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EVALUATION OF ALTERNATIVE ESF SHAFT CONSTRUCTION METHODS AND TEST SEQUENCES FOR YUCCA MOUNTAIN PROJECT OFFICE

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EXECUTIVE SUMMARY

The Structural Geology and Geoengineering Panel of the Nuclear Waste Technical Review Board (NWTRB panel) in their meeting of April 11-12, 1989, suggested the consideration of alternative methods of Exploratory Shaft Facility (ESF) shaft construction/test sequences in order to: (1) minimize site disturbance from a long-term repository performance standpoint; (2) improve test data quality; and (3) reduce the time required to access the Main Test Level (MTL). Therefore, a representative set of viable alternative construction methods/test sequences which embody the NWTRB panel's suggestions was identified and systematically evaluated with respect to a project-specific set of criteria. The scope of the study was focussed on specific construction methods and on the test strategies presented in the Site Characterization Plan (SCP).

The viable alternative ESF shaft construction methods and integrated testing sequences, as summarized in Table 1, included:

- Two methods for constructing the <u>first shaft</u>, i.e.

  Cases 0 (base case) through 4 - Conventionally (drill-and-blast) sink to full ESF size

  Cases 5 through 7 - Conventionally sink to small diameter, and then V-Mole to full ESF size

- Various methods for constructing the <u>second shaft</u>, i.e.

  Cases 0 (base case) and 1 - Conventionally sink to full ESF size

  Cases 2 and 5 - Raise bore to full ESF size

  Cases 3 and 6 - Raise bore to small diameter, and then V-Mole to full ESF size

  Cases 4 and 7 - Conventionally sink to small diameter, and then V-Mole to full ESF size

- Various <u>test sequences</u>, i.e.

  Case 0 (base case) - All testing conducted in-line with construction.

  Case a - All testing conducted in-line with construction, except for the thermomechanical testing conducted in the Upper Demonstration Breakout Room (UDBR) and specific hydrologic testing to be performed in the long radial boreholes.

Case b - All testing conducted in-line with construction, except for the thermomechanical testing conducted in the UDBR and all testing associated with the short and long radial boreholes.

Although not treated separately, a variation on the above major cases was also considered. This variation consisted of relocating the UDBR and associated testing out of the shaft to an area of similar rock type accessed from the MTL. The associated transient mechanical/hydrological effects testing (i.e., Excavation Effects Test) could be accommodated at this alternative location in various ways (e.g., in a horizontal mode or in a trial shaft section).

The criteria used to evaluate the alternatives were:

- Test Data Quality - The extent to which the testing strategy, and thus the relevant information needs, as identified in the SCP, can be accommodated, specifically considering access to test locations, possible disturbance/contamination, and the ability to observe transient conditions (including construction effects). This was based on an explicit evaluation of the currently planned test program with respect to possible deferral/delay, relocation, modification or elimination of each proposed test.

- Shaft Constructability - The likelihood that the shafts can be successfully constructed and operated, specifically considering whether or not the technology has been demonstrated, the adaptability of the method to unexpected conditions, and shaft verticality.

- Health and Safety - The potential hazards to workers associated with constructing and operating (including testing) the shafts.

- Schedule - The length of time from the initiation of shaft sinking until the MTL is available for development and full-scale testing, which requires both shafts to be completed and connected, one shaft to be lined and equipped for muck handling, and the other shaft to be equipped at least with an emergency hoist. It should be noted that, although limited access to the MTL (e.g., to look for a fatal flaw in the relatively limited excavations in and between the two exploratory shafts) may require less time, MTL availability is considered to be the more important criterion.

- Cost - The costs associated with construction of the shafts, including construction crew standby during in-line testing but not including other testing costs.

Other criteria were considered but assessed to be non-differentiating with respect to the various alternatives evaluated:

- Long-term repository performance - It is the DOE's position (based on analyses) that the effect of excavation-induced disturbance on long-term performance is not expected to be significant if all due care is exercised to reduce such disturbance to the extent possible. Regardless, the ESF shafts cannot be considered in isolation from the other repository shafts, which are currently planned to be conventionally sunk.

- ESF efficiency/repository integration - Once the MTL is available, all of the alternative construction methods/test sequences are essentially identical with respect to developing and operating the ESF and ultimately the repository.

- Environmental effects - The differences among the various alternative construction methods/test sequences with respect to environmental effects (i.e., dust, noise, air/water quality, etc.) are considered to be very small.

Each of the alternative construction methods/test sequences was evaluated with respect to the above set of criteria. First, the acceptability of each method with respect to each criterion was evaluated. All of the alternatives were considered to be acceptable since those which were not acceptable were screened out initially when the viable alternatives were being identified for evaluation. The various acceptable alternatives were then evaluated and compared with respect to satisfying each criterion independently on a relative, rather than an absolute basis. In some cases (i.e., cost and schedule), the comparisons were expressed quantitatively, whereas in other cases (i.e. test data quality, constructability, and health and safety) the comparisons were stated in qualitative terms (i.e., best, good, and satisfactory). Due to schedule requirements, these evaluations were largely subjective, based on readily available information and on the authors' expertise.

