- Unsaturated zone hydrochemical characteristics and spatial and temporal variation of the gas and water quality in the proposed repository host rock and surrounding units; and

- Velocities, fluxes, and travel times of water and gases in the unsaturated zone.

Site vertical boreholes (Activity 8.3.1.2.2.3.2), discussed above as part of the Features Drilling Program, will include two boreholes (USW UZ-7 and USW UZ-8) located on opposite sides of the Ghost Dance fault near the southeastern margin of the conceptual perimeter drift boundary to investigate hydrologic characteristics related to that fault. USW UZ-8 is located to penetrate the Ghost Dance fault. USW UZ-11 and USW UZ-12 will be located on opposite sides of the Solitario Canyon fault in a similar manner to USW UZ-7 and USW UZ-8

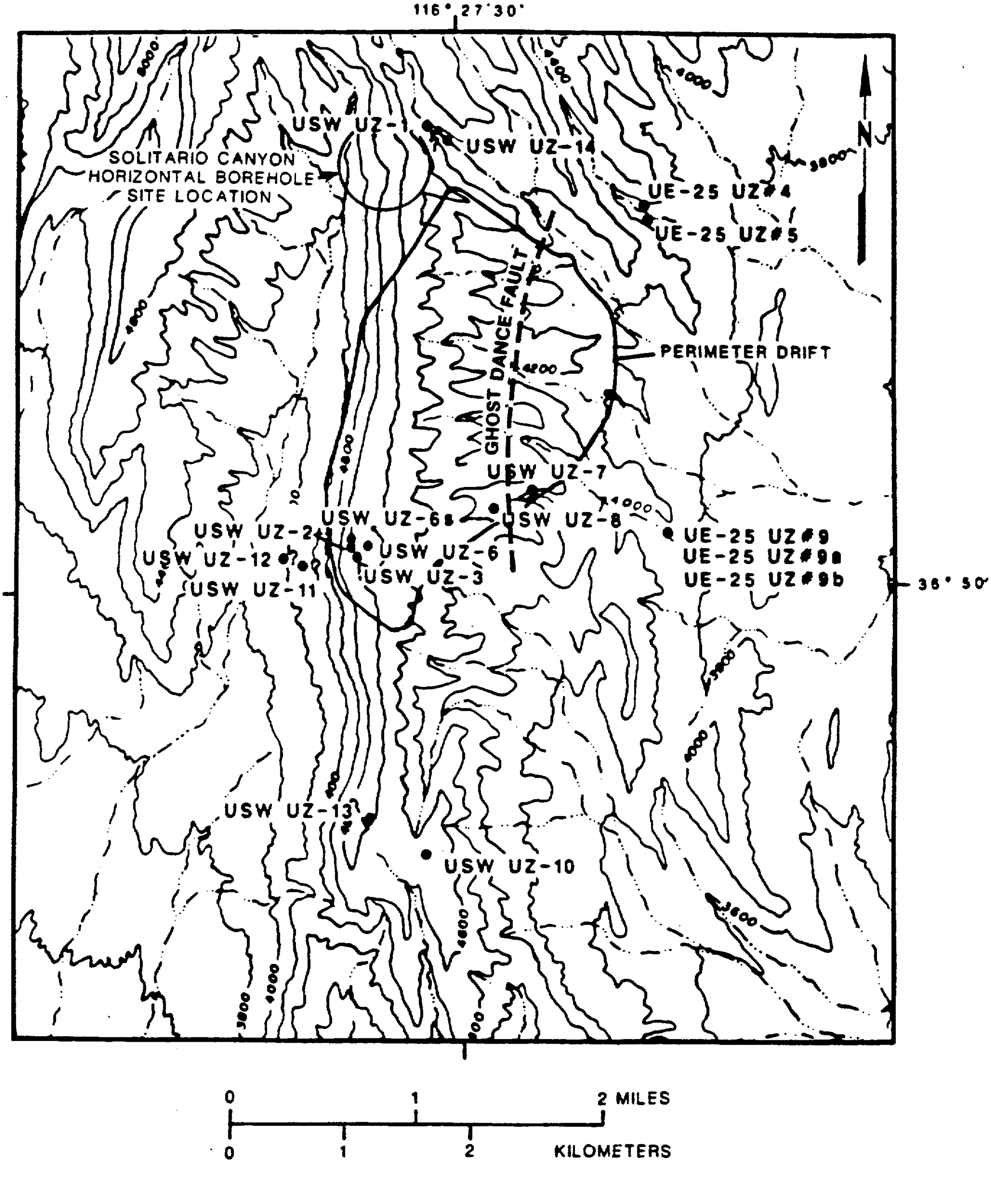

Figure 4-1 Map of existing and proposed unsaturated-zone borehole locations.

(Figure 4-1). These two boreholes, in addition to the Solitario Canyon horizontal borehole activity, are designed to hydrologically characterize the Solitario Canyon fault.

Characterization of gaseous-phase movement in the unsaturated zone (Study 8.3.1.2.2.6) is planned (1) to describe the pre-waste-emplacement gas-flow field, (2) to identify structural controls on fluid flow, (3) to determine conductive and dispersive properties of the unsaturated zone for gas flow, and (4) to model the transport of water and tracers in the gas phase. This study focuses on characterizing the Solitario Canyon fault as a potential boundary condition for the proposed repository block.

Surface and subsurface stratigraphic studies of the host rock and surrounding units (Activity 8.3.1.4.2.1.1) is intended to determine the spatial distribution, history, and characteristics of stratigraphic units within the Paintbrush Tuff, tuffaceous beds of Calico Hills, Crater Flat Tuff, and possibly older volcanic rock units within the site area. Characterization of the stratigraphic sequence within the site area will use (1) borehole drilling and coring, (2) sampling, lithologic examination and analysis of drill-bit cuttings and core, (3) borehole video surveys and logging, (4) surface-outcrop mapping, (5) petrographic and geochemical analysis of drillcore, cuttings, and outcrop samples, and (6) surface and borehole geophysical surveys.

Borehole evaluation of faults and fractures (Activity 8.3.1.4.2.2.3) is intended to: (1) Assess the reliability and usefulness of available borehole techniques for identifying and characterizing the subsurface fracture distribution; (2) Determine vertical and lateral variability and characteristics of subsurface fractures; and (3) Identify subsurface characteristics of fault zones.

Analysis and interpretation of subsurface characteristics of faults and fractures in the site area will, in part, be based upon (1) core sampling and fracture logging, (2) borehole video camera logging, and (3) acoustic televiewer surveys and logging. In addition, a standard suite of geophysical logs will be collected from all the deep site characterization boreholes.

Systematic Drilling Program

The systematic drilling program consists of drilling 12 boreholes within the conceptual boundary of the proposed repository block, or its immediate vicinity, to collect samples and data on lithostratigraphy, basic physical properties, fracture characteristics, mineral composition, in situ hydrologic conditions, and other characteristics, as discussed in SCP Section 8.4.2.1.4. This information will address various information needs, particularly the information needs for modeling unsaturated-zone flow and transport. The systematic drilling program is also an important source of samples for geomechanical, geochemical, and geophysical studies.

Seven of the 12 boreholes are distributed across the site area and in conjunction with other planned boreholes will provide areal coverage of the site with a spacing of about 3000 feet between boreholes. The other five boreholes of the systematic drilling program are clustered immediately to the southeast of the conceptual boundary of the proposed repository block, and their purpose is to provide information on small-scale lateral variabilities in matrix hydrologic properties and data on the faulting in this area. Due to a larger number of mapped faults, the southeastern area of Yucca Mountain is much more complex geologically than the proposed repository block (USGS, 1984). Its characterization will help extend the range of structural and hydrologic conditions investigated. Current plans call for each borehole to be drilled to approximately 200 feet below the water table.

The locations of the boreholes in the systematic drilling program will be based on several criteria including the following: (1) co-location with the pillar locations in the conceptual repository design; (2) coverage of the area within the conceptual boundary of the proposed repository; and (3) integration with other boreholes, both existing and planned, that can provide additional supporting data for modeling the spatial variability of rock characteristics. The planned systematic drilling program is based on geologic judgment and the need to obtain a data set that can be evaluated using geostatistical techniques such as kriging to assure the representativeness of samples and data (SCP Section 8.3.1.4.3.1 and 8.4.2.2).

The extensive surface-based investigations summarized above are described in greater detail in Section 8.3.1 and 8.4.2 of the Site Characterization Plan (DOE, 1988a) and in the Surface-based Investigations Plan (DOE, 1988b). Specific details concerning techniques and procedures to be used in conducting the characterization activities in the SCP are contained in study plans and related technical procedures. Many of these documents are still being developed by the responsible program participants. Planned surface-based testing is evaluated, relative to characterizing the Ghost Dance fault and to characterizing the western portion of the proposed repository block to determine whether any currently undiscovered, major north-trending structural features exist, in Sections 5.0 and 7.1, respectively.

4.3 Planned Exploratory Drifting and Underground Testing

4.3.1 Exploratory Drifting

As shown in Figure 4-2, the three exploratory drifts will be excavated in the main test level (MTL), which is located at the proposed repository horizon. The currently planned exploratory drifts will total about 5600 feet. The uncertainty in the drift-length estimates is about 200 feet for each of the three drifts. This uncertainty results from the absence of information concerning the subsurface dip of faults and from the resulting uncertainty in the projection of the faults from the ground surface down to the proposed repository horizon. Access to the long exploratory drifts for mining operations and testing is from the ESF dedicated testing area. All of the exploratory drifts will be excavated by controlled drilling and blasting.

Although the conceptual repository design may change as a result of information obtained during site characterization, the exploratory drifts are planned to be coincident with the proposed repository (and at planned repository grades) to limit constraints on the flexibility of the proposed repository layout. The locations of the exploratory drifts complement the conceptual repository design as far as possible and also achieve their principal objective of allowing the DOE to obtain access to the three potentially important geologic features (Ghost Dance fault, imbricate normal fault zone, and Drill Hole Wash) for purposes of in situ testing and direct observation.

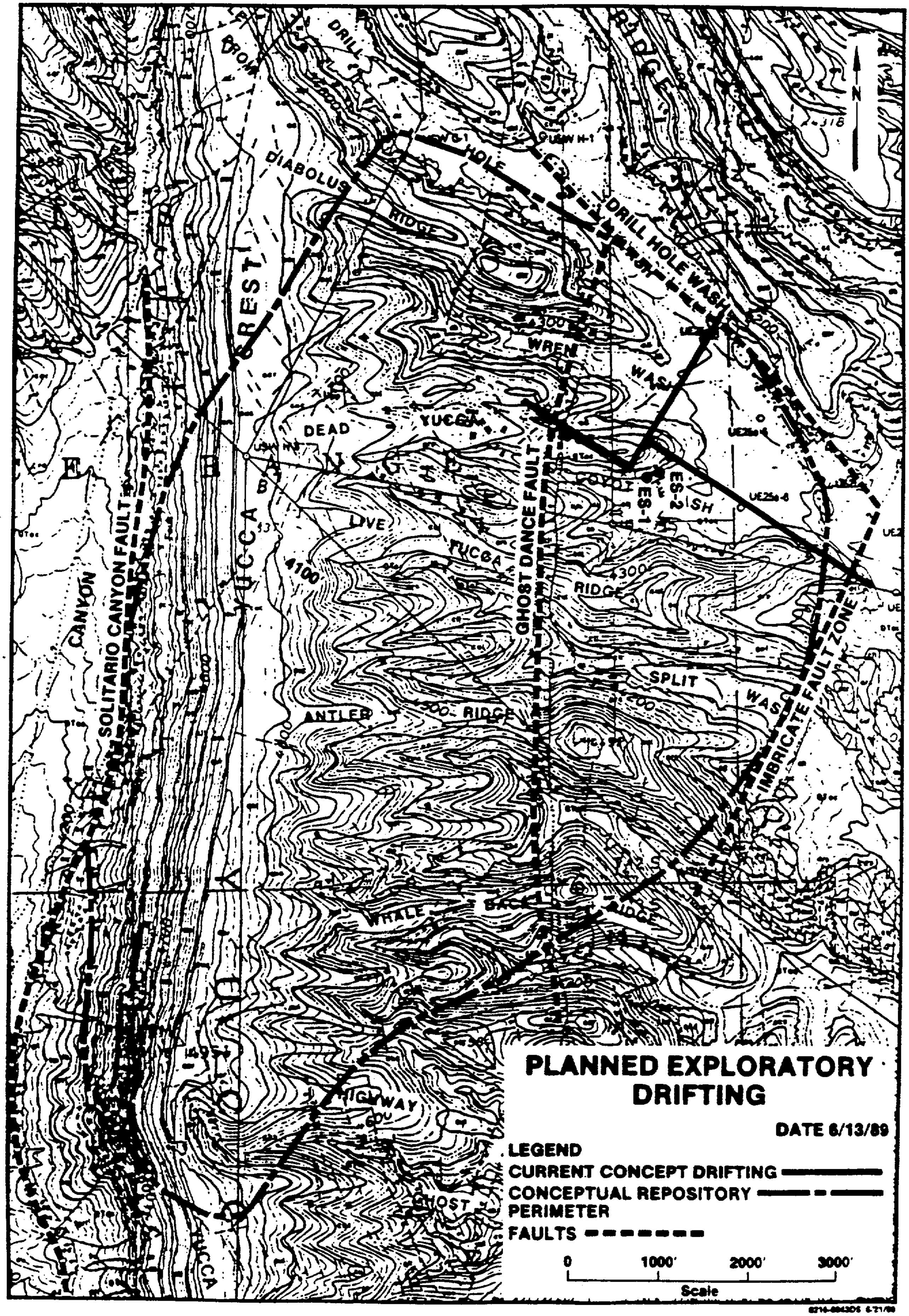
PLANNED EXPLORATORY DRIFTING
DATE 6/13/89
LEGEND
CURRENT CONCEPT DRIFTING
CONCEPTUAL REPOSITORY PERIMETER
FAULTS
0
1000'
2000'
3000'
Scale
SOLITARIO CANYON FAULT
GHOST DANCE FAULT
IMBRICATE FAULT ZONE
DRILL HOLE WASH
DIABOLUS RIDGE
WREN WASH
DEAD YUCCA
COYOTE WASH
ES-1
ES-2
LIVE YUCCA RIDGE
SPLIT WASH
ANTLER RIDGE
WHALE BACK RIDGE
CANYON
YUCCA CREST
4300
4100
N

FIGURE 4-2

The exploratory drifts are expected to provide information on the characteristics that may affect the construction and performance of the proposed repository, including hydrologic and geomechanical features. The hydrologic properties of major faults encountered in the ESF will be determined. In addition, the data collected during drifting will be used to test conceptual models of the hydrologic system and will be used in the development of a numerical model of the unsaturated-zone hydrologic system at Yucca Mountain.

Once information from planned exploratory drifting and surface-based investigations is available, the necessity for additional exploratory drifting will be reevaluated. If a need for additional drifting is determined, an analysis (F&S, 1988) has shown that construction of approximately 10,000 feet of additional drift on the MTL to the southern portion of the proposed repository block is feasible in terms of engineering concerns and personnel safety and is not precluded by planned construction and testing. The planned surface-based boreholes will provide stratigraphic control on the elevation and orientation of the proposed repository horizon with which such exploratory drifting would be integrated.

Ghost Dance Fault Drift

The planned exploratory drift to the Ghost Dance fault is to be coincident with a conceptual northwest-trending panel access drift (Figure 4-3) and extends approximately 2050 feet (SCP Section 8.4.2.3.4.4., DOE,1988a). It will provide access to test the transmissivity of the fault zone as well as other parameters. If the fault zone is more transmissive than the surrounding rock mass, it may indicate conditions where fracture flow predominates over matrix flow. An exploratory drift will allow direct observation, collection of samples, and measurements that will help to model the unsaturated-zone hydrologic system.

The exploratory drift may also yield additional information on the characteristics of the fault zone. For example, information on the direction and amount of displacement in the proposed repository horizon will be useful in design. Subsurface data will be integrated with surface-based investigations such as the displacement history of the fault as mapped in trenches, the degree of fracturing, and the in situ hydraulic characteristics that will help determine the setback distance from the fault zone to the waste-emplacement areas, if necessary.