As summarized in Table 2, the results of the evaluations are:

- <u>Test Data Quality</u> - Based on the evaluations contained in this report, all construction methods/testing sequences considered in this study are capable of satisfying the testing requirements within the exploratory shafts. The most significant discriminator among the methods is related to the timing of the performance of the Radial Borehole Tests and the ability to obtain transient data (including construction effects monitoring) from these tests concurrent with shaft sinking. The test sequence "b" options (Table 1) which delay these tests until following completion of shaft sinking are therefore rated lower than test sequence "a" options in terms of the data quality criterion. In addition, the option which employs the drill-and-blast/V-Mole method of construction for the second shaft is rated best because it offers timely access for mapping of the shaft walls constructed by two different mining methods, relatively undisturbed/uncontaminated immediate shaft walls, and the capacity for evaluating perched water conditions in both of the exploratory shafts.

- Shaft Constructability - All construction methods evaluated are considered technically feasible for the anticipated geotechnical and groundwater conditions at the site. The Single-Pass Raise Bore option is rated lowest of the various methods, because of uncertainties related to the stability of the shaft walls in specific horizons and the inability of the raise bore method to install support in a timely manner, lack of versatility of the method in accommodating unanticipated ground conditions, and difficulties associated with ensuring shaft verticality. By contrast, conventional drill-and-blast construction (including when used in conjunction with V-Moling) is well suited to addressing the above concerns and is therefore rated best from a constructability viewpoint. The hybrid Raise Bore/V-Mole method of construction is rated intermediate for the constructability criterion. The individual assessments were combined in order to assess the rating of each combination of methods. The test sequence has little impact on constructability.

- Health and Safety - Conventional drill-and-blast shaft construction is rated as satisfactory but lowest of the construction techniques considered because of the requirement for virtually continuous manpower presence at the shaft bottom under relatively adverse conditions (heat, humidity, dust, exposure to rockfall), frequent transport of men within the 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 V-Moling ranked slightly lower. The individual assessments were combined in order to assess the rating of each combination of methods. The test sequence has little impact on health and safety.

- Schedule - For comparable testing sequences, conventional sinking of the second shaft results in substantially shorter elapsed time between the start of shaft sinking and the availability of the MTL for development and testing (typically 70 to 75 percent of the time required for the methods which include a mechanically mined shaft), primarily because the shafts can be constructed in parallel rather than sequentially and the shaft connection is not on the critical path. For a comparable testing sequence and method of construction of the second shaft, conventional construction of the first shaft to full ESF shaft size results in the MTL being available for development and testing in a significantly shorter time period (typically 80 percent) than can be achieved by conventionally sinking the first shaft to a small diameter and subsequently reaming to full size, primarily because there is little difference in advance rates between the lined full-size shaft and the unlined pilot shaft. Compared to the current base case (conventional shaft construction with in-line testing), delaying all in-line testing for which transient data is not considered to be an issue results in schedule savings of up to 25 percent. If the Radial Borehole Tests could be delayed until the completion of shaft sinking, the current base case schedule can be almost halved. Further significant schedule savings could be achieved if an alternative location for the UDBR and associated testing (e.g., accessible by ramp from the main test level) can be found or if lining the scientific shaft can be delayed.

- 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 options which include the use of a V-Mole (because of the high capital cost associated with this equipment). Lowest estimated costs are associated with conventional shaft construction and with raise boring, with delayed testing where appropriate. The Raise Bore option is estimated to be of slightly lower cost than conventional sinking of both shafts because of manpower savings associated with raise boring.

If one construction method/testing sequence were to be rated best with respect to satisfying all of the criteria or if one criterion were to dominate all of the others, the best overall construction method/testing sequence alternative would be self-evident. Otherwise, tradeoffs must be made among the attributes addressed by the criteria. Such tradeoffs should consider the relative importance of the various criteria, as well as the differences among the alternatives with respect to satisfying each criterion. Although this study provides the technical input necessary for such tradeoff analyses, the determination of the relative importance of the various criteria was outside the scope of this study.

Hence, with respect to the NWTRB panel's suggestions regarding alternative ESF shaft construction methods/test sequences:

- Substantial schedule and cost benefits, and marginal health and safety benefits, can be achieved by alternative sequencing and possibly relocating specific aspects of the test program, without a significant adverse impact on test data quality.

- Although mechanical excavation of the second shaft offers benefits with regard to improving test data quality and health and safety, it has a significant schedule penalty due to sequential (rather than parallel) development with the first shaft.