Drill Hole Wash Drift

The planned exploratory drift to, and beneath, Drill Hole Wash is to be coincident with the conceptual tuff main (Figure 4-3) and extends northeast approximately 2170 feet (SCP Section 8.4.2.3.4.4, DOE, 1988a). Faults have been postulated to underlie the wash based on surface mapping data, borehole, and geophysical data. The purpose of the planned exploratory drift is to determine whether mined openings in the proposed repository beneath the wash will remain stable and could provide access to an additional area for waste emplacement to the northeast, if needed. The hydrologic character of the potential structures under Drill Hole Wash will also be studied from this drift. The wash appears to concentrate surface waters and channel them along a specific path, and therefore, higher than average infiltration rates could

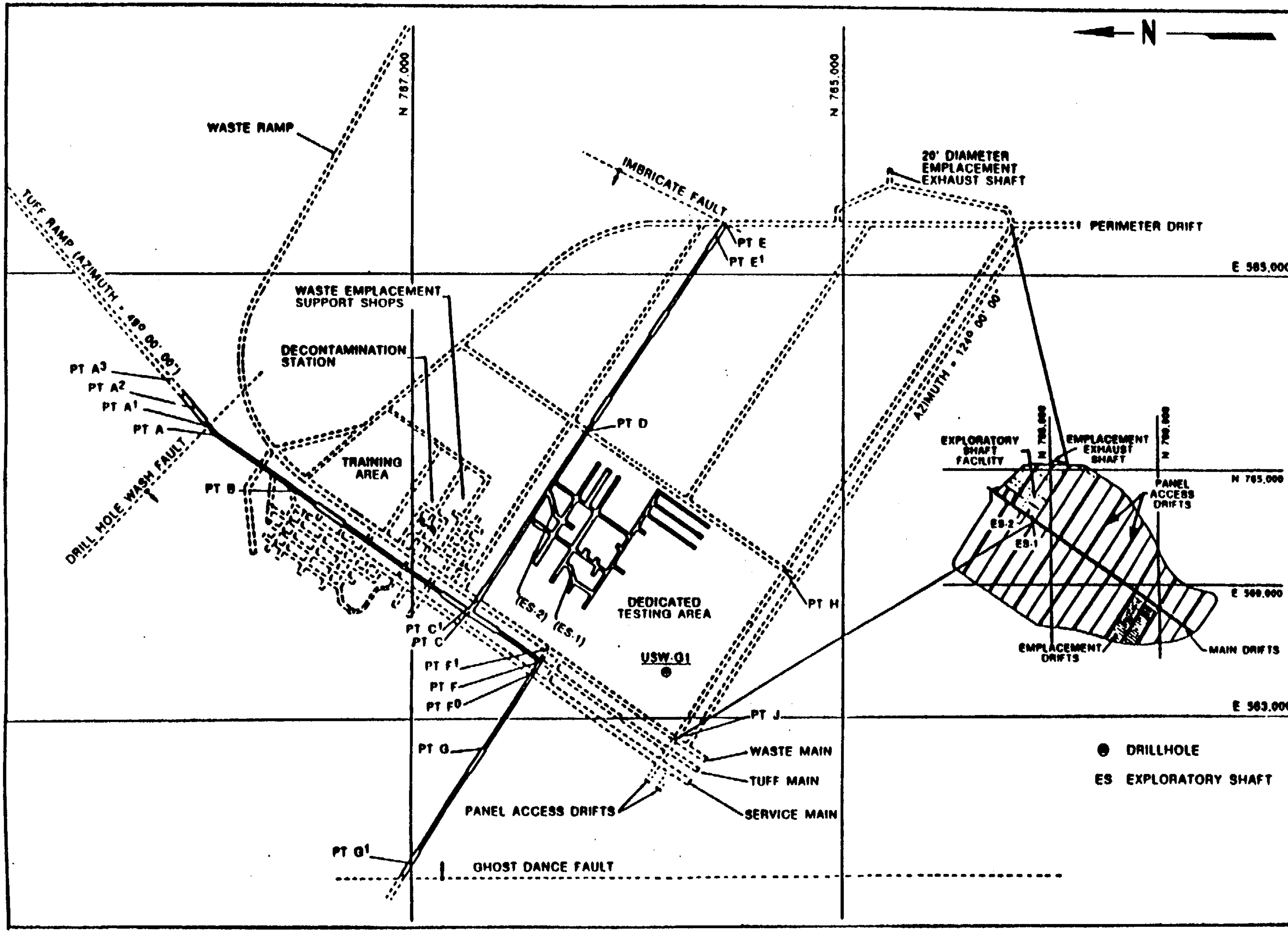

Figure 4-3. Conceptual repository layout in vicinity of the exploratory shaft dedicated test area and exploration drifts. (Modified from SCP Figure 8.4.2-4)

(Source: SCP 8.4.2)

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occur in this area. Direct observations in an exploratory drift may provide data to resolve concerns about the rates of ground-water recharge and the infiltration of water through fracture zones.

Imbricate Normal Fault Zone Drift

The planned exploratory drift to the imbricate normal fault zone will be excavated in order to study the geometry of the fault zone including the strike, dip, width, and displacement of the faults, and the location of the faults at the proposed repository depth. This drift will head southeast from the operations area at the MTL, coincident with a conceptual panel access drift (Figure 4-3), and will be approximately 1400 feet long (SCP Section 8.4.2.3.4.4, DOE, 1988a). It will help determine the location of the eastern boundary of the proposed repository block. Hydrologic studies will also be performed along this drift, as in the other exploratory drifts.

4.3.2 Underground Testing

Underground Mapping

The objectives of Geologic mapping of the exploratory shafts and drifts (Activity 8.3.1.4.2.2.4) are to: (1) determine the vertical and horizontal variability of fracture networks in the ESF shafts, drifts, and boreholes; (2) characterize major faults and fault zones in the subsurface; (3) map the lithostratigraphic features of the subunits, and the abundance and character of lithophysal zones; and (4) assist in evaluation of test locations in the exploratory shaft test facility.

Stereophotographs will be taken of all surfaces in the walls and crown of all exploratory drifts as mining progresses; floors and working faces will not be mapped unless anomalous geologic features are exposed. Stereophotography and in situ mapping will be done routinely as fresh rock is exposed. Geologic maps will be prepared from stereoscopic photographs by using close-range photogrammetry and direct observation. Geologic maps will include discontinuities such as faults, fractures, breccia zones, and other features of interest, including lithostratigraphic features and variations. In addition, line surveys will be made continuously along one wall, with more detail mapped, as required, at significant changes in lithology or geologic features.

Detailed mapping will be emphasized in the area adjacent to the ESF tests, near major geologic structures, and near the borders of the proposed repository block. The data will be combined with fracture-mapping from the shafts and surface-based fracture investigations to determine the three-dimensional fracture network. Infilling minerals in fractures and faults will also be sampled to collect isotope data for estimating the rates of tectonic processes.

Other Tests

Following are some of the tests planned for the ESF drifts directly relevant to characterizing faults and fracture systems. Section 8.4.2.3.1 of the SCP describes each of the 34 ESF test activities, including possible testing in the multipurpose boreholes. This SCP section also describes the layout-related constraints imposed on the ESF design, construction, or operations.

Fracture mineralogy studies of exploratory shafts and drifts (Activity 8.3.1.3.2.1.3) will be conducted to determine mineralogic variability throughout the ESF, to establish the time and conditions of fracture mineralogy deposition or alteration, and to identify fracture-coating mineral types, sorptive characteristics, and health hazard potential of fibrous zeolites.

Rock-mass strength experiment (Activity 8.3.1.15.1.7.2) will evaluate the mechanical behavior of the rock mass or its components. Experiments will be performed to obtain information on the mechanical response of single joints and multiply-jointed volumes of rock. It is envisaged that this experiment will be conducted in several areas that are representative of the range of conditions encountered in the ESF. The information will be used to evaluate potential scale effects between laboratory and in situ conditions, to provide data to evaluate empirical design criteria, and to provide data to evaluate and validate jointed-rock models.

Matrix hydrologic properties testing (Activity 8.3.1.2.2.3.1) is to develop a comprehensive data base on matrix flux properties in the unsaturated-zone tuffs at Yucca Mountain. This activity includes collecting bulk and core samples, taken after selected blasting rounds during ES-1 and drift construction and from core holes.

Intact-fracture test in the exploratory shaft facility (Activity 8.3.1.2.2.4.1) will be used to evaluate fluid-flow and chemical transport properties and mechanisms in relatively undisturbed and variably stressed fractures to enhance understanding of physics of flow and for flow modeling. Fracture-sampling locations will be selected on the basis of detailed fracture maps. At about 12 locations (to be determined), a small pilot hole will be drilled across a fracture, a rock bolt anchor will be installed, the pilot hole will be overcored, and the sample will be withdrawn for laboratory analysis.

Percolation tests in the exploratory shaft facility (Activity 8.3.1.2.2.4.2) will be used to observe and measure fluid flow through a network of fractures under controlled in situ conditions in order to characterize and quantify important flow processes in fractured welded tuff.

Perched-water test in the exploratory shaft facility (Activity 8.3.1.2.2.4.7) is intended to detect the occurrence, and delineate the lateral and vertical extent, of perched-water zones (if encountered) during shaft (and drift) construction to identify the perching mechanism(s), and to sample the water for chemical analyses. If perched water is encountered while mining, one or more small-diameter hole(s) will be drilled to enhance drainage, facilitate collection of water samples, and allow flow and/or pressure measurements to be made. The hole(s) will also be instrumented and sealed during testing to obtain data on hydraulic pressure and water potential over time.

Hydrochemistry tests in the exploratory shaft facility (Activity 8.3.1.3.3.4.8) will determine the chemical composition, reactive mechanisms, and age of water and gas in pores, fractures, and perched-water zones within the unsaturated tuffs accessible from the ESF and/or affiliated core holes.

Hydrological properties of major faults encountered in the main test level of the exploratory shaft facility (Activity 8.3.1.2.2.4.10) is designed to provide hydrologic information in parallel with a portion of Activity 8.3.1.4.2.2.4, geologic mapping of the exploratory shafts and drifts. Based on identification of a major fault (or faults) by the geologic mapping activity, a hydrologic testing program will be implemented. This program will consist primarily of tests conducted in boreholes drilled from drifts constructed through the fault zones and tests on core collected from the boreholes. All boreholes will be drilled using air to minimize changes in ambient moisture conditions. Onsite core examination will be conducted for preliminary determinations of fracture frequency, orientation, location and characteristics. This information will be used in conjunction with geophysical and television camera logs to select test intervals. In selected test intervals, air permeability tests will be conducted between boreholes. Other sets of boreholes will be used for cross-hole water-injection tests. All water will be tagged with a conservative (non-reactive) tracer. In addition, some boreholes will be instrumented to determine in situ conditions of the rock mass and monitored to determine any time-dependent changes. Rock core recovered from the boreholes will be tested to provide information relative to any recent moisture occurrence in the fault zone.

The underground testing program summarized above is described in greater detail in Sections 8.3.1 and 8.4.2 of the SCP. As mentioned above, at the end of Section 4.2, specific details concerning techniques and procedures are contained in study plans or technical procedures, many of which are still being developed. The planned underground and surface-based investigations are evaluated qualitatively relative to characterizing the Ghost Dance fault and to characterizing the western portion of the proposed repository block (to determine whether currently undiscovered, major north-trending structural features exist), in Sections 5.0 and 7.0, respectively.

5.0 EVALUATION OF PLANNED TESTING RELATIVE TO CHARACTERIZING THE GHOST DANCE FAULT

As mentioned in Section 4.0 of this report, the SCP is a general planning document that will be used to guide site characterization to fulfill the identified information needs. Therefore, the SCP does not provide the level of detail necessary to explicitly perform a technical evaluation of each individual activity that could provide site characterization data on the Ghost Dance fault and it is beyond the scope of this report to perform this evaluation. In addition, several activities are planned as feasibility studies prior to determining their applicability to the characterization of specific features at Yucca Mountain. For purposes of this report, it is assumed that the individual site characterization activities listed in Section 4.0 will provide useful data. As described elsewhere in this report, these data will be evaluated to determine whether additional data collection activities are required for repository design and performance assessments.

Due to the general nature of the objectives of the SCP activities, this section evaluates the ability of the planned site characterization program for five categories of activities (surface mapping, geophysics, drilling, underground mapping, and other underground tests) to characterize the Ghost Dance fault, and in particular the hydrologic properties associated with the fault. The criteria used for this evaluation are listed below:

- Nature of fractures in the Ghost Dance fault;
- Location and geometry of lithostratigraphic features bounding the Ghost Dance fault;
- Displacement across the Ghost Dance fault;
- Variability in rock properties across the Ghost Dance fault;
- Effects of the Ghost Dance fault on flow mechanisms; and,
- Gas flow permeabilities of the Ghost Dance fault.

Numerous surface-based and underground testing activities are planned, as discussed in the SCP and in Sections 4.2 and 4.3 of this report, to characterize the Ghost Dance fault which is the major structural feature within the proposed repository block. This section of the report will evaluate the adequacy of the planned activities for providing sufficient information to characterize the Ghost Dance fault. The activities discussed in this section can be conveniently divided into two separate categories based on whether or not the data will be obtained by surface-based activities or underground activities. The surface-based activities include surface mapping, geophysics, and drilling, the underground activities consist of underground mapping and other underground testing activities. Both types of activities have been designed to complement each other as part of the comprehensive site characterization program to characterize the Ghost Dance fault.

In this report, the term adequate should be understood to mean that a particular testing activity, or category of testing (e.g., surface-based, underground), will provide an incremental reduction of the uncertainty in estimates of relevant parameters or repository design and performance assessments based on the data from the tests. As discussed elsewhere, the integrated data resulting from the testing activities will be evaluated periodically to determine the need for additional testing.

5.1 Surface-based Testing

The nature and the intent of the surface-based testing program, in conjunction with the underground testing program, is adequate to initiate new surface-based characterization of the hydrology and structures associated with the Ghost Dance fault. The planned program will also be able to identify the need for additional surface-based or underground tests and drifting.

Many of the surface-based activities, as discussed below, are associated with surface mapping and trenching, others are geophysical activities, and numerous other activities are associated with the features drilling program or the systematic drilling program. These activities, from a surface-based testing perspective, encompass a range of tests and test locations adequate to characterize the Ghost Dance fault, or alternatively, identify the need for additional surface-based or underground testing activities, that would be required to adequately understand the hydrology of the Ghost Dance fault or its stratigraphic displacement as input for repository design. The site characterization program is flexible and as more results are obtained the program can be modified as necessary.

5.1.1 Surface Mapping

Relative to the range of existing surface mapping techniques, the various surface mapping activities that are planned to characterize the proposed repository block will provide much of the necessary information to characterize the Ghost Dance fault. Geologic mapping, mapping of surficial deposits, and development of a geomorphic map will be completed. The surface mapping will help determine locations for trenches across the fault, and also determine the role of erosional effects on the observed surface expression of the fault that will refine estimates of its displacement. Surficial deposits mapping along the surface trace of the fault will be used in the infiltration studies. The surface-fracture network studies surrounding the Ghost Dance fault will support modeling of potential hydrologic flowpaths. Although the planned surface mapping activities are adequate, greater confidence could be gained by specifically performing detailed mapping along the surface trace of the Ghost Dance fault.

5.1.2 Geophysics

Surface-based geophysical activities will be conducted, in conjunction with the surface mapping and drilling activities, that together will evaluate the Ghost Dance fault from the surface. Assuming that the geophysical methods are successful in acquiring data of high enough quality, fault characteristics can be extrapolated along and across the fault from points of known control, such as boreholes and subsurface exploratory drifts. Seismic reflection surveys and detailed ground magnetic, gamma-ray, and geoelectric surveys will be the primary geophysical methods used to characterize the Ghost Dance fault. This would provide the necessary information on the dip and the structure of the fault, and could possibly provide input for determining fault offset at depth.

5.1.3 Drilling

The surface-based drilling program consists of the features drilling program and the systematic drilling program as discussed in Section 4.2 of this report. Data from these drilling programs will provide the most reliable surface-based data on offset along the fault zone and the hydrologic properties of the rock mass on either side of the Ghost Dance fault. Two boreholes (UZ-7 and UZ-8) are planned to the east and west of the Ghost Dance fault approximately 1 mile south of the area where the planned exploratory drift to the northwest would intersect the fault. This will provide a control point on the hydrologic characteristics of the fault farther south of where the drift intersects the fault, as well as providing information on the dip and offset of the fault. This information will provide constraints on repository layout due to fault offset. Presently only one borehole (UZ-8) is planned to intersect the fault. Testing in UZ-8, in addition to the planned crosshole tests between UZ-7 and UZ-8, would provide information on the hydrologic properties of the fault at depth which is critical to its characterization.

Exploratory drifting would be the preferred method to obtain subsurface data on the hydrologic properties associated with the Ghost Dance fault since this method provides access for direct observation. From a surface-based testing perspective, several lines of boreholes transecting the Ghost Dance fault and possibly inclined boreholes that would intersect the fault at various depths would enhance the surface-based investigation program's ability to determine the offset along the Ghost Dance fault. However, a disadvantage of this approach would be the increased number of borehole penetrations of the proposed repository block.

In addition to the surface-based activities that will generally provide data to characterize the proposed repository block and the Ghost Dance fault as discussed above, Activity 8.3.1.17.4.6.2 (Evaluate age and recurrence of movement on suspected and known Quaternary faults) has been designed specifically to characterize the Ghost Dance fault. Presently five trenches have been excavated along or near the Ghost Dance fault and this activity calls for an additional two trenches, provided that suitable locations can be found.

5.2 Underground Testing

Based on the planned underground testing activities and drifting, the underground testing program, in conjunction with the surface-based testing program, will result in reducing uncertainty regarding the structural and hydrologic characteristics along the northern portion of the Ghost Dance fault. The planned program will also be able to identify the need for additional underground tests or exploratory drifts, or surface-based tests. However, the presently planned underground testing program could be enhanced by extending the exploratory drift to Drill Hole Wash to the southwest from the dedicated testing area to intersect the Ghost Dance fault as discussed in Section 6.0.

The underground activities planned to characterize the Ghost Dance fault will be conducted from an exploratory drift driven from the dedicated testing area of the ESF towards the northwest as discussed in Section 4.3 of this report. Several testing activities will be conducted within the exploratory drift, particularly where the drift intersects the Ghost Dance fault. The underground testing activities that would help characterize the fault include hydrologic investigations, mapping of the exploratory drift walls on either side of the fault, and geochemical and rock characteristics testing as mentioned in Section 4.3. Integration of the underground testing program with the surface-based testing program would most likely provide the data necessary to characterize the hydrology and structure of the northern portion of the Ghost Dance fault, or perhaps more importantly, these activities would also identify the need for additional testing activities or exploratory drifting that would be required to obtain adequate data for performance assessments and repository design.

5.3 Summary Evaluation of Testing

Whereas the planned surface-based and underground investigations appear adequate to initiate new site characterization activities, discussions in Section 5.1 and 5.2 and the evaluation discussed below indicate that valuable hydrologic and structural information useful for performance assessments and repository design would be obtained by extending the exploratory drift to Drill Hole Wash (conceptual repository main drift) southwest from the dedicated testing area to intersect the Ghost Dance fault at a location where the displacement across the fault may be greater. This proposed alternative, discussed in Section 6.0 of this report, would provide access to the Ghost Dance fault at a location approximately 1/2 mile south of the currently planned intercept and approximately 1/2 mile north of boreholes UZ-7 and UZ-8. The surface-based testing activities appear to be adequate to initiate surface-based characterization of the hydrologic and structural properties of the Ghost Dance fault, although detailed surface mapping along the fault trace could specifically be added. Based upon an early assessment of these surface-based data, it is recommended that the DOE consider expanding the drilling program to include drilling several lines of boreholes transecting the Ghost Dance fault and possibly inclined boreholes across the Ghost Dance fault.

A discussion of how the planned surface-based and underground tests address each criteria is provided below. This evaluation assumes that the surface-based and underground activities identified in Section 4.0 can obtain useful information (i.e., the techniques will be found to be feasible to determine the parameters listed in the SCP for their respective descriptions).

Evaluation Criteria:

1) Nature of fractures in the Ghost Dance fault
2) Location and geometry of lithostratigraphic features bounding the Ghost Dance fault
3) Displacement across the Ghost Dance fault
4) Variability in rock properties across the Ghost Dance fault
5) Effects of the Ghost Dance fault on flow mechanisms
6) Gas flow permeabilities of the Ghost Dance fault

Criteria 1: Nature of fractures in the Ghost Dance fault

Characteristics of fractures in the Ghost Dance fault, such as fracture density, aperture, permeability, and infilling minerals can be identified through surface mapping, drilling, and possibly geophysics. Surface mapping includes pavement studies of fracture networks in bedrock outcrops and trenching the fault at two additional locations. The drilling program will investigate the fault zone fractures by crosshole testing in UZ-7 and UZ-8, and coring and geophysical logging in UZ-8 which intersects the Ghost Dance fault along its southern portion. Underground mapping and testing, where the planned exploratory drift intersects the fault, will investigate the fracture characteristics associated with the Ghost Dance fault, but only along the northern portion of the fault.

Criteria 2: Location and geometry of lithostratigraphic features bounding the Ghost Dance fault

This criteria will be addressed primarily by the drilling program (through coring and geophysical logging) and surface mapping of the lateral distribution of stratigraphic units within the site area. Geophysics (shallow seismic reflection) can be used to extrapolate known lithostratigraphic properties from known points of borehole control to other areas along the Ghost Dance fault. Underground mapping in the exploratory drift will also investigate the stratigraphy surrounding the fault at the horizon of the proposed repository, but this will only provide underground data along the northern portion of the fault.

Criteria 3: Displacement Across the Ghost Dance fault

Surface mapping activities will provide refinements or constraints on the estimated offset across the Ghost Dance fault. However, detailed surface mapping along the fault trace could specifically be added. Geophysical activities could also be used to estimate displacement across the fault if high quality, shallow seismic reflection data can be obtained, however the ability to achieve the necessary quality is uncertain at this time. The drilling programs will provide the most reliable surface-based information on fault offset by correlating (core samples and geophysical logs) between boreholes across the fault. Underground mapping in the northwest exploratory drift on either side of the fault could provide a control point for fault displacement, but this would only be for the northern portion of the fault approximately 1 mile from boreholes UZ-7 and UZ-8, and offset across the fault appears to diminish to the north based on surface mapping. Based upon an early assessment of these data, DOE may want to consider drilling several lines of boreholes transecting the Ghost Dance fault or inclined boreholes across the Ghost Dance fault.

Criteria 4: Variability in rock properties across the Ghost Dance fault

Geophysical techniques could provide some preliminary rock property data, however, the drilling program will provide the bulk of the data, and geophysical techniques would be used to extrapolate data between boreholes. The most extensive rock property testing will be conducted in the ESF, however, the liability is that this is only planned at one intersection along the Ghost Dance fault.

Criteria 5: Effects of the Ghost Dance fault on flow mechanisms

The drilling program (UZ-8) and the underground testing program will provide information that will determine the effects of the Ghost Dance fault on flow mechanisms. However, this will only provide one point of control by direct observation (at the intersection of the Ghost Dance fault and the northwest exploratory drift) and one indirect control point (at the intersection of the Ghost Dance fault and UZ-8). Since the hydrologic properties of the fault are a key issue, an additional point of direct observation should be considered. Based upon an early assessment of these data, DOE may want to consider drilling several lines of boreholes transecting the Ghost Dance fault or inclined boreholes across the Ghost Dance fault.

Criteria 6: Gas flow permeabilities of the Ghost Dance fault

The same two control points identified for Criteria 5 could possibly be used to collect measurements of gas flow permeabilities of the Ghost Dance fault. However, as above, this provides very limited subsurface data and additional points of direct observation should be considered.

6.0 QUALITATIVE EVALUATION OF EXPLORATORY DRIFTING TO THE GHOST DANCE FAULT

As discussed in Section 3.1 of this report, the Ghost Dance fault is mapped as a near vertical, north-trending fault that has been projected through the proposed repository block. Based on existing surface information, relative displacement along the fault increases to the south (DOE, 1988a). Section 4.0 discusses the planned testing to characterize the Ghost Dance fault. Section 5.0 evaluates this testing and Section 5.3 concludes that while planned surface-based and underground investigations appear adequate to initiate new site characterization activities, valuable hydrologic and structural information useful for performance assessment and repository design would be obtained by extending the exploratory drift to Drill Hole Wash (conceptual repository main drift) southwest to intersect the Ghost Dance fault. This section discusses this alternative, which is consistent with the NWTRB Panel suggestion to drift to the Ghost Dance fault (Section 2.1), and compares this alternative to the planned exploratory drifting using a set of evaluation factors.

6.1 Alternative for Exploratory Drifting

Based on the description of the Ghost Dance fault in Section 3.1 and the data expected from planned site characterization activities focused on characterization of the Ghost Dance fault, an alternative to the planned exploratory drifting plan is suggested. The alternative is to simultaneously excavate an extended exploratory drift to intersect the Ghost Dance fault at a second location. This alternative approach to the planned three exploratory drifts (Figure 6-1) calls for an extension of the Drill Hole Wash exploratory drift to be driven southwest from the dedicated testing area (Figure 4-3) along the repository main drift as far as necessary to intersect the Ghost Dance fault (approximately 2000 feet) (Figure 4-3). The extended exploratory drift to the south is preferred in addition to (or rather than) the planned exploratory drift to the Ghost Dance fault because the geologic and hydrologic conditions of the fault are expected to be different farther to the south. The planned exploratory drift to the Ghost Dance fault is estimated to be 1000 feet. Therefore, the fault will be intersected by this exploratory drift prior to being intersected by the extended exploratory drift to the south. Assuming a relatively constant dip at the MTL, the estimated total length of the extended exploratory drift can be estimated more accurately. If the planned exploratory drift to the Ghost Dance fault is longer than anticipated, the DOE will have the option to modify the extended exploratory drift by turning northwest along a conceptual repository panel access drift to intersect the Ghost Dance fault, or terminating the extended exploratory drift if information from the planned exploratory drift and surface-based testing suggests a second intersection of the Ghost Dance is not necessary.

The alternative was developed to be consistent with the specifications and assumptions made for the planned exploratory drifts. The specifications are discussed in Appendix C and the assumptions are described in the following subsection. Based on the results of the report on extended drifting (F&S, 1988), the operational requirements of the alternative approach do not exceed the haulage capacity of the shafts, ventilation system capacity, or infrastructure requirements.

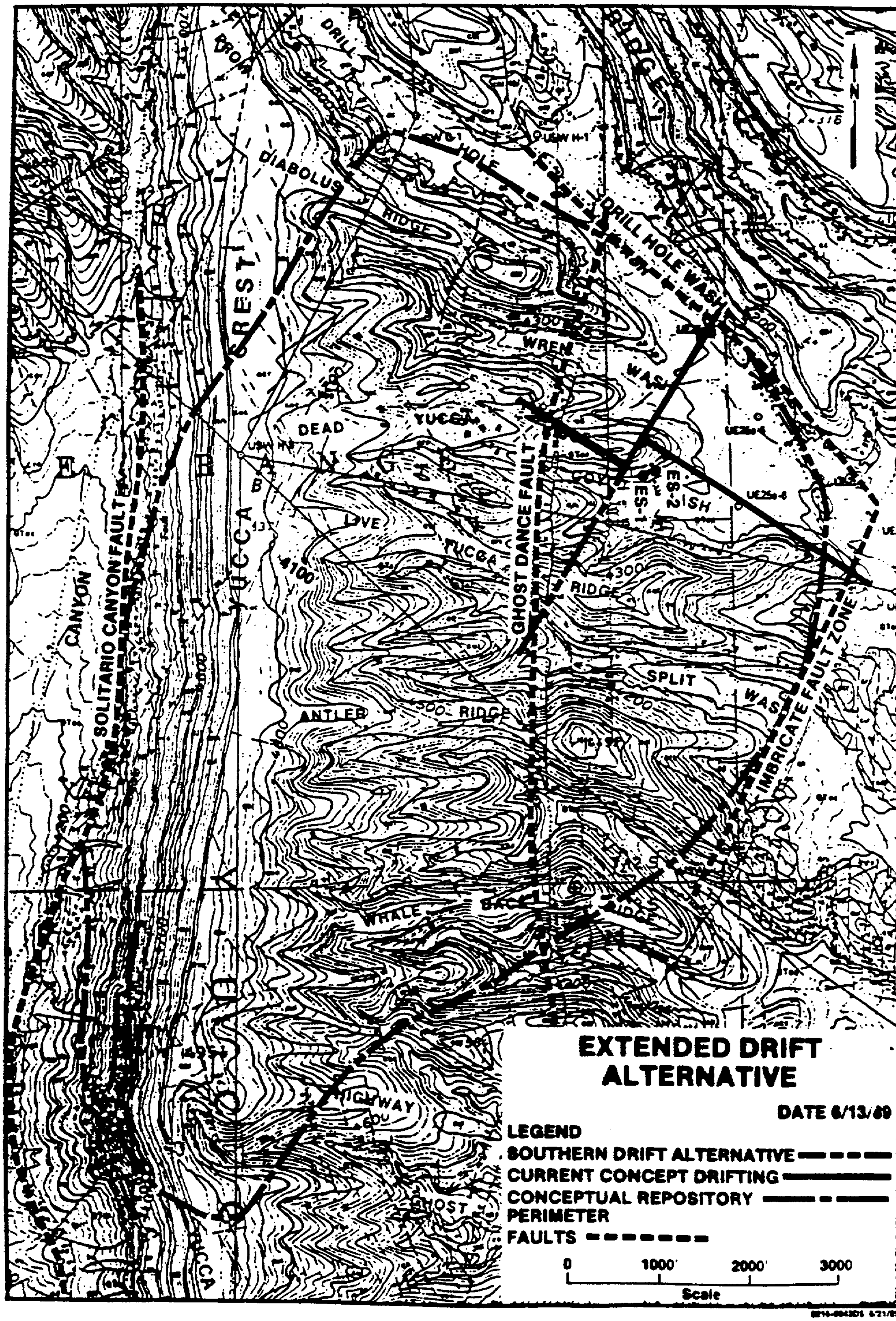
EXTENDED DRIFT ALTERNATIVE
DATE 6/13/89
LEGEND
SOUTHERN DRIFT ALTERNATIVE
CURRENT CONCEPT DRIFTING
CONCEPTUAL REPOSITORY PERIMETER
FAULTS
0
1000'
2000'
3000
Scale
DRILL HOLE WASH
DIABOLUS RIDGE
WREN WASH
DEAD YUCCA
GHOST DANCE FAULT
ES-1
ES-2
YUCCA RIDGE
SPLIT WASH
ANTLER RIDGE
IMBRICATE FAULT ZONE
WHALE BACK RIDGE
SOLITARIO CANYON FAULT
CANYON
CREST
HIGHWAY
GHOST
N

FIGURE 6-1

6.2 Assumptions

A limited amount of information about the geologic and hydrologic conditions of the host rock is available; therefore, assumptions were made in developing the planned exploratory drifts (YMP, 1988). Many similar assumptions, have been made for the alternative approach. These assumptions are discussed below.

- Both exploratory shafts have the same finished diameter of 12 feet and will be available for supporting the drift excavation operations.

- The operational capacity of the support system can accommodate an extended exploratory drift simultaneously excavated with the three planned exploratory drifts.

- The cross-section of the extended exploratory drift will be consistent with the planned exploratory drifts.

- The construction methods for extended exploratory drifting will be the same as planned exploratory drifting, i.e., conventional drill and blast techniques (DOE, 1988a).

- The layout of the underground facility will be consistent with the conceptual repository design layout (SNL, 1987).

- Underground testing and surface-based testing related to characterization of the Ghost Dance fault will be repeated to characterize the host rock and the fault zone exposed in the extended exploratory drift.

- The length of the planned exploratory drift as well as the length and orientation of the extended exploratory drift are based on the strike and dip of the Ghost Dance fault remaining relatively constant.

6.3 Evaluation Factors

To evaluate the alternative approach against the planned exploratory drifting to the Ghost Dance fault, eight evaluation factors have been identified. The factors considered are listed below.

- Information for Characterization of the Ghost Dance fault (Representativeness of Data);
- Information for Design and Performance Issues;
- Postclosure Performance;
- Non-radiological Health and Safety;
- Integration with the Repository;
- Repository Design Flexibility;
- Cost; and,
- Schedule

The excavation method was assumed to be conventional drill and blast. Mechanical mining methods were not considered in this evaluation, but were addressed in Appendix C. Given the planned shaft diameters and the amount and the lengths of the planned exploratory drifting it was concluded that mechanical mining (tunnel boring machine) is not justifiable. Therefore, this evaluation did not consider excavation methods as a factor.

6.4 Evaluation

The evaluation of the factors was qualitative, taking all eight factors and the discussions of Sections 2.0 through 5.0 into consideration. The evaluation team consisted of mining engineers, performance assessment specialists, geoscientists, and licensing specialists. The evaluation compared the planned exploratory drifting to the alternative approach. The following is a discussion of the evaluation. Table 6-1 summarizes the evaluation.

6.4.1 Information for Characterization of the Ghost Dance Fault (Representativeness of Data)

The site characterization program, as currently planned, will integrate data obtained from surface-based and underground testing and mapping to develop three-dimensional conceptual geologic models of Yucca Mountain. Geostatistical techniques will then be used to assess the need for additional data and evaluate the representativeness and uncertainty in data across the repository block. The site-characterization program is designed to be flexible in order to maintain the capability to modify the testing program should preliminary results of studies suggest that changes are warranted.

The planned exploratory drift to the northwest will provide the first intersection of the Ghost Dance fault. This intersection will provide considerable information on the characteristics of the fault at the MTL. While this drift will provide information on the structural and hydrologic conditions of the fault, the parameters measured may not be representative of the fault farther to the south.

If an extended exploratory drift to the Ghost Dance fault is excavated to the south (alternative approach) another control point, perhaps more representative of the Ghost Dance fault, would be available for comparison and testing at the MTL. Since displacement along the Ghost Dance fault apparently increases to the south, the southern intersection, approximately mid-way between the planned exploratory drift intersection and boreholes UZ-7 and UZ-8, may be more representative of the structural and hydrologic conditions at the MTL. The extended drift to the southwest would also provide more information on the geologic and hydrologic conditions of that portion of the host rock.

The Ghost Dance fault has been identified as the major structure within the proposed repository; therefore, there is merit in two intersections of the Ghost Dance fault, particularly when the characteristics of the fault may significantly vary both laterally and vertically.