- Subsequent reaming of a conventionally sunk small diameter first shaft offers no significant benefit in terms of early limited access to the MTL or in terms of test data quality, and instead results in increased costs and a schedule delay in terms of availability of the MTL for testing and development.

Based on the results of this study, it is recommended that:

- In light of their significant impact on the schedule, the following changes to the test program should be considered:

  - relocating the UDBR and the associated testing (including the Excavation Effects Test) out of the shaft, if a suitable rock type is available in the vicinity of the MTL.

  - delaying the Radial Borehole Tests until after shaft construction.

- The various alternatives should be reevaluated if the information needs/testing strategies or the criteria change (e.g., if the repository shaft construction method changes).

- The relative importance of the various criteria should be established so that tradeoffs among the criteria herein can be made and considered with other programmatic factors, and a collective evaluation of each of the alternatives can be performed.

Table 1. Alternative ESF Shaft Construction Methods/Testing Sequences (Page 1 of 2)

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
(5) Drill-and-Blast/V-Mole Shaft 1, Raise Bore Shaft 2			Case 5b
(6) Drill-and-Blast/V-Mole Shaft 1, Raise Bore/V-Mole Shaft 2			Case 6b
(7) Drill-and-Blast/V-Mole Shaft 1, Drill-and-Blast/V-Mole Shaft 2			Case 7b

Table 1. Alternative ESF Shaft Construction Methods/Testing Sequences (Page 2 of 2)

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 Borehole Tests until after shaft construction.

Table 2. Simple Ranking of Alternative ESF Shaft Construction Methods/ Testing Sequences with Respect to Each Criterion (Page 1 of 2)

a) Qualitative Criteria[a]

	TEST DATA QUALITY	CONSTRUCTABILITY	HEALTH AND SAFETY
Best 5b	Cases 3a, 4a*	Cases 0*, 1a*, 1b*, 4a, 4b, 7b	Cases 2a, 2b,
Good+	Cases 0*, 1a, 2a		
Good 6b	Cases 1b, 2b, 3b, 4b*, 5b, 6b, 6b, 7b*	Cases 3a, 3b, 6b	Cases 3a, 3b,
Satisfactory+ 1b,			Cases 0, 1a, 4a, 4b, 7b
Satisfactory		Cases 2a, 2b, 5b	

b) Quantitative Criteria[b]

SCHEDULE (Months)	COST (Million $)
Case 1b (13.5)	Case 2b (18.1)
Case 1a (18.7)	Case 1b (19.1)
Case 4b (19.5)	Case 2a (20.7)
Case 2b (22.0)	Case 3b (21.7)
Case 3b (24.0)	Case 1a (21.9)
Case 7b (25.8)	Case 5b (22.7)
Case 4a (26.3)	Case 3a (24.4)
Case 0 (26.4)	Case 4b (24.5)
Case 5b (26.7)	Case 6b (25.3)
Case 2a (27.3)	Case 0 (25.6)
Case 6b (28.7)	Case 4a (27.1)
Case 3a (29.2)	Case 7b (27.9)

Table 2. Simple Ranking of Alternative ESF Shaft Construction Methods/ Testing Sequences with Respect to Each Criterion (Page 2 of 2)

Note: See Tables 4-1 and 6-1 for a description and evaluation of each case, respectively.

[a] All of the cases were considered to be acceptable with respect to each of the above criteria. A "*" indicates a preference within a category, and thus additional detail in the ratings.

[b] Schedules and cost estimates are approximate and suitable for comparisons only; they are not intended to be accurate absolute estimates.

1.0 INTRODUCTION

1.1 PURPOSE/OBJECTIVES

The Structural Geology and Geoengineering Panel of the Nuclear Waste Technical Review Board (NWTRB panel) has suggested that construction methods and testing sequences other than those currently planned for the Yucca Mountain Project (YMP) Exploratory Shaft Facility (ESF) shafts might be preferred for various reasons and should thus be considered (TRB, 1989). Golder Associates Inc (GAI) was therefore directed to undertake a preliminary study in order to respond to the NWTRB panel's comments (DOE, 1989a and h).

The purpose of this study is to: (1) identify alternative ESF shaft construction methods, including integrated testing, which will accomplish the testing strategies and thereby satisfy the information needs identified in the Site Characterization Plan (SCP) (DOE, 1988a); and (2) systematically evaluate the alternatives technically with respect to a defined set of criteria.

1.2 SCOPE

The scope of this study is focussed on the identification and evaluation of alternative ESF shaft construction methods, with integrated testing, of the type suggested by the NWTRB panel. The following items are outside the scope of this study and have not been considered:

- Changes in the size, location, and final design of the ESF shafts. Access to the Main Test Level (MTL) at the proposed repository horizon by ramps and/or shafts of different sizes have been considered in previous studies (e.g., Beall, 1984).

- Changes in the design and construction of the MTL, as well as changes in the MTL test program.