6.4.2 Information for Design and Performance Issues

The site characterization program will provide considerable information about the variation in rock properties across the site. It will provide some information about certain major features, such as fracture density associated

Table 6-1 Summary of the Qualitative Evaluation Between Planned Exploratory Drifting and the Alternative Approach Taking the Eight Factors into Consideration

<u>Factors</u>	<u>Summary of Evaluation</u>
Information for Characterization of the Ghost Dance fault (Representativeness of Data)	Geologic and hydrologic conditions may vary along length - extended drifting preferred for direct observation
Information for Design and Performance Issues	Design issues - additional testing is helpful to determine amount of offset across the Ghost Dance fault and its effect on the planned repository horizon. An expanded surface-based testing program may be more applicable Performance issues - additional information from drifting is preferred to reduce the uncertainty of the parameters used in the performance assessment models.
Postclosure Performance	Additional exploratory drifts consistent with conceptual repository layout do not adversely impact site performance.
Non-radiological Health and Safety	Relative to repository development, impact is negligible.
Integration with the Repository	Additional drift is an integral part of the conceptual repository layout.
Design Flexibility	No additional impact on flexibility; proposed drift would be perpendicular to dip of tuffaceous units and consistent with conceptual repository layout.
Cost	Approximately $9.4 million, a 2.8% increase.
Schedule	Increase of <u>4 months</u> over planned exploratory drifting if excavated concurrently.

with the Ghost Dance fault but little information on how geologic and hydrologic properties of the Ghost Dance fault, particularly lateral components of ground-water flow, vary along its length. It will also provide limited information about the way the major features could affect rock properties or the elevation of the repository horizon on opposite sides of the fault zone.

The alternative approach would extend exploratory drifting to the south and would provide an additional intersection with the Ghost Dance fault. Therefore, additional information about the variability of the host-rock matrix, fracture network, and offset along the fault would be obtained for addressing both design and performance issues. The additional data about the Ghost Dance fault would provide valuable information about the variability of the ground-water flow characteristics of this feature.

6.4.3 Postclosure Performance

The SCP Section 8.4.3 provides a thorough analysis of the impacts of site-characterization activities on the ability of the site to meet postclosure performance objectives. These objectives are the requirements for waste isolation, including limits on radionuclide releases from the repository system, individual protection, and ground-water protection; requirements for the containment of the wastes within the waste packages; limits on the release rate of radionuclides from the engineered-barrier system; and requirements on the pre-waste-emplacement ground-water travel time to the accessible environment. Section 8.4.3 of the SCP concludes that no adverse effects are expected from site-characterization activities at the surface (e.g., ground preparation), from surface-based drilling activities, from the exploratory shafts, or from the exploratory drifting and tests that are here described as the current plans.

An analogous detailed analysis of possible effects on postclosure performance has not been performed for extended exploratory drifting. However, on general grounds, it can be concluded that the excavations and tests associated with extended drifting are not likely to affect postclosure performance for the same reasons as previously evaluated. The extended exploratory drifting would be integrated into the design of the repository itself. Therefore, the effects of the extended exploratory drifting alternative are not likely to be different from those of the repository. The same care and methods that would be used in the construction of the proposed underground repository would be used in the exploratory drifting. The same practices for sealing and closure would be used. It is therefore unlikely that any new pathways for ground-water travel would be created or that the host rock would be disturbed beyond the disturbance expected from development of the proposed repository. If for some reason the extended exploratory drift is not integrated with the proposed repository, no adverse impact on postclosure performance is expected. However, the potential impacts that may result if this exploratory drift (or the planned exploratory drifts) is not integrated into the proposed repository should be analyzed.

Some additional testing would be conducted in the extended exploratory drift. These additional tests could conceivably affect portions of the host rock. It is unlikely, however, that such tests would have a significant effect on postclosure performance. These tests would be similar to those analyzed for the current plans in Section 8.4.3 of the SCP, and the SCP analysis indicates that the approach planned for testing at the Ghost Dance fault and other structures, such as the imbricate normal fault zone, would not have an adverse effect on performance. Therefore, it is not likely that the activities associated with an extended exploratory drift would have a more adverse effect on postclosure performance than the activities associated with the current plans.

6.4.4 Non-radiological Health and Safety

The conditions pertinent to evaluations of this factor are the stability of ground conditions, ground support, maintenance of underground openings, air quality, working temperature, and the potential for equipment-related accidents. Regardless of the amount of drifting, worker safety can be ensured by the assignment and implementation of appropriate design safety factors, the establishment of design criteria that mandate compliance with regulations governing health-and-safety requirements, evaluation of design to ensure compliance with the required regulations, and the establishment of training and safety programs.

The potential for mine accidents is somewhat dependent on underground time for workers and enforcement of the worker safety requirements. From this perspective, the potential for accidents and/or personal injury will be less under the planned underground activities; however, the difference is expected to be minimal for the alternative approach because it would eventually be mined as a repository main drift. Likewise, the quality of underground operations is also dependent on the extent of drifting. As the drifting is increased, the ventilation underground becomes less effective. The ventilation system may require enhanced facilities.

6.4.5 Integration with the Repository

The current plan for exploratory drifting has evolved with the SCP conceptual design of the repository. Appendix E of the Generic Requirements Document (DOE, 1986) as well as the site-specific ESF Subsystem Design Requirements Document (SDRD; YMP, 1988) require that the ESF and repository designers coordinate on the underground location, layout, and permanent ESF structures, systems, and components. The current ESF design does complement the conceptual repository design, and the layout of exploratory drifts to geologic features is coincident with repository drifts and repository grade. As seen from Figure 4-3, this concept provides the least disturbance to the overall repository area and still provides intercepts of the geologic features of interest.

The extended exploratory drift of the alternative approach follows the current conceptual repository layout in terms of orientation and grade. Therefore, the alternate approach is integrated with the conceptual repository design.

6.4.6 Design Flexibility

Both the currently planned exploratory drifting and the alternative approach offer flexibility in design in terms of opening up additional areas for testing and exploration. It should be noted, however, that although flexibility exists in the current ESF design for extensive drifting, such drifting should preferably be limited to that essential for characterization. It will be possible to construct more drifts (exploratory or otherwise) in the future when the design for the repository is more advanced or when facilities for the repository are constructed (e.g., access ways, utilities). As stated earlier, the less disturbance in the repository block, the greater the flexibility available for the final repository layout. From this viewpoint, the current concept appears to be better than the alternative approach. However, the proposed extended drift would be subparallel to the strike of the tuff units. This would limit the constraints imposed on the repository grade relative to discussions presented in Section 4.2.3.

6.4.7 Cost

The reference for the cost estimates for the planned ESF was drawn from the "ESF Budget Support Data" (April 11, 1989) provided by the Yucca Mountain Project Office (YMPO). All amounts are quoted in fiscal year (FY) 1990 dollars, and all amounts are given without contingency or escalation and should be regarded as preliminary. The cost estimates for the southern exploratory drift to the Ghost Dance fault (alternate approach) were developed from the reference cost estimates by using multiplying factors and unit costs (dollars per foot) when applicable.

The cost estimate for a drift to the south to intersect the Ghost Dance fault is $9.4 million more than the planned ESF expenditures. This is the cost for the approximate 2000 feet of additional exploratory drift. The cost impacts of the drift on each major cost component are shown in Table 6-2.

6.4.8 Schedule

The schedule references are the repository schedule baseline ("Document Change Proposal 13: Issue Cost and Schedule Baseline," May 1989) and (F&S, 1988). This schedule is based on an advance rate of 3000 feet per year and includes exploratory drift mapping. This advance rate is 14 feet-per-day plus mapping time and is based on a 3 shift-per-day, 300 day-per-year work schedule. The advance rate is dependent on mapping requirements, work schedule, and mining methods (drill & blast, haulage, roof control, etc.).

The southern exploratory drift would take about 8 months to complete and would run concurrent with the three other exploratory drifts except for the last four months during which the other exploratory drifts are completed.

TABLE 6-2

COST ESTIMATE FOR EXTENDED EXPLORATORY DRIFTING SOUTH TO GHOST DANCE FAULT
Millions of FY 1990 Dollars

	PLANNED EXPLORATORY SHAFT FACILITY estimate, prior years plus Budget through 1995 (1)	COST WITH SOUTH DRIFT TO GHOST DANCE FAULT (2)	Cost Increase Above PLANNNED EXPLORATORY SHAFT FACILITY
Management & Integration			
TEC Design	17.2	17.7	0.5
Construction	4.3	4.3	-
NON-TEC Design	38.7	40.2	1.5
Operations	86.7	88.4	1.7
Site Preparation	19.0	19.0	-
Surface Facility	9.5	9.5	-
First Shaft	10.2	10.2	-
Second Shaft	9.3	9.3	-
Subsurface Excavations			
Design	1.2	1.4	0.2
Construction	20.0	23.7	3.7
Underground Service System			
Design	5.0	5.8	0.8
Construction	15.5	16.2	0.7
Operations			
NON-TEC	70.4	70.6	0.2
TEC	25.6	25.6	-
TOTAL	332.6	341.9	9.3

(1) Source: "Exploratory Shaft Facility Budget Support Data"; 4-11-89.
Cost estimates for extending the exploratory drifts were developed by applying factors that were developed from the PLANNED EXPLORATORY SHAFT FACILITY estimates and by using $/ft costs when applicable.
No contingency or escalation is included.

(2) Four months additional geological drifting.

7.0 EVALUATION OF PLANNED TESTING RELATIVE TO CHARACTERIZING NORTH-TRENDING STRUCTURAL FEATURES

The surface-based and underground testing activities that were presented in the SCP for the study of the proposed repository block and specifically apply to the identification and characterization of structural features are described in Sections 4.2 and 4.3 of this report. This section discusses the adequacy of these planned testing activities to identify and characterize north-trending structural features in the western portion of the proposed repository block between the two major north-trending features that are already known to exist (the Ghost Dance fault, which crosses the proposed repository block, and the Solitario Canyon fault, which bounds the proposed repository block on the west).

As mentioned in Section 4.0 of this report, the SCP is a general planning document that will be used to guide site characterization so that the presently identified information needs are fulfilled. As such, the SCP does not provide the level of detail necessary to explicitly perform a technical evaluation of each activity that could provide site characterization data on undetected major north-trending features in the western proposed repository block. In addition, several activities are planned as feasibility studies prior to determining their applicability to the characterization of Yucca Mountain. For this report, it is assumed that the site characterization activities identified in Section 4.2 and 4.3 will obtain useful data.

Due to the general nature of the SCP activity objectives, this section evaluates the tests in terms of the adequacy of the three categories of surface-based tests (surface mapping, geophysics, and drilling) and the underground tests expected to identify and characterize any currently undiscovered major north-trending features in the western portion of the proposed repository block.

In this report, the term adequate should be understood to mean that a particular testing activity, or category of testing (e.g., surface-based, underground), will provide an incremental reduction of the uncertainty in estimates of relevant parameters or repository design and performance assessments based on the data from the tests. As discussed elsewhere, the integrated data resulting from the testing activities will be evaluated periodically to determine the need for additional testing.

Sections 7.1 and 7.2 provide a general discussion of the adequacy of the planned tests to identify and characterize major north-trending features, including brief descriptions of the corroborative relation between the types of tests (e.g., boreholes provide control for geophysical surveys, mapping helps determine trench locations, etc.). Section 7.3 provides a summary evaluation of the planned testing categories against specific criteria. These criteria are:

- Identification of major north-trending features;
- Nature of fractures in fault zones;
- Extent and variability of fracture networks in the host rock;
- Location and geometry of lithostratigraphic features;
- Nature of hydrologic properties;
- Fault offsets;

- Rock strength properties;
- Variability in properties across the proposed repository block;
- Effect of major features of flow mechanisms; and,
- Gas flow permeabilities of fault zones.

7.1 Surface-based Testing

7.1.1 Surface Mapping (Including Trenching)

Surface-based mapping of the Yucca Mountain site, conducted in conjunction with photo interpretation, will be used to identify and characterize the surface expression of anomalous features within the proposed repository block, including the area of the proposed repository block between the Ghost Dance and Solitario Canyon faults. The trace, orientation, offset (if any), and deformation characteristics of these features will be determined, to the extent possible, on the basis of these mapping activities, in order to identify any major features that may be significant with respect to performance assessment or repository design. Based in part on the results from surface-based mapping, trench locations will be selected to identify and characterize (known or suspected) Quaternary faults; these trenches will also provide information on the deformation characteristics of older faults or fracture zones.

Given the large percentage of exposed bedrock on the surface of Yucca Mountain and the extensive nature of the (previous and planned) mapping and trenching programs, this aspect of the site characterization program, when integrated with the other relevant methods discussed below, will provide adequate initial characterization of any major north-trending features in the western portion of the proposed repository block. Added confidence in the surface mapping program could be gained by specifically conducting detailed mapping (strip mapping) east-west across the proposed repository block. This could be conducted at selected intervals across the block.

7.1.2 Geophysics

The results from surface-based geophysical surveys will be used to supplement the mapping and trenching activities by providing data on the subsurface characteristics of major structural features down to and below the proposed repository horizon. The primary sources of geophysical data for evaluation of specific structural features are expected to include ground-based magnetic and gravity surveys, geoelectric surveys, vertical seismic profiling/tomography, and seismic reflection profiles. No single geophysical method will provide unambiguous data to identify and characterize north-trending structural features in the proposed repository block. However, the numerous planned techniques, in concert with borehole and surface mapping control, will collectively provide adequate evidence on the existence and nature of these features, if present.

7.1.3 Drilling

The drilling program described in Section 4.2 provides hydrologic and structural information pertinent to the identification of major north-trending structural features. The site vertical boreholes (SCP 8.3.1.2.2.3.2) will provide information on the hydrologic characteristics and properties of the unsaturated zone at specific locations within the proposed repository block.

In particular, two boreholes (UZ-7 and UZ-8) are planned to be drilled to the east and west of the Ghost Dance fault in the southern part of the proposed repository block (see Figure 4-1) and two boreholes (UZ-11 and UZ-12) are planned on either side of the Solitario Canyon fault to the southwest of the block. These boreholes will provide information on the hydrologic characteristics of these faults and provide better control on the dip and offset of the faults at these locations. The information from the boreholes on either side of the Ghost Dance fault will also provide constraints on repository layout due to fault offset. The hydrologic information from the surface-based testing of the Ghost Dance fault will be complemented by the planned testing of the fault at depth in the exploratory drift (Section 4.3), providing information on the hydrologic characteristics of this fault at a location near the northern end of the proposed repository block. The planned subhorizontal borehole through the Solitario Canyon fault to the north of the block will provide additional information on the hydrologic properties of this major north-south feature.

The systematic drilling program, in combination with the results from the site vertical boreholes, will provide representative information on the distribution of hydrologic properties of the unsaturated zone across the site. In addition, these boreholes will provide lithostratigraphic control, through coring and geophysical logging, within the proposed repository block that should be sufficient to support evaluations of offset on any major, currently unknown north-trending structural features should they be discovered and to determine the potential constraints imposed by these features on repository layout. These boreholes will also provide important input to the design and interpretation of the planned geophysical surveys.

7.1.4 Adequacy of Surface-based Testing

The total program of planned surface-based testing within and adjacent to the proposed repository block (including mapping, trenching, geophysics, and drilling-related activities) is sufficient to identify and initially characterize any major unknown north-trending structural features that may exist in the western part of the proposed repository block between the Ghost Dance and Solitario Canyon faults. As discussed above, a large percentage of the surface of the western portion of the proposed repository block is not covered by surficial deposits (e.g., alluvium, colluvium, soil, etc.). Thus, there is extensive bedrock outcrop that will enhance the capability of surface mapping to detect the surface expression of any structural features. Based on project experience and the surface expression of the Ghost Dance fault, fault offsets on the order of 7 to 10 feet (2 to 3 meters) or more could be detected. The information obtained through surface-based mapping, geophysics and drilling investigations will be of adequate distribution and quality to support the repository design process with respect to identification of constraints on repository layout west of the Ghost Dance fault.

For any major, currently unknown, structural feature that is identified in the western part of the proposed repository block, the planned surface-based program will be adequate to initiate characterization of these features and to compare these features with known major structural features in the area. The results of the planned investigations, taken together with the results from the hydrologic testing to characterize the three known or suspected major structural features to be intersected by the planned exploratory drifts (the Ghost Dance fault, suspected structures beneath Drill Hole Wash, and the imbricate normal fault zone) and the results of surface-based investigations of the Solitario Canyon fault, will be adequate to bracket the expected range of hydrologic properties for any features that are identified. Thus, until major features are encountered that appear to fall outside this expected range of hydrogeologic properties investigated by the surface-based investigations and planned exploratory drifting, no additional exploratory drifting is needed. The need for additional exploratory drifting to the western portion of the proposed repository block should be evaluated at specific decision points and milestones tied to the availability of results from the planned surface-based and underground testing.

7.2 Underground Testing

7.2.1 Planned Testing

The planned program of exploratory drifting and underground testing related to the characterization of the proposed repository block and major unknown structural features, is described in Section 4.3 of this report. The relationship of this underground testing program to the characterization of the Ghost Dance fault is discussed in Section 5.2. This section discusses how the underground testing program, as presently conceived, relates to the information expected to be obtained from the surface-based testing program, as described in Section 7.1, and to the overall need to characterize the western part of the proposed repository block, including any major, currently unknown north-trending structural features.

Current plans call for approximately 5,600 feet of exploratory drifting on three headings from the exploratory shaft dedicated testing area at the main test level in the Topopah Spring Member. These exploratory drifts are intended to intersect three known or suspected major structural features: the imbricate normal fault zone to the southeast, suspected structures underlying Drill Hole Wash to the northeast, and the Ghost Dance fault to the northwest. These exploratory drifts will cumulatively provide access to characterize approximately 3,000 feet of the east-west expanse of the proposed repository horizon. As described in Section 4.3, the SCP contains plans to conduct mapping and other testing activities in these drifts that will provide information on the structural characteristics of the proposed repository host rock for input to both design and performance assessment activities. Section 4.3 also describes plans for in situ tests to characterize the hydrologic properties of the major structural features expected to be encountered. There is no plan, at present, to extend the exploratory drifting to the west of the Ghost Dance fault during the site characterization phase in order to provide information on the western portion of the proposed repository block. As discussed above, the need for additional exploratory drifting to the western portion of the proposed repository block should be evaluated at specific decision points and milestones tied to the availability of results from the planned surface-based and underground testing.

7.2.2 Adequacy of Underground Testing

As described in Section 7.1, the planned surface-based activities, in conjunction with the planned exploratory drifting and underground testing, will be adequate to bracket the expected range of hydrologic properties for any new features that are identified. Unless the surface-based activities indicate that the characteristics of any major north-trending features discovered do not fall within this expected range, it would be appropriate to extrapolate the results of the planned underground testing to describe and model the performance of these north-trending features.

For any major north-trending structural features that are identified in the western part of the proposed repository block, the information from the surface-based program will be adequate to initially characterize the properties of these features that are important in evaluating their expected hydrologic behavior. This evaluation will be supported by the surface-based hydrologic testing planned for the Ghost Dance and Solitario Canyon faults, which are themselves major north-trending features. As stated earlier, this information taken together with the results from the underground hydrologic testing to characterize the three currently known or suspected major structural features to be intersected by the planned exploratory drifts will be adequate to initially characterize any new features that are identified.

7.3 Summary Evaluation of Testing

On the basis of the following evaluation and the discussions in Sections 7.1 and 7.2, there is not a compelling need to augment the planned programs of exploratory drifting and underground testing by extending the exploratory drifts to the west of the Ghost Dance fault. The present plans are sufficient to identify any major unknown north-trending structural features and to initially characterize any features that may be identified.

This section provides a summary evaluation of the planned surface-based testing categories against the criteria identified in Section 7.0 and repeated below. A discussion of how the planned surface-based tests meet each criteria follows.

As stated earlier, this evaluation assumes that the surface-based activities identified in Section 4.0 can obtain useful data (i.e., the techniques will be found to be feasible to determine the parameters listed in the SCP in their respective descriptions). Also, as is discussed above, it is assumed that the results of investigations of known fault zones (e.g., Ghost Dance fault, Solitario Canyon fault) will be available, and that based on the surface-based data used to identify any currently unknown north-trending features, a decision can be made that the results of planned fault zone investigations can be extrapolated to these north-trending features.

Evaluation Criteria

1) Identification of major north-trending features
2) Nature of fractures in fault zones
3) Extent and variability of fracture networks in the host rock
4) Location and geometry of lithostratigraphic features
5) Nature of hydrologic properties
6) Fault offsets
7) Rock strength properties
8) Variability in properties across the proposed repository block
9) Effect of major features of flow mechanisms
10) Gas flow permeabilities of fault zones

Criteria 1: Identification of major north-trending features

The identification of major north-trending features is expected to be achievable through surface mapping, geophysical surveys, and drilling. As described in Section 4.2, and based on project experience, surface mapping will identify fault offsets on the order of 35 feet (10 meters) or less (DOE, 1988a), and identify breccia zones and other evidence of faulting in the western portion of the proposed repository block. Geophysical surveys, including seismic reflection, gravity, magnetics, and resistivity, will delineate zones of major structural disturbance (e.g., fault offset, breccia zones). Although any one method may not unambiguously identify these zones, the combined data base will allow reasonable interpretations of the proposed repository block structure. The surface-based drilling program will provide stratigraphic control to help identify areas of potential fault offset. Also, the drilling program may penetrate unknown geologic features. The drilling program could be especially useful if inclined holes are incorporated into the program based on the success of the prototype slant hole now being planned. This would enhance the capability to intersect near vertical features.

Criteria 2: Nature of fractures in fault zones

Characteristics of fractures in fault zones such as fracture density, aperture, permeability, and infilling minerals can be identified through surface mapping, drilling, and possibly geophysics. Surface mapping includes pavement studies of fracture networks in bedrock outcrops and trenching of known or suspected Quaternary faults. The drilling program can investigate fault zone fractures by cross hole testing (in USW UZ-7 and 8 and USW UZ-11 and 12) and coring and geophysical logging of USW UZ-8. Vertical seismic profiling/tomography performed in these holes may provide three dimensional subsurface data on these fractures.

Criteria 3: Extent and variability of fracture networks in the host rock

The same techniques mentioned under Criteria 2 apply here. The drilling program could be especially useful if inclined holes are incorporated into the program based on the success of the prototype slant hole now being planned.

Criteria 4: Location and geometry of lithostratigraphic features

This criteria will be satisfied primarily by the drilling program (through coring and geophysical logging) and surface mapping. Geophysics (e.g., seismic reflection) can be useful in extrapolating from points of borehole control.

Criteria 5: Nature of hydrologic properties

This criteria can be satisfied by the hydrologic tests planned as part of the drilling program.

Criteria 6: Fault offsets

The same techniques described for Criteria 1 will contribute to determining fault offsets. Detailed surface mapping east-west across the proposed repository block could increase confidence in the identification of north-trending faults and the determination of fault offsets.

Criteria 7: Rock strength properties

The drilling program (through core and geophysical logs) will provide the bulk of the data on rock strength properties across the proposed repository block. Seismic reflection, resistivity, gravity, and magnetic surveys will aid in interpolating between boreholes. In addition, data from the ESF in situ tests can also be projected across the proposed repository block based on the lithostratigraphic control provided by drilling and geophysics.

Criteria 8: Variability in properties across the proposed repository block

Again, the drilling, geophysics, and surface mapping activities will provide control for the mapping of hydrologic and rock properties across the proposed repository block.

Criteria 9: Effect of major features on flow mechanisms

With respect to currently unknown north-trending features in the western portion of the proposed repository block, the planned activities do not provide specific means to study the effects of these features on flow mechanisms. However, it is expected that the studies planned for known features (e.g., Ghost Dance fault, Solitario Canyon fault, the imbricate normal fault zone) will provide results that can be extrapolated to any major north-trending features discovered in the western portion of the proposed repository block.

Criteria 10: Gas flow permeabilities of fault zones

With respect to currently unknown north-trending features in the western portion of the proposed repository block, the planned activities do not provide specific means to study the gas flow permeability of these features. However, it is expected that the studies planned for known features (e.g., Ghost Dance fault, Solitario Canyon fault, the imbricate normal fault zone) will provide results that can be extrapolated to any major north-trending features discovered in the western portion of the proposed repository block.

8.0 QUALITATIVE EVALUATION OF EXTENDED EXPLORATORY DRIFTING TO CHARACTERIZE NORTH-TRENDING STRUCTURAL FEATURES

This section presents the evaluation of an additional exploratory drift that could be driven to the northwest across the western portion of the proposed repository block from the conceptual repository main drift. This evaluation is based on the various factors, listed in Section 8.3, that were also the basis for the current plans for site characterization.

8.1 Alternative for Extended Exploratory Drifting

The previous evaluation of the adequacy of data expected from the planned SCP surface-based and underground testing relative to characterizing north-trending features in the western part of the proposed repository block (Section 7.0), indicates that there is no compelling need at this time to augment the planned programs by extended exploratory drifting to the western side of Yucca Mountain. However should the planned surface-based test program or initial underground drifting identify the potential for additional significant north-trending structural features, the alternative to drive an additional exploratory drift to the northwest to intersect and characterize these features, needs to be reevaluated. This decision will be based on several factors:

- adequacy of the data already obtained;
- the uncertainty associated with this data; and,
- the need to decrease uncertainty by direct observation.

This alternative to the planned program would consist of an additional exploratory drift approximately 4100 feet long, driven northwest from the proposed southern extension of the conceptual repository main (or from the planned drift to the Ghost Dance fault). In order to be compatible with the conceptual design of the repository, the drift would be located to be coincident with a proposed repository panel access drift in terms of orientation and grade (Fig. 8-1).

The following discussion identifies assumptions made to design the alternative, and evaluates this alternative against the various factors on which the current plans for site characterization were based.

8.2 Assumptions

In developing the current exploratory drifting plan, several assumptions were made. Similar assumptions have been made for the alternative exploratory drift plan to the northwest. These are identified below.

- Two exploratory shafts with a finished inside diameter of 12 feet will be available during drifting.

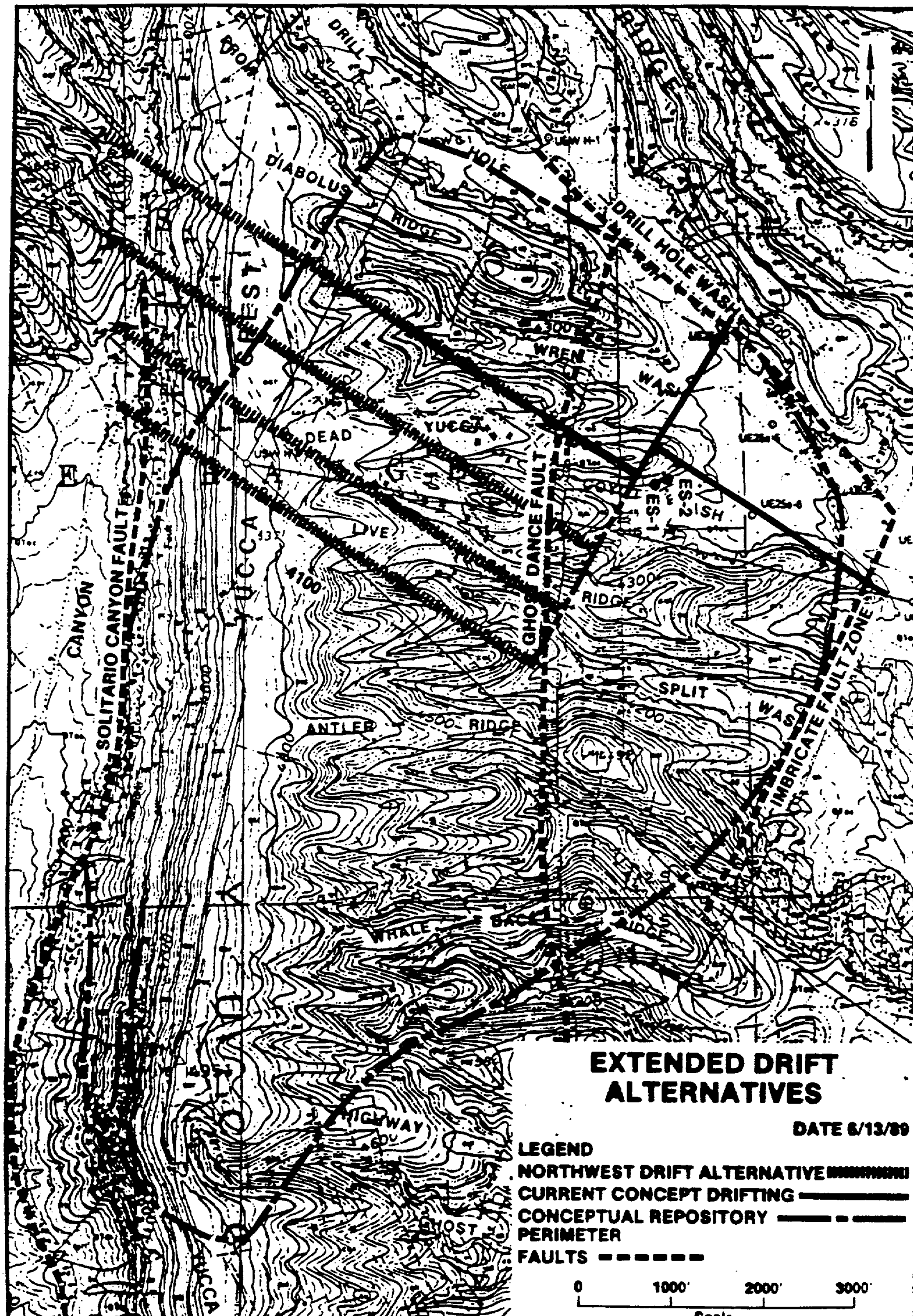
EXTENDED DRIFT ALTERNATIVES
DATE 6/13/89
LEGEND
NORTHWEST DRIFT ALTERNATIVE
CURRENT CONCEPT DRIFTING
CONCEPTUAL REPOSITORY PERIMETER
FAULTS
0
1000'
2000'
3000'
Scale
DIABOLUS
RIDGE
DRILL HOLE WASH
WREN
WASH
DEAD
YUCCA
LIVE
GHOST DANCE FAULT
SOLITARIO CANYON FAULT
CANYON
IMBRICATE FAULT ZONE
SPLIT
WASH
ANTLER
RIDGE
WHALE BACK
RIDGE
ES-1
ES-2
4100
4300

FIGURE 8-1

- When exploratory drifting starts, the two shafts will have been connected and the hoist capacity will remain the same. (Yucca Mountain Project Exploratory Shaft Facility Title I Design Summary Report; YMP, 1988).

- The cross-section of the extended exploratory drift to the northwest will remain as for the planned exploratory drifts (14 feet wide and 14 feet high).

- The construction methods for any extended exploratory drifting will be the same as currently planned drifting--controlled drilling and blasting.

- The design of the proposed repository will be consistent with the description in the Site Characterization Plan Conceptual Design Report (SCP CDR; SNL, 1987).

- The tests currently proposed for the planned exploratory drifts would be repeated to characterize the rock exposed by additional drifting.

- The proposed extended exploratory drift to the northwest will be coincident with a proposed repository panel access drift in terms of orientation and grade.

- Support systems for the planned exploratory drifts will be adequate to handle an additional 10,000 feet of exploratory drifting (F&S 1988).

- It is beyond the scope of this report to consider exploratory drifting that is not consistent with the conceptual design of the repository. Therefore, considerations for extended exploratory drifting are assumed to be at the proposed repository horizon only.

8.3 Evaluation Factors

To evaluate the feasibility of this alternative, several factors must be considered. These factors are listed below and discussed in Section 8.4.

- Information for Characterization of the North-trending Structural Features;
- Postclosure Performance;
- Non-radiological Health and Safety;
- Integration with the conceptual repository design;
- Design Flexibility;
- Information for Design and Performance Issues;
- Cost; and,
- Schedule

Construction methods such as conventional drill and blast versus mechanical mining methods are addressed in Appendix C. Given the planned shaft diameters and the amount and the lengths of the planned exploratory drifting it was concluded that mechanical mining (tunnel boring machine) is not justifiable. Therefore, this evaluation did not consider construction methods as a factor.

8.4 Evaluation

8.4.1 Information for Characterization of the North-trending Structural Features

As discussed in Section 7.2, the planned program of surface-based testing is considered to be sufficient to identify and initially characterize north-trending structural features in the western part of the proposed repository block. However, additional information obtained from extended exploratory drifting to the northwest would increase the confidence in data obtained from the surface-based testing program because the exploratory drift intersection of north-trending features at repository depth would provide direct observation of the location, orientation and displacement of these features.

The information acquired from the drifting and mapping programs should be periodically reevaluated for representativeness and adequacy. This may lead to the need for an exploratory drift to the northwest. If a decision is made to excavate this drift, it would probably be initiated either late in site characterization or at the completion of the additional proposed southwest exploratory drift to the Ghost Dance fault. The extended exploratory drift would also allow an additional approximate 4100 feet of fracture mapping to be performed, and would provide more detailed information on the hydrologic, mechanical, and geochemical properties of the host rock and associated geologic features.

8.4.2 Postclosure Performance

Section 8.4.3 of the SCP provides a thorough analysis of the impacts of site-characterization activities that are identified in the SCP on the ability of the site to meet postclosure performance objectives. These objectives are the requirements for waste isolation, including limits on radionuclide releases from the repository system, individual protection, and ground-water protection; requirements for the containment of the wastes within the waste packages; limits on the release rate of radionuclides from the engineered-barrier system; and requirements on the pre-waste-emplacement ground-water travel time to the accessible environment. Section 8.4.3 of the SCP concludes that no adverse effects are expected from site-characterization activities at the surface (e.g., ground preparation), from surface-based drilling activities, from the exploratory shafts, or from the exploratory drifting and tests that are here described as the current plans.

An analogous detailed analysis of possible effects on postclosure performance has not been performed for extended drifting. However, on general grounds, it can be concluded that the excavations and tests associated with extended drifting are not likely to affect postclosure performance for the same reasons as previously evaluated. The extended drifting would be integrated into the design of the repository itself. Therefore, the effects of any extended drifting alternatives are not likely to be different from those of the repository. The same care and methods that would be used in the construction of the underground repository would be used in the drifting. The same practices for sealing and closure would be used. It is therefore unlikely that any new pathways for ground-water travel would be created or that the host rock would be disturbed beyond the disturbance planned for the repository. If for some reason the extended exploratory drift is not

Table 8-1 Summary of the Qualitative Evaluation of Exploratory Drifting to Characterize North-trending Structural Features

Factors	Summary of Evaluation
Information for Characterization of North-trending Structural Features	Not necessary now, but would increase confidence.
Postclosure Performance	No adverse effects expected if drift is coincident with conceptual repository layout.
Non-radiological Health and Safety	Relative to repository development, no additional effect on worker safety if exploratory drift is coincident with a conceptual repository panel access drift.
Integration with the Conceptual Repository Design	No effects on conceptual repository layout, however, may not be coincident with final layout.
Design Flexibility	Design becomes less flexible as additional drift subparallel to dip of tuff units is constructed because it may impact the plane of the repository horizon; drift orientation may not be coincident with final repository layout.
Information for Design and Performance Issues	Not necessary at present, but may be necessary to reevaluate later in planned program.
Cost	Increased cost of approximately $23 million.
Schedule	Based on conventional drill and blast methods, an additional 16 months for exploratory drifting; it will not provide data for early input to a determination of site suitability.

integrated with the proposed repository, no adverse impact on postclosure performance is expected. However, the potential for adverse impacts on performance if this exploratory drift (or the planned exploratory drifts) is not integrated with the proposed repository should be analyzed.