- Changes in the design and method of construction of the repository.

The U.S. Department of Energy (DOE) has determined that the information needs and related test strategies identified in the SCP are appropriate, and that the test program proposed in the SCP is adequate to satisfy those information needs/test strategies. It should be noted that changes in the information needs or in the test strategy could affect the evaluation of the ESF shaft construction methods/test sequences. Although changes in the information needs/test strategy have not been considered, some flexibility in the shaft test program has been considered. For example, within the current test strategy, some testing might be delayed, deferred, relocated or modified while still providing the necessary information.

Each of the alternative ESF shaft construction methods/test sequences has been evaluated with respect to individual criteria, such as schedule, safety, quality of information, etc. These criteria have been identified by GAI, consistent with DOE's guidance (DOE, 1989a) and the NWTRB panel's comments (TRB, 1989). These evaluations are largely subjective, based on readily available information and on the authors' experience and judgement. Moreover, although this study provides the necessary technical input, the tradeoffs which must be made among various criteria in order to make a collective evaluation of each alternative with respect to the entire set of criteria, and to thus identify the best alternative overall, is outside the scope of this study.

1.3 IMPLEMENTATION

Golder Associates Inc. was initially directed (DOE, 1989a) to conduct a preliminary study in order to respond to the NWTRB panels's comments as quickly as possible. An implementation plan (Golder, 1989) was developed and approved, as presented in Appendix A. The study was then conducted according to this implementation plan. As described therein, the study consisted of five tasks:

- Task 1 - Review SCP Information Needs and Testing Requirements Relevant to the ESF Shafts
- Task 2 - Identify Alternative ESF Shaft Construction Methods/Test Sequences
- Task 3 - Develop Evaluation Methodology and Criteria
- Task 4 - Evaluate Alternatives with Respect to Criteria
- Task 5 - Management and Prepare Report

A draft report (dated June 22, 1989) was produced in accordance with the implementation plan and subsequent DOE review comments. Subsequently, the scope was expanded to explicitly consider additional alternative ESF shaft construction methods (DOE, 1989h). This final draft report is the result of that expanded study.

The results of Tasks 1 - 4 are presented in the following Sections 3 - 6, respectively. These results are preceded by a brief discussion of the relevant background to this study in Section 2, and followed by the conclusions and recommendations resulting from this study in Section 7. Additional supporting materials for this study are presented in appendices.

This study was conducted in accordance with a Quality Assurance Program Plan (QAPP), as presented in Appendix A. The QAPP meets or exceeds Quality Level III, as designated by DOE.

2.0 BACKGROUND

2.1 CURRENT ESF DESIGN CONCEPT

The current ESF design concept, as presented in the SCP (DOE, 1988a) and the Title I Design Report (DOE, 1988b) and as illustrated in Figure 2-1, consists of two 12 foot inside-diameter, concrete-lined shafts extending from the surface to the Main Test Level (MTL) at the repository horizon. Both shafts are to be sunk by conventional drill-and-blast methods, with the placement of the lining following a short distance behind excavation. All tests in the shafts, including those in the Upper Demonstration Breakout Room (UDBR), are to be conducted during excavation. The majority of the tests will be conducted in one shaft (i.e., the "scientific" shaft), whereas the other shaft (i.e., the "muck" shaft) would be reserved primarily for ESF construction and operations, such as hauling men, materials, and waste rock.

Initially, the ESF was to contain only one shaft. The decision to sink this shaft by conventional methods rather than by wet drilling was made in 1982 (Vieth, 1982). This decision was based primarily on the expected impact of water loss during drilling on site characterization and possibly on future repository performance, as well as other factors (Bertram, 1984).

Subsequently, a second access was added for safety, i.e., for emergency egress, and to allow for additional drifting at depth, i.e., for ventilation. Various options were considered for this second access, including various sized shafts and ramps (Beall, 1984). A raise bored second shaft, with a finished diameter of six feet, was initially selected. This was subsequently revised to make the second shaft 12 feet in diameter, sunk by conventional methods (Knight, 1987). Other methods of constructing the ESF shafts, including raise boring and shaft boring, have been evaluated to various degrees (Bullock, 1989; Irby, 1986).

In addition, non site-specific studies have previously evaluated a variety of methods for the construction of repository shafts in various rock types (Gonano et al, 1982).