Some additional testing would be done in the additional northwest drift. These additional tests could conceivably affect portions of the host rock. It is unlikely, however, that such tests would have a significant effect on postclosure performance. These tests would be similar to those analyzed for the current plans in Section 8.4.3 of the SCP, and the SCP analysis indicates that the approach planned for testing at the Ghost Dance fault and other structures, such as the imbricate normal fault zone, would not have an adverse effect on performance. Therefore, it is not likely that the activities associated this additional drift would have a more adverse effect on postclosure performance than the activities associated with the current plans.

8.4.3 Non-radiological Health and Safety

Factors pertaining to the non-radiological health and safety of workers include the exposure of workers to underground environments, dust, and mining hazards. The conditions pertinent to evaluations of these factors are the stability of ground conditions, ground support, maintenance of underground openings, air quality, working temperature, and the potential for equipment-related accidents. Regardless of the drift location, worker safety can be ensured by the assignment and implementation of appropriate design safety factors, the establishment of design criteria that mandate compliance with regulations governing health-and-safety requirements, evaluation of design to ensure compliance with the required regulations, and the establishment of training and safety programs.

It is safe to assume that the non-radiological safety of workers is directly dependent on the extent of exploratory drifting, however as the location of the extended northwest drift will be coincident with a proposed repository panel access drift, the probability of worker related accidents within the exploratory drift will remain the same, but the exposure will occur in a different timeframe.

Should the information obtained from site characterization change the currently conceived repository layout in terms of orientation and grade, and the extended exploratory drift does not become coincident with a repository panel access drift, the exposure of workers to mining hazards will increase slightly, due to the additional approximate 4100 feet of extended drifting.

8.4.4 Integration with the Conceptual Repository Design

The current concept for the ESF design has basically evolved simultaneously with the SCP conceptual design of the repository. Appendix E of the Generic Requirements for a Mined Geologic Disposal System (GR; DOE, 1986), as well as the Yucca Mountain Project Exploratory Shaft Facility Subsystem Design Requirements Document (SDRD; YMP, 1988) require that the ESF and repository designers coordinate the underground location and layout of permanent ESF structures, systems, and components. The current ESF design does complement the conceptual repository design, and the layout of drifts to the geologic features is coincident with repository drifts and at repository grades. This concept provides the least disturbance to the overall repository area and still provides intercepts to the geologic features of interest.

The extended northwest drift follows the currently conceived repository layout in terms of orientation and grade, and therefore is integrated with the conceptual repository design.

8.4.5 Design Flexibility

Both the currently planned exploratory drifting and the extended northwest drift offer flexibility in design in terms of opening up additional areas for testing and exploration. It should be noted, however, that although flexibility exists in the current ESF design for extended exploratory drifting, such drifting should preferably be limited to that essential for characterization only at this stage. It will be possible to construct more drifts (exploratory or otherwise) in the future when the design for the repository is more advanced or when facilities for the repository are constructed (e.g., access ways, utilities). As stated earlier the less disturbance in the repository block, the greater the flexibility available for the final repository layout. Additionally, an extended northwest drift would be subparallel to the dip of the tuff units. Thus, this exploratory drift would impose constraints on the repository grade (see discussion in Section 4.2.3).

8.4.6 Information for Design and Performance Issues

Information needed for design and performance issues will be obtained as described in Section 7.0, above. The evaluation of those data is summarized above regarding representativeness. As described in Section 7.3, any undiscovered major faults and offsets are expected to be detected though planned surface-based testing. Other information important for design is also expected to be obtained from the current planned program. Information for performance issues would largely be obtained from the existing program and extrapolated to any currently unknown structure, should one be discovered. As stated in Section 8.4.1, the need for initiating a northwest-trending drift should be deferred until after the completion of planned surface-based mapping, drilling, exploratory drift excavations or until the data from surface-based investigations have been evaluated to determine whether additional data are needed to achieve representativeness.

The representativeness of data from planned site-characterization activities is evaluated in the SCP by (1) describing the data needed for performance and design analyses and (2) considering the alternative methods for obtaining this information as well as the rationale for selecting the proposed test methods. Section 8.4.2.1.5 of the SCP describes this process in detail. The confidence level in the ability of the proposed repository to meet performance objectives increases directly with the extent of data available before design decisions are made. From this perspective, the more extensive the exploratory drifting during characterization, the better will be the representativeness of the data collected. Therefore some additional confidence in the representativeness of data would be gained by driving the extended northwest drift into the western part of the proposed repository block. A decision as to whether drifting to the northwest should occur as planned during the performance confirmation phase, or whether it should be initiated earlier, could be made when data from the surface-based drilling and underground drifting activities are completed.

8.4.7 Cost

The cost estimate for an exploratory drift to intersect any north-trending structural features in the western portion of the proposed repository block is preliminary and not a detailed estimate. The reference for the cost estimates for the planned ESF was drawn from the "ESF Budget Support Data" (April 11, 1989) provided by the Yucca Mountain Project Office (YMPO). All amounts are quoted in fiscal year (FY) 1990 dollars, and all amounts are given without contingency or escalation and should be regarded as preliminary. The cost estimates for the northwest exploratory drift across the repository block were developed from the reference cost estimates by using multiplying factors and unit costs (dollars per foot) when applicable.

The cost for a 4,100 feet drift to any north-trending faults is $23.2 million. The cost implications are shown in Table 8-2.

8.4.8 Schedule

The excavation time for a 4100 feet drift is 16 months. This is in addition to the time needed for the southwest drift to the Ghost Dance fault. An exploratory drift to the northwest would not provide early input into the determination of site suitability. Additionally, this drift will not provide data for early input to a determination of site suitability.

TABLE 8-2

COST ESTIMATE FOR EXTENDED EXPLORATORY DRIFTING FOR NORTH-TRENDING FAULTS
Millions of FY 1990 Dollars

	PLANNED EXPLORATORY SHAFT FACILITY estimate, prior years plus Budget through 1995 (1)	COST WITH DRIFT TO NORTH TRENDING FAULTS (2)	COST OF 4100' DRIFT TO NORTH TRENDING FAULTS (2)
Management & Integration			
TEC Design	17.2	18.1	0.9
Construction	4.3	4.3	-
NON-TEC Design	38.7	41.2	2.5
Operations	86.7	93.4	6.7
Site Preparation	19.0	19.0	-
Surface Facility	9.5	9.5	-
First Shaft	10.2	10.2	-
Second Shaft	9.3	9.3	-
Subsurface Excavations			
Design	1.2	2.9	1.7
Construction	20.0	27.6	7.6
Underground Service System			
Design	5.0	6.3	1.3
Construction	15.5	16.9	1.4
Operations			
NON-TEC	70.4	71.5	1.1
TEC	25.6	25.6	-
TOTAL	332.6	355.8	23.1

(1) Source: "Exploratory Shaft Facility Budget Support Data", 4-11-89.
Cost estimates for extending the exploratory drifts were developed by applying factors that were developed from the PLANNED EXPLORATORY SHAFT FACILITY estimates and by using $/ft costs when applicable.
No contingency or escalation is included.

(2) Sixteen months of additional geological drifting' (4100').

9.0 CONCLUSIONS AND RECOMMENDATIONS

In planning a site characterization program, the DOE has adopted an approach that begins with the evaluation of regulatory requirements promulgated by the Nuclear Regulatory Commission (NRC) in 10 CFR Part 60, and that must be satisfied in siting and licensing a repository; identifies the performance and design information needed to address those requirements; and then develops specific investigations to obtain the needed information.

The DOE's site characterization program consists, essentially, of surface-based and underground testing, associated laboratory tests, and analyses of data including performance assessments. The extensive surface-based and underground tests are designed to complement each other so that the information gathered during site characterization can be integrated and projected confidently across the entire proposed repository block. Results from the planned surface-based and underground testing will be evaluated periodically to determine whether additional data are required to reduce uncertainty for performance assessments and repository design.

In the SCP, the DOE described investigations designed to reduce uncertainty in geologic models of the Yucca Mountain area. As these investigations proceed, the integrated results from planned surface-based mapping, geophysics and drilling activities and tests performed in the ESF will be used to;

- Refine the geologic models;
- Provide input to repository and waste package designs;
- Provide input to performance assessment calculations; and
- Reevaluate performance allocations.

This will be an iterative process, based on the results of site characterization investigations. This iterative process will reduce uncertainty in the estimates of geologic features and processes, and it will provide a basis to reevaluate the adequacy of the site characterization program.

The NRC's siting criteria (10 CFR 60.122) states that it must be demonstrated that "the potentially adverse human activity or natural condition has been adequately investigated, including the extent to which the condition may be present and still be undetected taking into account the degree of resolution achieved by the investigations." One of the many aspects of this issue that will be addressed during site characterization is the minimum vertical offset of a fault that can be recognized by surface mapping techniques. As described in the SCP (Section 8.3.1.4.2.2.1 - Geologic mapping of zonal features in the Paintbrush Tuff), vertical offsets of 35 feet (10 meters) or less due to displacement along faults should be recognized by geological mapping of bedrock exposures. Because of the gradational nature of contacts (zonal features) within the Tiva Canyon Member and the degree of exposure, the level of confidence or accuracy in locating these contacts varies across the site. Based on project experience, zonal contacts can be located with a vertical error of plus or minus approximately 1.5 feet (0.5 meters) with high confidence. At locations with greater colluvial cover and less frequent outcrops, the possible error is somewhat greater. In general, it appears that dip-slip offsets greater than 7 to 10 feet (2 to 3 meters) would be detected by surface mapping of bedrock outcrops. Since the Ghost Dance fault is visible on air photos, and at the surface in Coyote Wash, where the offset is only 3-4 meters, it is assumed that mapping faults with this degree of near-vertical displacement would provide adequate stratigraphic and structural input for repository design.

In complying with the aforementioned regulation, it may become obvious, at some point in the site characterization program, that uncertainty in the geologic models cannot be reduced sufficiently by planned surface-based testing (e.g., fault offset cannot be resolved within less than 35 feet). If this is the case, based on the available (integrated) results of planned surface-based mapping, geophysics and drilling, then the DOE could consider expanding the planned surface-based testing program to include additional investigations or boreholes to either investigate specific features of interest or to increase confidence in the ability to make predictions of performance assessments or to refine repository design. An expanded surface-based program could include additional investigations such as detailed geologic strip-maps, additional geophysical surveys and vertical and inclined boreholes. If an expanded surface-based program could not provide the necessary reduction in uncertainty (or if the results of an expanded surface-based program do not sufficiently reduce uncertainty), then an additional means of reducing uncertainty could be to expand the exploratory drifting program beyond what is currently planned. This decision may be better accomplished at some time in the future (as opposed to expanding the program now) when surface-based testing and integrated data analysis will have provided better stratigraphic control across the proposed repository block. Deferring this decision would have the advantage of permitting the expanded drifting to be located to investigate the features of interest and to be better integrated with the proposed repository, as the elevation, grade, and orientation of the conceptual repository design may change.

An illustration of the process described above is the recommendation, presented below, to include an additional exploratory drift to the Ghost Dance fault. This recommendation is based on the conclusion that uncertainty in characterizing this specific feature will not be sufficiently reduced by the planned surface-based and underground testing.

Based on the integration and interpretation of early results of the planned surface-based and underground testing, the DOE should decide whether additional exploratory drifting to the west should be conducted during site characterization (and before a license application is submitted) or could be conducted during the performance confirmation phase of the repository program as is currently planned.

9.1 Conclusions

9.1.1 Exploratory Drift to Ghost Dance Fault

Several factors (discussed in Section 6.0) indicate that extended exploratory drifting is advantageous; specifically, an exploratory drift to the southwest along the conceptual repository main drift to intersect the Ghost Dance fault. The factors leading to this conclusion are listed below:

- The Ghost Dance fault appears to be a significant structural feature within the proposed repository block. The ability to adequately characterize this structural feature is important in reducing the uncertainty of performance assessment calculations;

- The Ghost Dance fault is thought to have variable displacement (a "hinge" or "scissors" fault) as compared to faults with typical normal or reverse displacement. Fault characteristics such as dip and degree of deformation may vary along the length of the fault and with depth;

- Based on existing information from surface mapping, displacement along the Ghost Dance fault appears to increase substantially to the south and therefore, the planned repository horizon may be effected;

- Greater displacement toward the south may have resulted in a greater degree of fracturing and brecciation, and therefore hydrologic characteristics of the fault and across the fault may vary from north to south;

- Characteristics of the fault appear to vary at the surface but are not known at depth;

- The intersection of the planned exploratory drift with the Ghost Dance fault toward the north will provide direct observation of the fault at only one location;

- Extended exploratory drifting to the Ghost Dance fault supplemented by an expanded drilling program would provide access for direct and indirect observation and testing, and would aid in refining the location and orientation of the proposed repository horizon;

- It appears that an extended exploratory drift can be excavated without a significant adverse impact to the program schedule;

- The extended exploratory drift to the Ghost Dance fault (Figure 6-1) will reduce uncertainty regarding structural and hydrologic characteristics along the southern portion of the fault;

- The additional data obtained would further reduce uncertainty in lateral and vertical variabilities for purposes of performance assessment and repository design; and,

- This extended exploratory drift would provide access to directly observe and test the fault zone at a location of potentially greater deformation which may have hydrologic characteristics different from those to the north.

9.1.2 Exploratory Drift to North-trending Features

There is not a compelling need to augment the planned exploratory drifting program with a drift to the western perimeter of the proposed repository at this time; however, new data from site characterization activities may require reevaluation of this conclusion. The factors contributing to this conclusion are listed below:

- Based on what is presently known about the hydrologic and geologic conditions of the proposed repository block, the planned surface-based testing will be sufficient to identify and initially characterize any major north-trending features that may exist between the Ghost Dance and Solitario Canyon faults.

- The information obtained from the surface-based and underground testing is expected, at this time, to be adequate to support the repository design process with respect to identification of constraints on the repository layout west of the Ghost Dance fault, without the need for additional information from exploratory drifting.

- Evaluations of the results of early site characterization testing activities may indicate a need to more thoroughly characterize the hydrologic and geologic conditions of the western portion and boundary of the proposed repository block. This may include additional drilling, mapping or exploratory drifting.

- Depending on the location of the feature(s) of concern, an additional exploratory drift approximately 4,100 feet long could be located coincident with one of several proposed panel access drifts (Fig. 8-1) in the conceptual underground repository layout. The location and grade of an appropriate panel access drift is less likely to change after new site data have been incorporated into repository design.

- If it is determined that a drift to the northwest is necessary based on an evaluation of the information from the planned surface-based and underground testing, the additional drift should be driven to the northwest from a point near the intersection of the recommended additional exploratory drift to the southwest with the Ghost Dance fault. The northwest drift would then pass through the central portion of the proposed repository block to a point where the Solitario Canyon fault is nearest to the proposed repository block.

- The current ESF program is considered flexible enough to allow for an exploratory drift to the western perimeter of the proposed repository block at some later time, if required.

- The planned exploratory drifting to the imbricate normal fault zone and the Ghost Dance fault cover approximately 50 percent of the east-west width of the proposed repository block. The western portion of the proposed block has exposures at the surface in outcrop that will help provide controls for mapping. Therefore, the combination of the planned exploratory drifting and the surface-based testing program should identify any significant north-trending structural features within the western part of the proposed repository block.

9.2 Recommendations

9.2.1 Alternative for Exploratory Drift to the Ghost Dance fault

The recommendations for the alternative exploratory drift to the Ghost Dance fault are presented below. These recommendations are based on the conclusions discussed above.

- It is recommended that an additional extended exploratory drift should be driven to the southwest coincident with the conceptual repository main drift, approximately 2,000 feet, to intersect the Ghost Dance fault. This intersection would be near a mid-point between the planned drift to the north and the boreholes (UZ-7 and UZ-8) to the south.

- The extended exploratory drift should be excavated simultaneously with the excavation of the other three exploratory drifts (e.g. four concurrent headings) to minimize schedule impacts.

- The extended exploratory drift, as described in this report, should be incorporated as proposed changes to the Title II design.

- If only one exploratory drift is driven to the Ghost Dance fault, it should be the extended exploratory drift to the south where offset and deformation may be greater, rather than the currently planned drift to the northwest.

- In addition to the extended exploratory drift, the DOE should consider expanding its drilling program to include several lines of boreholes transecting the Ghost Dance fault, and possibly inclined boreholes to intersect the fault. These additional boreholes will help define stratigraphic offset across the Ghost Dance fault and provide information for repository design. In addition, the DOE should consider more detailed surface mapping along the fault trace.