2.2 NEED FOR EVALUATION

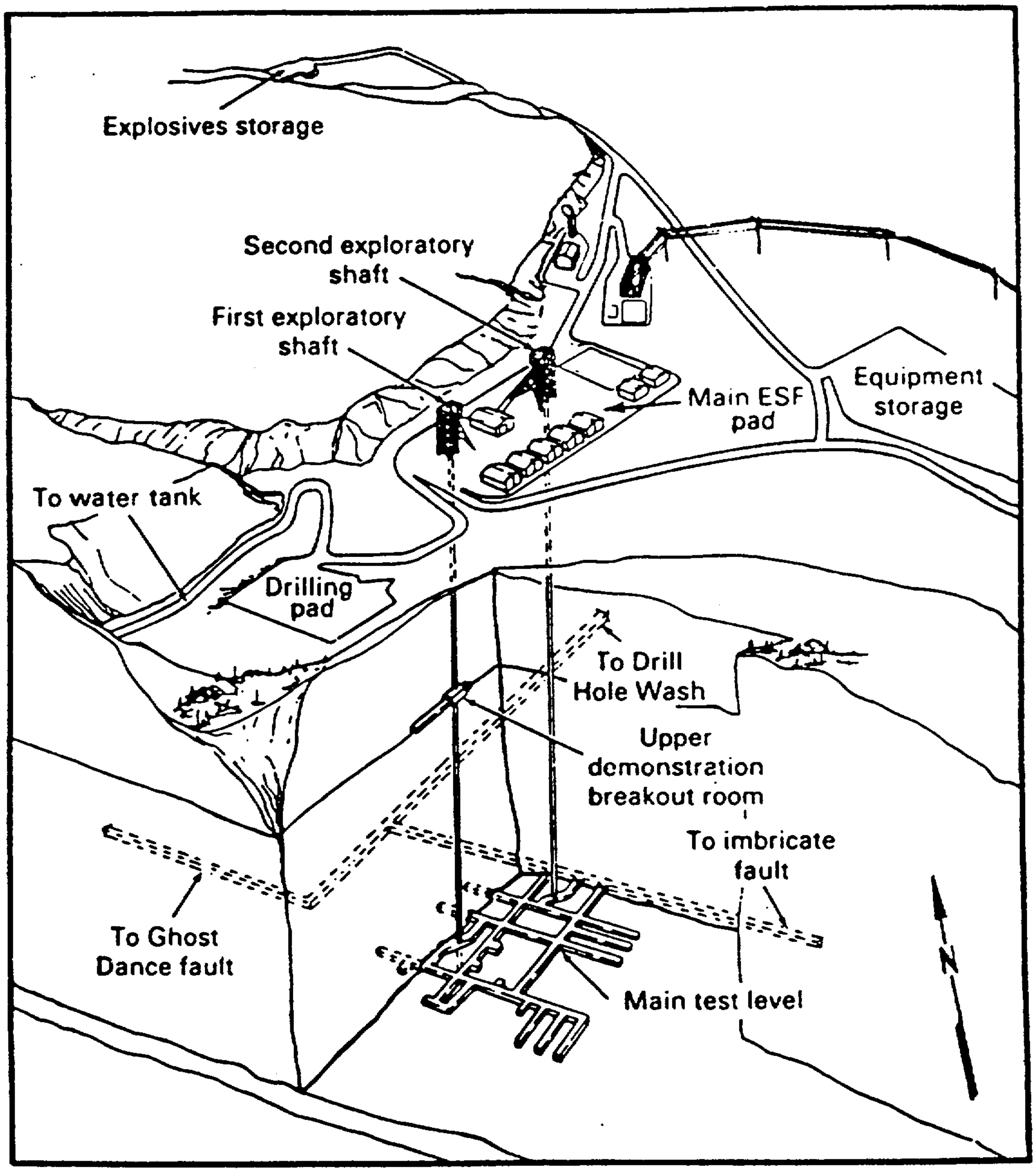
The NWTRB panel met with the DOE on April 11-12, 1989 in Las Vegas to review, among other things, the proposed ESF shaft construction methods. They expressed the following ideas (TRB, 1989):

- Site characterization could possibly be improved by
  - reducing blast-induced damage to the shaft wall
  - reducing contamination of samples taken from the immediate vicinity of the shaft due to construction water and blast gases

- The shaft construction schedule could possibly be shortened by
  - delaying some of the tests until after shaft construction is complete (rather than in-line with shaft construction)
  - using different construction methods
- Long-term repository performance could possibly be improved by reducing the disturbance associated with shaft construction.

In order to accomplish the above, several possible alternative methods for constructing the two ESF shafts (ES-1 and ES-2), including testing, were identified by the NWTRB panel for further consideration, including (TRB, 1989):

- For ES-1, either
  - conventionally sink to full ESF size
  - conventionally sink ES-1 to a small diameter (9-10 ft) and subsequently ream (e.g., V-Mole) to full ESF size
- For ES-2, either
  - conventionally sink to small diameter (9-10 ft) and then either raise bore (ream) or V-mole to full ESF size
  - raise bore to small diameter (6 ft) and then either raise bore (ream) or V-mole to full ESF size
  - raise bore to full ESF size in one pass.
- Delay some of the in-line tests and possibly relocate some of those to ES-2 after ES-1 and ES-2 have both been completed.



Current ESF Design Concept

Figure 2-1

Source: DOE, 1988a

3.0 REVIEW OF ESF REQUIREMENTS

3.1 INFORMATION NEEDS/TESTING REQUIREMENTS

The SCP (DOE, 1988a) identifies the information needs to be addressed by testing in the ESF shafts. The current test program for satisfying these information needs, as summarized in Table 3-1 and Figure 3-1, is to be conducted in-line with shaft construction. This test program was evaluated as part of Task 1, especially with respect to whether or not:

- The tests/activities are required in both shafts.
- The test results are affected by the construction method.
- The test/activity can be:
  - modified
  - deferred
  - relocated

In this evaluation, it was recognized that the information needs being addressed by testing in the shafts will also be addressed by other testing (e.g., surface-based testing, testing in the MTL, and laboratory testing).

Based on available information (i.e., the SCP and associated study plans) and on discussions with the Yucca Mountain Project Office (YMPO) personnel, the following observations can be made regarding the shaft test program (ignoring the MTL test program):

- Geologic Mapping (DOE, 1989e) - Geologic mapping consists of photographing all exposures in both shafts, detailed line mapping in one shaft, mapping of unusual or anomalous features in the other shaft, and the collection of joint infilling samples. This provides detailed information on the geologic structure and lithology along the vertical lines defined by the shafts, which cannot be adequately obtained in any other way. This information is supplemented by information developed from boreholes (both from the surface and from within the shaft), from drifting at the MTL, and, at a larger scale, from geophysical surveys.

  This activity must be done continuously along the entire shaft, after the walls have been stabilized (e.g., with rock bolts and mesh) but before placing the lining (or shotcrete) which would obscure the surface. It is strongly preferred that mapping be conducted in both shafts so that the continuity of structure can be determined. Blasting during excavation tends to create additional fractures in the exposed shaft wall and may contaminate infilling samples. Alteration of exposed rock and joint surfaces and infilling will occur prior to mapping if mapping is delayed. Both of these conditions reduce the quality of data, although not necessarily to a significant degree.

- Rock Sampling (DOE, 1989d, e, and f) - Rock samples will be obtained from various locations along the vertical line defined by the shaft, both from the muck during mining and from boreholes drilled from within the shaft. This activity provides samples for the detailed laboratory investigation of mineralogy, petrology, and hydrochemistry (including pore water and chlorine-36). These samples are supplemented by those obtained from surface boreholes and from the MTL.

  This activity must be undertaken representatively along the entire shaft, and must result in essentially undisturbed samples for hydrochemistry testing. Blasting during excavation may contaminate the pore fluids within the near vicinity of the shaft (especially in the muck). Delays in sampling tend to result in changes in specific features and in the hydrochemistry near the shaft; the degree of alteration and the extent of this disturbed zone increases with the amount of the delay. Either of these conditions reduces the quality of hydrochemistry data, although not necessarily to a significant degree, since relatively uncontaminated samples can be obtained from outside the construction-induced disturbed zone in boreholes drilled from within the shaft and tracers can be used to detect contamination.

- Vertical Seismic Profiling (DOE, 1989e) - Vertical Seismic Profiling consists of installing geophones in short (less than ten feet long) boreholes drilled into the shaft wall at about 30 foot intervals along the length of each shaft. Tests are then run along each shaft, between the shafts, and from the surface to the shafts, possibly including the multipurpose boreholes. This provides approximate information regarding the three-dimensional geologic structure (in terms of seismic velocity profiles) in the zone between the shafts. This information supplements the geologic mapping in the shafts, and information obtained from the surface boreholes and from geophysical surveys.

  This activity will be done along the entire length of both of the shafts in order to fully characterize this limited block of ground. Neither the shaft construction method nor delays in testing will significantly affect the quality of data obtained in Vertical Seismic Profiling.

- Shaft Convergence Test (SCT) (DOE, 1989c) - The SCT consists of:

  - determining stresses ahead of the shaft face (at three depths) by overcoring a borehole deformation gage set in a pilot hole drilled up to 10 m ahead of the face

- installing mechanical instrumentation (e.g., convergence points, multipoint borehole extensometers, and pressure cells) in the wall near the face of one of the shafts in order to monitor displacements and stresses during excavation.

This testing will be carried out at three locations in one of the shafts, and provides some information regarding the transient mechanical response of the rock in the vicinity of the shaft, due to excavation of the shaft. This information supplements large scale mechanical testing planned for the UDBR and in the MTL, as well as the Excavation Effects Tests planned for both the UDBR and the MTL. It also provides repository and ESF design performance information if monitoring is continued beyond lining.