9.2.2 Characterization of North-trending Structural Features

The recommendations for exploratory drifting to the western portion of the proposed repository block are presented below. These recommendations are based on the conclusions reached above.

- Although the present surface-based testing program has been evaluated as being adequate to initiate new site characterization activities, the DOE should consider including inclined boreholes in the systematic drilling program. This would enhance the ability to characterize any near vertical features (e.g., fractures) encountered in the proposed repository block.

- Exploratory drifting to the northwest should be limited, at this stage, to that which is currently planned. However the flexibility to expand the exploratory drifting to the northwest should be evaluated in the Title II design process to assure the capabilities of the underground support systems are adequate to support extended exploratory drifting.

- Decision points based on the results of surface-based and underground testing should be established to reevaluate the decision not to extend northwest exploratory drifting. Suggested decision points are as follows:

  - Periodically during site characterization;
  - After completion of the detailed surface mapping of Yucca Mountain;
  - After completion of the systematic drilling program; or
  - After completion of planned exploratory drifting.

- The DOE should consider expanding the use of inclined boreholes and conducting detailed geologic mapping in an area or direction of interest (e.g., east-west strip maps across the central portion of the proposed repository block) during early surface-based testing and prior to initiating the excavation of a long drift to the northwest.

REFERENCES

10 CFR Part 60 (Code of Federal Regulations), 1988, "Disposal of High-level Radioactive Wastes in Geologic Repositories," U.S Government Printing Office, Washington, D.C.

30 CFR Part 57 (Code of Federal Regulations), 1988, "Safety and Health Standards - Metal and Non-Metal Underground Mines," U.S. Government Printing Office, Washington, D.C.

DOE (U.S. Department of Energy), 1986, "Generic Requirements for a Mined Geologic Disposal System," OGR/B-2, Washington, D.C.

DOE (U.S. Department of Energy), 1988a, "Site Characterization Plan," DOE/RW-0199, Washington, D.C.

DOE (U.S. Department of Energy), 1988b, "Surface-based Investigation Plan," YMP/88-25, Las Vegas, NV.

F&S (Fenix & Scisson, Inc.), 1988, "Impact Analysis on ESF Design for Calico Hills Penetration and Exploratory Drift and Tuff Main Extension to Limits of the Repository Block," DOE/NV/10322-35, Prepared by Fenix & Scisson, Inc., Las Vegas, NV.

SNL (Sandia National Laboratories), 1987, "Site Characterization Plan Conceptual Design Report," SAND84-2641, 6 vol., Sandia National Laboratories, Albuquerque, NM.

USGS (U.S. Geological Survey), 1984, "Preliminary Map of Yucca Mountain, Nye County, Nevada, with Geologic Sections," USGS-OFR 84-494, U.S. Geological Survey, Denver, CO.

USGS (U.S. Geological Survey), 1984, Stratigraphic and Structural Characteristics of Volcanic Rocks in Core Hole USW G-4, Yucca Mountain, Nye County, NV," USGS-OFR 84-789, U.S. Geologic Survey, Denver, CO.

YMP (Yucca Mountain Project)/88-02, Nov. 8, 1988, "Yucca Mountain Project Exploratory Shaft Facility Title I Design Summary Report," Final Draft, Yucca Mountain Project Office, Las Vegas, NV.

YMP (Yucca Mountain Project), 1988, "Yucca Mountain Project Exploratory Shaft Facility Subsystem Design Requirements Document (SDRD)," NVO-309, Las Vegas, NV.

APPENDIX A

ACTION PLAN FOR EVALUATING ADDITIONAL DRIFTING FOR SITE CHARACTERIZATION AT YUCCA MOUNTAIN

ACTION PLAN FOR THE DEVELOPMENT OF REPORT ON NWTRB SUGGESTIONS RELATED TO ADDITIONAL DRIFTING IN THE ESF

DEVELOPED BY:

D. STUCKER — 5/1/89 Date

R. Lahoti — 5/2/89 Date

D. Alexander — 5/2/89 Date

CONCURRED BY:

S. Brocoum — 5/2/89 Date

for H. Jackson Hale / M. Frei — 5/2/89 Date

J. Saltzman — 5/2/89 Date

APPROVED BY:

S. Kale — 5/2/89 Date

ACTION PLAN FOR EVALUATING ADDITIONAL DRIFTING FOR
SITE CHARACTERIZATION AT YUCCA MOUNTAIN PROJECT

1. BACKGROUND:

The April 11-12, 1989 meeting with the Nuclear Waste Technical Review Board (NWTRB) focused on alternative shaft construction methods and perimeter drifting to more fully characterize the site. With respect to perimeter drifting, the NWTRB originally suggested (March 7-8, 1989 meeting) that such drifting should include the entire perimeter of the repository as currently conceived. As a result of the briefing and subsequent discussions in the April 11-12 meeting, the NWTRB rescinded their suggestion on perimeter drifting but suggested that the current drifting plans be expanded to intersect the Ghost Dance fault at two or three locations (rather than the single intercept currently planned) in order to obtain more definitive information on the characteristics of the fault and underground conditions. Specifically, the NWTRB recommended the following:

- Extend the planned Ghost Dance drift (northwest drift) through the Ghost Dance fault to intersect the western perimeter of the repository block.

- Perform additional drifting to intersect the Ghost Dance fault at at least one other location, preferably to the south.

DOE-OFSD has assigned Weston to evaluate NWTRB's suggestion and report to them by June 2, 1989.

2. PURPOSE AND SCOPE:

The Weston evaluation will focus on examining the NWTRB suggestion "expanded drifting", from the perspective of characterization needs and adequacy (comparison of existing plan with proposed plan), potential impacts on repository performance (waste isolation), and impacts on repository design. The effort will culminate in a technical report which will include assumptions and criteria used for this study, historical background, rationale for current ESF drifting plans, technical evaluation of the NWTRB suggestion, cost/schedule impacts, programmatic impacts and recommendations.

3. REQUIREMENTS:

The expertise required for evaluation and review will be drawn from qualified personnel from the DOE-HQ, YMPO, and WESTON. Areas of expertise will include mining engineering, geoscience, testing, performance assessment, licensing, and cost/schedule.

The evaluation team members will have sufficient knowledge of the Yucca Mountain Site Characterization Plan as well as programmatic requirements defined in documents such as the Mission Plan, 10 CFR Part 60, 10 CFR Part 960, ESF Title I design, GR Appendix E, and the SCP repository conceptual design report. Further, the members will be cognizant of recent NRC interactions on ESF related issues as well as other historical YMPO reports such as the Design Acceptability Analysis, YMPO White Paper on Drifting and Construction Methods, NNWSI ES Site and Construction Method Recommendation Report (Bertram), etc.

The evaluation will be performed using the following assumptions:

- Two 12ft. inside diameter shafts will be available during drifting as currently planned .
- When drifting commences, the two shafts will have been connected.
- Cross section and size of drifts for extended phase will remain the same as currently planned drifts (14'W x 14'H) to the geologic features.
- Construction methods for extended drifting portion will be the same as for currently planned drifting.
- Repository design will be as currently conceived in the SCP-CDR.
- Testing currently proposed to be conducted in the planned geologic drifts would be extended to include any additional drifting.
- Consideration of TRB's views contained in the latest full transcript of DOE/TRB meeting of 4/11-12/89.

The draft report shall be completed by June 2, 1989. The final report, due to HQ by June 16, 1989, will be approximately 50 pages long and, additionally, will contain appropriate appendices. The report will require acceptance by the DOE/OFSD Associate Director.

4. PLAN BASIS:

4.1 ORGANIZATION:

WESTON will be responsible for the evaluation and preparation of the report on expanded drifting. The WESTON evaluation team will be headed by P. Kumar and will consist of the following members:

P. Kumar, UG Facility (WESTON-Lead)
J. Montgomery , UG Facility (Tech. Lead)
D. Fenster, Geoscience
W. Haslebacher, (Support to DOE Tech. Lead)
L. Rickertsen, Perf. Assessment
D. Michlewicz, Preclosure Safety
H. Bermanis, Licensing
J. Saliunas, Scheduling*
F. Bugg, Cost*

*As Needed.

During the evaluation process, interactions with the DOE-HQ and YMPO personnel will be required on an "as needed" (minimum weekly) basis. The following key personnel from HQ and PO are identified for such interactions:

R. Lahoti, OFSD-UFB (HQ Lead)
S. Brocoum, OFSD-SGB
J. Hyde, OFSD-UFB
D. Stucker, OFSD-SGB (HQ Tech. Lead)
J. Kimball, OFSD-SGB
D. Alexander, OSIR
J. Robson, YMPO (PO Lead)
A. Girdley (PO)

M. Cline will act as the coordinator with the contractor for concurrent alternative shaft construction evaluation activity.

4.2 SCHEDULE:

The schedule proposed for the evaluation of the NWTRB recommendations and completion of the report is as follows:

Key Milestone	Start Date	Completion Date
HQ Approves Action Plan	4/26/89	5/2/89
WESTON Kick-off Meeting	5/8/89	
Report Outline	5/8/89	5/10/89
HQ Approves Report Outline		5/12/89
Evaluation of Excerise	5/8/89	5/22/89
Report Preparation (Draft)	5/15/89	6/2/89
Review of Draft Report	Week of	6/5/89
Final Report to HQ/PO		6/16/89
HQ Accepts Report		6/20/89
Attend TRB Meeting	Week of	6/26/89

A status report will be provided to D. Stucker (Technical Lead), and to R. Lahoti, Branch Chief, UFB, each Monday at the UFB-WESTON weekly meeting.

APPENDIX B

SELECTED EXCERPTS FROM APRIL 12, 1989 DOE/NWTRB MEETING TRANSCRIPTS

Page 281-285: North, Blanchard on NRC Point Paper Comment 100

North concerning DOE response to Comment 100; additional drifting during construction

Dr. North: Now, I interpret this to mean that you don't want to do it as part of the process up through the license application, but rather after that, in the early stages of construction. Which means this information wouldn't be available at the time of the license application, and you know, some uncertainties that we might have resolved at that point won't be resolved until later, where they perhaps would affect not only the performance of the repository, but also the potential size of the repository.

Page 286: Dr. North, M. Blanchard on flexibility for additional drifting

M. Blanchard: . . . Another 5,000 feet of drifting could probably be accommodated. But a sixfold increase couldn't be accommodated with the current engineering design. It's flat out not possible.

Dr. North: What about with total (sic) boring machines?

M. Blanchard: I can't answer that question. Our engineering staff, I think, should answer that question.

Page 292: Cording, Deere, Voegele on geologic boundaries of repository

Cording: Briefly, could you just show approximately where the perimeter drift is located on that?

Voegele: It basically falls in this area. ...

Deere: Round those corners a little so the TBN (sic) can get at it.

Voegele: Joe is actually willing to discuss that.

Page 305: Deere, Voegele, Wilson on drilling program

Deere: Do any of the borings that have been laid out or have been done at the moment cross diagonally the Ghost Dance Fault?

Voegele: Not at the present time. I believe there's a program of two boreholes, one on either side of the Ghost Dance Fault, to try to do some communications experiments.

Wilson: And one of them will cross the fault.

Page 311: Deere, Voegele on ground support investigations

Voegele: There are questions related to whether or not you could drift through a fault like the Ghost Dance Fault and not have stability problems.

Deere: Well, we know you can do it, no problem. The question is, is there water there? I mean the hydrologic thing is number one.

Deere: If we can't drift through it, it's because there is water there.

Page 312: Voegele on drifting to Solitario Canyon

Voegele: . . . it (the site characterization program) also contains flexibility such that as we begin to understand the site character a little better and find ourselves in a position where we may have to [do] additional drifting to look at structures like the Solitario Canyon or features to the south . . .

Page 316: Deere, Voegele on (fault zone) hydrology

Deere: . . . I just wonder if you have in the program sufficient exploration to get the information on that Ghost Dance Fault; it's right in the center of everything. And all of the sketches where we see scenarios showing perched water and we have the ten-degree depths and then we have the Ghost Dance Fault. So it can dam it up, and it can also allow it to percolate down. So it's both a dam and a drain. And I don't think we can -- I'm not sure you have enough exploration at present for a stage program to intersect that in enough places to be able to/characterize it. And it's certainly going to influence Bill's model terrifically, I would think, one way or another.

Pages 317-319: Deere, Voegele on Ghost Dance Fault drifting

Deere: I think the danger you would run into with a limited amount of exploration on the Ghost Dance Fault is that if the boreholes give fairly good information and indicates that's an impermeable fault and will not have much effect, we will be basing our decision on only two points. Only going to cross two places. And it's such a horrendous feature with respect to a crosscutting structure, as compared to the rest of the site inside of the boundary zone, as we know it. I mean, you might say it is a boundary in itself, and maybe we should be on the two sides of it, rather than having cut through. So it seems before you can make information as needing more information, you have to get more information. I would think that's one point you could accelerate the amount of drilling. And concentrate a little bit more on that because I see it as a potential dominant character on the studies that you made.

Voegele: . . . The current plan for the repository conceptual design actually is predicated upon being able to develop that repository and stand off from features like that if they turn out to be hydraulic conduits. So the comment that maybe we should be on either side of the fault is something that's currently planned. I believe the repository design has sufficient flexibility to avoid features like that if they are adverse.

Deere: I think that's very good.

North: Could you give us maybe a couple sentences as to what that plan might look like? Would you avoid the fault entirely by putting essentially two repositories on either side of it? Or would you go entirely on one side or the other? Or would you drill one tunnel underground through the fault and protect it in a certain way?

Voegele: All of those are options that would have to be pursued. I believe the current thinking leans more heavily toward the fact that the Ghost Dance Fault will not be a major barrier to the development of our repository.

North: One of my questions is if you find out it is a major barrier, when are you going to find that out, and what/is it going to mean in terms of time and money to fix it?

Page 320-321: Cording on exploring for vertical structures

Cording: Your exploration program, as was being pointed out, I think, in terms of the vertical holes, obviously you're looking more at stratigraphy than you are not by doing sampling to any significant extent of unknown faults. You may sample across a known fault, but you're not doing sampling of unknown near vertical structures. You have a primary area there with nothing through it to sample those types of structures. The possibility of offshoots from Solitario Canyon or Ghost Dance or other features in there which you cannot detect from surface mapping seems to me to be high, and therefore, is there -- shouldn't there be some sort of program for going across at least normal to those primary directions of primary structures, regional structures? Principally, a north, northeast, northwest sorts of structures, across the entire site? In other words, once you've gone across the Ghost Dance and looked at it and then you've decided that that is or is not a problem, what do you know about that primary area? It still remains an unknown.

Page 322-324: Allen, Voegele, Sinnock, Cording on characterizing repository block

Allen: But isn't it true that if the characterization plan goes through as now envisioned, we really won't know anything more about the primary area than we know right now, except we'll have some vertical holes through it that won't tell us anything or very little about faults.

Voegele: From the perspective of having obtained horizontal information from a horizontal sample of that feature.

Allen: Well, insofar as faults are obviously perhaps the major concern in terms of anomalies, we may not know more about it than we know now.

Sinnock: (responds defending drilling program, discussion turns to prototype slant hole in Solitario Canyon)

Cording: Really, your slant holes are not -- I would assume that you're not going to be able to cover the entire profile using slant holes at locations of known or suspected/faults. You're not doing that to explore for unknown ones; is that correct?

Voegele: That's correct. (cites 10 CFR 60.15; limiting penetrations and integration with repository)

Page 327-328: Allen, Cording on contingencies for expanded drifting

Allen: I guess I would argue that no matter how good our geological program is up to date -- and I have no reason to be critical of[f] it -- I guess, based on experience, we are going to have surprises. And somehow we have to be prepared to not be too surprised.

Cording: You say well, it is possible that we can extend the drifts at some later time, and although I'm not sure anywhere in your documentation you have an indication that we would, for example here is a contingency. We will drive across the site if we see such-and-such conditions. so at this point it remains sort of a generalized --

(discussion turns to capability to support 10,000 feet of additional drifting)

Page 330: Voegele, Deere on additional drifting

Voegele: If it turned out that it was more important or more productive or more highly warranted to drift to Solitario Canyon to get information, as Dr. Cording was suggesting, I believe that could be supported by the facility.

Deere: You can see one potential, and that's the drift that goes to the northeast is to extend that on down to the southwest. You get yourself a second look at the Ghost Dance.

Pages 345-346: Tillerson, Deere on use of TBMs for perimeter drifting during repository construction

Tillerson:
. . . So the perimeter drift would be developed on a piecemeal type of basis, according to the design that's published in the SCP.

Deere: Would you run by that again for me, please? The two TBN's (sic) are coming in from the ramps, they are now available. One would continue down through the central/drift?

Tillerson:
Go through.

Deere: And it would go all the way through?

Tillerson:
That's correct.

Deere: The other would be on a standby basis?

Tillerson:
The others would be used to develop for this particular region here in the early development, and then on a stand by basis, being used periodically to develop the perimeter drift.

Page 367: Deere on need for stratigraphic control before perimeter drifting

Deere: Well, I think that's pretty persuasive there, that an early drift could not or should not precede your stratigraphic boreholes that you have laid out now. Because the stratigraphic boreholes and position of those contacts are going to affect your repository greatly.