This activity must be performed representatively along the length of the shaft. If a different construction method is used for the second shaft and if that method is being considered for repository shaft construction, then such testing should be done to the extent possible in both shafts. Although care must be exercised in conducting this test to protect the instruments from blasting damage, the construction method does not significantly impact the test. In order to determine the transient mechanical response of the shaft due to excavation, the mechanical instrumentation must be installed during excavation; i.e., delays in testing would result in failure to observe the displacements and stress changes associated with excavation. However, some of the transient response will have occurred prior to installation of the instruments due to stress redistribution ahead of the face. Obviously, the lining pressure cells cannot be installed until the lining is placed, which will occur some time following excavation. The determination of in situ stresses could be delayed until after shaft excavation/lining in boreholes drilled into the zone unaffected by construction from within the shaft.

- Upper Demonstration Breakout Room (UDBR) (DOE, 1989c) - This test consists of excavating a repository-sized room off one of the shafts in a high lithophysal zone, while installing mechanical instrumentation (e.g., convergence points and multipoint borehole extensometers) near the face and monitoring the mechanical behavior during excavation. This provides some information regarding the constructability and transient mechanical response of a repository-sized room in this type of rock. This information supplements other large-scale mechanical testing planned for the UDBR and in the MTL, including a similar demonstration breakout room in the MTL (MTLDBR), as well as the Shaft Convergence Test and Excavation Effects Tests. It also provides repository design performance information.

  This activity must be performed in the appropriate rock type, although the UDBR may not have to be accessed from the shafts; e.g., a similar zone might be accessed by ramp from within the

MTL. Neither the shaft construction method nor delays in testing will significantly affect the quality of data obtained in the UDBR.

- Thermomechanical Testing in the UDBR (DOE, 1988a) - This testing consists of a variety of thermomechanical tests (e.g., borehole heater tests, plate loading tests, overcore stress measurements) conducted in the UDBR in a high lithophysal zone. This provides some information regarding the thermomechanical response of this type of rock. This information is supplemented by other large-scale mechanical testing planned for the UDBR and in the MTL, as well as the Shaft Convergence Test and Excavation Effects Tests. It also provides repository design performance information regarding waste package emplacement.

  This activity must be performed in the appropriate rock type, although as previously noted, the UDBR may not have to be accessed from the shafts. Again, neither the shaft construction method nor delays in testing will significantly affect the quality of data obtained in thermomechanical testing in the UDBR.

- Excavation Effects Test (DOE, 1989d) - This test consists of installing hydrologic and mechanical response instruments (e.g., stress meters and multipoint borehole extensometers) in air-cored boreholes ahead and outside of the shaft face, and then monitoring the response as excavation proceeds. The hydrologic response is determined by repeated gas permeability testing in specific holes, as well as by monitoring the penetration of construction fluids. This test is conducted in a high lithophysal zone at the UDBR and in a welded fractured zone in the MTL. This provides some information regarding the effects of excavation on the hydrologic characteristics and the transient mechanical response of the rock in the vicinity of the shaft, due to excavation of the shaft, in both zones, as well as the movement of construction fluids in the rock. This information supplements large-scale hydrological and mechanical testing planned for the UDBR and in the MTL, and is supplemented by the Shaft Convergence Tests and the Radial Borehole Tests. It also provides repository and ESF design performance information.

  This activity must be carried out in both rock types in order to provide ESF and repository design performance information. If a different construction method is used for the second shaft and if that method is being considered for repository shaft construction, then such testing should be performed to the extent possible in both shafts. However, this activity is not obviously essential for determining the hydromechanical response of the rock. For example, similar instrumentation could be incorporated in a horizontal fashion in the demonstration breakout rooms. Care must be exercised in conducting this test to protect the instruments from blasting damage. In order to determine the transient mechanical response of the shaft due to excavation, the mechanical instrumentation must be installed prior to excavation; i.e., delays in testing would result in failure to observe the displacements and stress changes associated with excavation. Similarly, in order to determine the movement of construction fluid in the shaft wall, this must be done in line with construction. However, again this activity may not be essential for determining the movement of construction fluids. For example, construction fluids could be introduced to the shaft wall, in a controlled manner, after construction and their movement monitored, or the test could be relocated out of the shafts.

- Short Radial Borehole Tests (SRBT) (DOE, 1989d) - SRBT's consist of the following activities conducted within each set of two horizontal, perpendicular, 30 foot long boreholes air-cored into the shaft wall as close as possible to the shaft face at seven specific horizons (i.e., geologic contacts):

  - laboratory testing of the core
  - repeated neutron logging and single borehole gas permeability testing as excavation proceeds
  - instrumentation and monitoring of borehole conditions
  - gas sampling
  - cross-hole permeability testing of geologic contacts.

  The actual locations of the SRBT's may be feature specific, based on the conditions observed in the shaft walls.