Page 382-383: Cording on repository development to the west and repository orientation

Cording: When in the program would you first drive across, say in an east/west direction fully across the site in what was described in one figure as the primary area? You talk about driving the perimeter drift and driving the mains. When do you, in the plan at present, when do you first drive east/west across the full site?

Tillerson:
The first time you would have in the current plan east/west across the whole site is when you would begin to develop these panels in this area. So obviously you could develop . . . you could, if you wanted to, modify your sensitivity to develop one or several of those early in the development. . . .

Cording: If you decide to change the orientation of the mains, that would be done during your preliminary or your exploration phase in the vicinity of the northeast corner, and the drifts that you had planned that extend out to the Ghost Dance; is that correct?

Page 385: Deere, Tillerson on reorienting/redesigning the repository based on results of investigating the major faults

Deere: And we're talking about something that would mean a major change; that is the structural features and whether it's water bearing or potentially can be water carrying if the climate were to change or we have perched water tables that can drain into it. Really something that is a very great restraint if it has certain adverse characteristics.

Tillerson:
Yes. It's that type of thoughts that have led us in the exploratory shaft program. I believe the proposal is to drill in front of the development into those areas, the drill hole wash structure to see if it has large amounts of water. Then the question is do you really want to physically complete your drift all the way in through.

Page 388-389: Deere on second drift to Ghost Dance along the tuff main

Deere: It would seem to me like the minimum you would want to do with those drifts would be to extend where you turn and go out to the left. Is to come right on down the main drift until you cross the Ghost Dance a second time. . . . Now I think you are really looking at what I consider a key structural question.

Page 390: Cording on drifting to the west

Cording: It seems to me that there's also advantages and you're not just searching -- you're searching to try to find what other conditions across the site. If you don't find faults across the site, that's wonderful. Or if you find minor features.

A lot of what you have at the point before you drift across are interpretations based on surface mapping, and based on, again, interpretations from vertical boreholes and offsets, which is not a direct indication but an interpretation of the possibility of faults.

And if one goes across this site, you actually get down there and see what the conditions are, and you have essentially proven across that zone what some of the anticipated conditions are based on interpretations. It's specific site information that you won't have with the present plan until you are actually drifting out with your emplacement, to get ready to emplace waste.

Page 394-395: Cording, Allen on drifting to the west including the Ghost Dance

Cording: I think that also brings up a point that when you get down and drive across these things, then you have a chance to physically test the ground. I know there are other levels you're concerned about in terms of the flow of water. But you physically test across your site and check out the things which are basically hypothesis at that level, in the facility. This is hypothesis now, and a lot of it will remain hypothesis until you've actually drifted across.

Allen: Also, the photograph we were shown in Washington had a very clear lineation on it. It demanded some sort of geologic explanation.

Page 404-407: Deere, North, Cording on additional exploratory drifting

Deere: Therefore, it comes down to the fourth one: Improved data base could indicate need for additional exploratory drifting -- as you have already discussed -- (perhaps coincident with mains, drifts, perimeter drifts) or indicate viability of perimeter drift.

Well, I think that this is a conclusion that I would imagine we would be able to agree to. That we do need the information to get a better data base which will be coming from your planned drilling program, before one could look at this in greater detail.

North: I'd like to reinforce that. It seems to me the implication of point four is the need for detailed contingency plans, as to how the additional exploratory drifting might be done, given all the logistical issues, and given the information needs and site characterization.

In other words, pull it all together. What information in the improved data base is going to take you in what direction? And then given that direction, how do you propose to take action as a consequence.

Deere: I think another point is we need an improved data base to be able to proceed with repository design. If the fault, the Ghost Dance has a displacement of ten feet at one end and 150 feet farther down, as Scott mentioned, this has to be verified early with your boring program to see where that takes place. Otherwise I can see our horizon, our target horizon being 150 feet apart on one side of drift with respect to the other. Do we have 150 feet of room to play with in our restraints between the lithophysae and the/vitrophyre?

So the offset is fairly important, otherwise it's very difficult to make a design at the present time; not only for the perimeter drift, for all of the drifts. So I think we should relook real fast at your boring sequence, as you have already suggested you think you should.

Cording: I think one other point is that in looking at the improved data base, regardless of what that data base shows, there may be an indication here that one should expand exploratory drifting, that one could make that decision even at an earlier stage.

You've made a decision to go so far. The decision could be made to go further or less, even at this point. And it seems to me that in looking at the possible ranges of results that you will get from the surface drilling, one could still conclude that, regardless of what the conclusions are, we will need to do more drifting, even in certain specific directions. Or at least we will need to definitely use so many more feet of drift in one or two possible directions; something that, in other words is not just a contingency later on, but building even in at this point that we're going to do something more.

Cording: And building confidence in what is across, for example, the full width of the site. In terms of an east/west direction where most of the major structures pass. Or would pass if they're there.

Page 414-417: Deere summarizing

Deere: (dismisses perimeter drift suggestion) . . . We also like your number four bullet, which stated that as a data base is established with a drilling program that you now have laid out, you will always reevaluate the information and see the desirability if increasing the lengths of some of your exploratory drifts, or the viability of a perimeter drift at that time. Again, we are very much in agreement with that. (discusses "hinged" nature of Ghost Dance fault) . . . So we might not get a representative look at that fault by borings, or by our drifts as currently laid out, near the north end.

Deere: . . . Then we come to your conclusion, and again are in agreement with the conclusions on your last slide, with a minor modification. I will quote that last sentence: "Information from the site characterization program will help define the repository boundaries, and may/warrant additional drifting, perhaps a perimeter drift at a future date." Our change would be to have the "may" become "will" because we definitely feel that your information will warrant additional drifting, and perhaps a perimeter drift at a future date. . . . we think it would be prudent right now to increase your drift lengths at this stage and not leave them as contingency things. You[r] still may have a contingency that will require additional drifting. But at least we will hit the Ghost Dance Fault in two places, and one farther to the south where the offset is greater. It's still not very far south, but it's in the right direction. And that, together with the borehole information, may suffice to characterize it. We also feel you do need a perimeter drift across the site to the west. If that --

Gertz: Not perimeter, exploratory drift.

Deere: Exploratory drift. Excuse me. -- across the site to the west to prove that you have no important cross north/south striking, more or less, or northwest/southeast structure cutting through the main area of your future repository site.

APPENDIX C

MINING CONSIDERATIONS

C. Mining Considerations

Excavation of underground openings in the ESF will meet the requirements of Appendix E of the Generic Requirements for a Mined Geologic Disposal System (GR) which specifies requirements and criteria for ESF design, construction, and operations based on 10 CFR Part 60, mining regulations (Mine Safety and Health Administration, 30 CFR Part 57), DOE Orders, and other programmatic documents. These requirements flow down into the site specific requirements documents such as Systems Requirements (SR) and the Subsystem Design Requirements Document (SDRD). The underground openings will be excavated in such a way as to meet the overall performance requirements of the repository since they are expected to become part of the geologic repository operations area. Additionally, health and safety of the workers is given utmost importance in the mining process by assuring proper ground support, ventilation, and safety training. The exploratory drifts provide access to the geologic features, and during the mining of these drifts, characterization of the exposed rock faces will continue (geologic mapping, sampling, and construction records maintenance). Therefore, the emphasis during this exploratory drifting will be on characterization and testing rather than establishing a fast mining cycle. Thus, this operation should be looked at as mainly testing oriented and not as production oriented.

C.1 Planned Mining Method

This section briefly describes the currently planned mining method for ESF excavations and also summarizes an alternative method of construction by using tunnel boring machines (TBM).

Section 8.4.2.3.4.4 of the SCP describes in detail the ESF construction plans. As currently planned, the exploratory drifts to the geologic features will be excavated by conventional drill-blast-muck methods using controlled drilling and blasting techniques. This method consists of drilling a series of small diameter bore holes in the drift face, loading the holes with suitable explosives, and timing the charges in the holes to produce a sequential, controlled blast which will provide optimum blasting performance and a relatively smooth wall. The broken rock will be loaded and transported to the shaft loading pocket (surge pocket excavated below the shaft station) for hoisting to the surface. Depending on the ground conditions, the drift walls and the roof will be suitably supported by using rockbolts, wire mesh, or shotcrete either individually or in combination. Utilities (such as ventilation ducting, compressed air, water, power lines, etc.) will be extended as the exploratory drift progresses. Measures will be taken to limit water usage during the drilling cycle.

As seen from the above description, the conventional drill-blast-muck method is an intermittent operation. The facilities provided in the ES-2 for muck handling are adequate to support such operations in terms of capacity and hoisting speeds. Also, the operation allows for characterization tests and mapping to proceed to the extent desired as the drifts advance. This method offers greater flexibility in reacting to site conditions quickly (for example, making turns if necessary in order to excavate short side drifts). Approximately 5,600 ft of long exploratory drifts are needed per current plans. The alternative drifting plans described elsewhere may add up to approximately 6,000 ft of additional drifting depending on the alternative selected. Such lengths are well within the limits of conventional excavation methods.

As the conventionally mined drifts are advanced, probe holes will be drilled ahead of each drill face to a minimum depth of twice the depth of the drill round in areas where faulting or disturbed zones are expected. These probe holes will help to identify adverse ground conditions ahead of the face, and the current mining plans include the flexibility to adapt ground control techniques and support components to a wide range of conditions to ensure long-term drift stability. This advanced information may not be available if other mechanical mining techniques such as TBMs were used.

C.2 Tunnel Boring Machines

Unlike the intermittent operation of the conventional drill-blast-muck method of drifting, the TBM is a continuous mining machine. In this method, the material at the drift face is removed by the continuous rotation of a series of cutting tools mounted on a circular cutting head. The cutting tools are mounted and arranged on the cutting head such that a drift of the required size (diameter) can be excavated when the head is rotated under thrust against the working face. The TBM incorporates tools for breaking up the excavated material into sizes that can easily be removed. Muck is conveyed to the back of the tunneling machine where it discharges into another transportation system, usually entirely independent of the TBM, for removal from the drift. The advance rates are better than those for the conventional mining method, and they also have good alignment controls (laser guided) to provide accurate drilling. Unlike the conventional drill-blast method, disturbance to the rock mass is minimal. These machines require approximately 300 foot radius curves to turn from one direction to another. However, newer designs may be available which could negotiate 30 foot radius turns.

TBMs come in a variety of sizes to suit individual needs. They are very massive steel structures weighing over 200 tons. The three largest sections (main beam, cutting head, and support member) weigh from 20 tons to 37 tons each. The main beam is about 30 feet long, and would require special consideration in the design of the shaft station at the Main Test Level. The drive motors are electric, and the four motors driving the cutting head could require a total of 900 horse-power. This would require a significantly larger power supply than that needed for conventional mining equipment. All of the above requirements would add to the impacts on shaft design, necessitating a larger hoisting compartment and higher lifting capacities.

Current safety/health regulations require that dust levels in the underground atmosphere be kept low. With TBMs, the dust is confined to the face by a dust shield. From there, it is conducted by vacuum to a dust collector and the exhaust air is then released into the exhaust fan line. In practice, however, some wetting of the face during drilling may be required to prevent excessive dust generation. Such wetting may use approximately 5-10 gallons per minute (GPM) of water while the TBM is cutting, depending upon the size of the drift. However, much of this water is immediately removed by the TBM with the muck. Constrastingly, typical water requirements for conventional drill-blast-muck methods are approximately 3-5 GPM per drill machine, plus about 10 GPM for some period following each blast to suppress dust. Further, unless water usage is limited and/or special measures are taken to collect drill water, some of the water employed in conventional mining methods may potentially become available to enter exposed fractures in the rock. Thus, in contrast to the TBM method, conventional mining methods could employ more water, some of which could potentially be introduced into the adjacent rock. However, analysis (SCP 8.4.3) has shown that the small amounts of water which could be introduced into the formation, as reduced by water vapor removed by the ventilation system, would cause no significant change in the ambient saturation distribution in the unsaturated zone.

It has been shown that the TBMs reach their economic limit when boring in hard rock of 25,000 pounds per square inch (psi) compressive strength due to the reduced performance of cutters as the rock strength increases. Topopah Spring Tuff is expected to have a compressive strength varying from 17,000 to 26,000 psi. Another factor that affects cutter life is the abrasiveness of rock formation. Because of these site conditions which will limit the fully effective use of a TBM, a cost comparison between conventional and TBM methods has shown that only beyond 7,000 ft does the TBM show slightly less cost than the conventional method.

Most TBMs perform well as long as they penetrate uniform ground conditions. If unstable ground is encountered, this may cause severe operating problems. Most TBMs will effectively block access to the face when alternative excavating methods must be performed in order to penetrate variable ground conditions such as might be encountered when passing through a fault zone. This would be considered a major disadvantage during ESF characterization activities.

The current conceptual repository design calls for the use of TBMs for excavating long repository drifts (such as perimeter drifts, mains, etc.) Sizes of such repository drifts are much larger than the planned ESF exploratory drifts and will produce more muck per foot of advance, therefore, efficient muck handling is a very important aspect of TBM operation. During repository development the TBM system will have a permanent conveying system in the tuff main and tuff ramp to support muck handling. However in the ESF, such a system is not available and the shaft hoisting system, which is an intermittent system, is not considered adequate to support the increased muck output from a TBM, unless the advance rate of the TBM were to be modified to suit the capacity of the hoisting system. Such a change would reduce the economic and schedule advantages attributable to a TBM operation.

If a TBM were to be utilized during the exploratory drifting phase of site characterization, it could have the following impacts on the ESF layout or plans:

(1) An initial area approximately 200 ft. long would need to be excavated (probably by drill-blast methods) for a starter room to setup the TBM and necessary ancilliary equipment. This room would also need to have an area about 40 ft. long with extra height and width to accommodate assembly of the TBM components.

(2) Drift intersections would need to be redesigned to allow the TBM to be moved from one heading to another without complete disassembly and reassembly. If only one heading is planned for the TBM, this would not be necessary.

(3) Mucking capacity at the ES-2 shaft would be impacted to a certain extent. Assuming a fairly slow advance rate for a 14 ft. diameter TBM of 30 ft. per day on two shifts, an advance rate, while cutting, of 5 ft. per hour would result in approximately 50 tons per hour of broken rock produced. This would reduce the available handling capacity for other development in ES-2 about 40%. As long as ES-1 is available for hoisting men, this may not be an excessive impact. However, ES-1 is currently planned for exclusive use by the testers.

(4) Muck haulage back to the shaft from the TBM may be accomplished by using three, 10 ton trucks. This would have a significant impact on the traffic in the drifts, and would also require mining widened sections in the drifts for turning, passing, etc., using drill-blast techniques. However, since this haulage could be constrained to two shifts per day, the third shift could be utilized by geologic crews and drift maintenance.

(5) Dust control and ventilation would probably be impacted to a greater extent with the TBM than with the drill and blast operations, since the dust generation would be greater over an extended period.

(6) The ES-2 shaft has only a 5 ft. x 5 ft. open area to lower equipment. This would require breaking down the TBM in small pieces and would present problems in the reassembly process underground.

(7) Drill hole G-4 near the ESF location indicates that fracture densities are high in the welded tuff section which is targeted as the repository horizon. The USGS Open File Report 84-789, 1984, indicates that G-4 identifies the fracture density to be $34/m^3$ in the welded tuff. Such fractured rock is likely to cause oversize rock fragments to jam the TBM muck removal system, thereby increasing downtime and reducing production rates. Assuming that G-4 is typical of the average rock conditions in the ESF, drifting with a TBM would be more difficult than with the conventional method of excavation.

(8) With the varied conditions noted above, it is difficult to predict what the advance rate with a TBM might be. The drill and blast method would provide relatively more flexibility in handling these varying conditions.

C.3 General Specifications of Facilities to Support Underground Drifting (YMP, 1988)

- Two 12 ft. diameter, concrete lined shafts, ES-1 Testing shaft, ES-2 men, materials, and muck handling shaft;
- ES-2 hoist capable of hoisting a double deck man cage, 17 men per deck, over a 10 ton skip at 2,000 ft per min.;
- Main test level (MTL) 1,050 ft. below surface;
- During the development of the underground drifts and test rooms, three sets of mining equipment will be used, consisting of electric-hydraulic drill jumbos, 5 cy load-haul-dump muck transporters, and utility vehicles (all diesel powered);
- Ventilation is provided by fans pulling return air through exhaust ducting in both shafts and fresh air entering via the hoisting compartment;
- Total ventilation is approximately 200,000 cu. ft. per min. (CFM) which allows about 60,000 CFM for the combined Ghost Dance and Drill Hole Wash development area and 50,000 CFM for the drift to the imbricate fault area. Fresh air travels to the working face through the drift and returns to the shaft via an overhead duct;
- Dust control is effected by the use of mobile dust collectors which follow the mining operations;
- Underground shops and storage areas are very limited on the MTL, as shown on the Title I design layout. However, additions are expected during Title II design;

- Title I design shows development rock handling reaching a maximum of 800 tons per day (TPD) with an additional 35% of uncertainty allowance required for 1,100 TPD total. Hoisting capacity is 249 TPH but is reduced to 135 TPH with normal delays;

- Total number of underground personnel cannot exceed the maximum required by safety regulations. These state that the hoisting system must have the capability of hoisting all personnel to the surface in one hour; and

- Present planning shows 87 personnel underground, including development crews, testing personnel, and visitors.