  This testing provides some information on the undisturbed hydrologic conditions and on the transient hydrologic response of the rock in the vicinity of the shaft, due to excavation of the shaft, as well as the movement of vapor and the chemistry of gases in this zone, due at least in part to the introduction of construction fluids. This information supplements large-scale hydromechanical testing planned for the MTL, as well as the Excavation Effects Tests, surface borehole tests, and laboratory tests on samples. It also provides some repository design performance information.

  This activity must be carried out representatively along the length of the shaft, and must result in some essentially undisturbed samples for gas testing. If a different construction method is used for the second shaft and if that method is being considered for repository shaft construction, then such testing should be done to the extent possible in both shafts to determine the extent of disturbance associated with the mining method.

Blasting during excavation should cause more disturbance, and hence greater changes in permeability, and may introduce more fluids than would occur in mechanically mined shafts.

In order to determine the transient hydrologic response of the shaft wall rock due to shaft excavation (i.e., permeability as a function of stress), either

- the boreholes must be installed as close to the face as possible and the air permeability tests repeated as excavation proceeds (and the stress regime changes); however, the stress regime will have changed substantially prior to installing the boreholes due to extensive stress redistribution ahead of the face so that much of the transient response will not be observed in any case.

- air permeability in the boreholes can be determined as a function of radial distance from the shaft and related to the stress at each point, which varies with radial distance from the shaft; this testing can be done at any time.

Hence, delays in testing would result in the loss of transient data at a specific location or for specific features associated with excavation. However, the average change in permeability as a function of stress and the average change in water content due to excavation and ventilation can still be determined by testing at different radial distances, with the undisturbed condition existing at large radial distances (i.e., several shaft diameters). In order to determine the transient hydromechanical response associated with shaft excavation, a test such as the Excavation Effects Test would be preferred.

In order to monitor the transient effects of construction fluids, such fluids can be introduced in a controlled manner after construction.

Delays in testing would not have any impact on the quality of the remaining data to be collected in the SRBT's (e.g., temperature, gas pressure, water potential, gas and vapor samples, and cross-hole permeability testing across geologic contacts), as the collection of that data will be significantly delayed in any case.

- Long Radial Borehole Tests (LRBT) (DOE, 1989d) - LRBT's are similar to the SRBT's, except

  - they are located at six different horizons, roughly in the middle of each geologic unit

- the boreholes are much longer (100-120 feet), extending beyond the surface-based multipurpose borehole (drilled parallel but off-set to the shaft) by about 50-60 feet

- the initial permeability tests will be cross-hole type tests, incorporating the multipurpose borehole

- the boreholes will not be subsequently instrumented and monitored, nor will gas samples be obtained.

This testing provides information on the relatively undisturbed hydrologic characteristics of the site, possibly of specific features and at a larger scale than is possible otherwise, and also helps to determine the extent of the construction-induced disturbed zone (including consideration of construction fluids). This testing is supplemented by the SRBT's, by hydrologic testing in the surface boreholes, and by testing in the MTL.

This activity must be performed representatively along the length of the shaft. The method of shaft construction and delays in testing should have similar but significantly less impact on the quality of the data collected in the LRBT's than in the SRBT's, as discussed above.

- Perched Water Test (DOE, 1989d) - Perched Water Tests will be conducted whenever perched water is encountered in the shaft. Such testing consists of flow measurements, borehole permeability tests, and borehole instrumentation and monitoring in the perched water zone. This information is supplemented by that provided by the multipurpose boreholes, other surface boreholes, the SRBT's and LRBT's, and rock samples provided by other means.

  This activity must be carried out continuously, as required, along the length of the shaft. It is desirable, although not essential, that such testing be done in both shafts to determine the lateral extent of such zones. Blasting used in excavation may contaminate the water samples, but mechanical disturbance due to blasting should not have any impact on the quality of data. Delays in testing, however, could have a significant impact on the ability to detect such zones and to determine their extent, especially if the zones are relatively small. If the zones can be detected (e.g., by geophysics), the perched water conditions (especially sampling) can be observed in boreholes drilled from within the shaft after construction, although some of the conditions may have changed, especially near the shaft.

In addition to the above:

- Construction will be monitored during excavation of shafts and drifts (including the UDBR and MTLDBR), regarding such factors as type and quantity of explosive, blast size, blast pattern, mucking rate, advance rate, dust control methods, etc., depending on the type of construction method utilized. This information will be gathered routinely, and will subsequently be used to develop recommendations for the construction methods to be used in repository development.

- Shaft seal testing is being considered subsequent to shaft construction, although it has not yet been developed.

- Testing will be conducted in the multipurpose boreholes (drilled vertically downward from the surface with air prior to shaft construction), which are planned to be located between the two shafts and offset from the shafts by about 50 ft; a third multipurpose borehole is being considered midway between the other two. This will provide some information on the relatively undisturbed (pre-shaft construction) hydrologic and engineering characteristics of the site, in order to: (1) confirm the ESF design basis or detect anomalies so that the shafts can be successfully constructed; and (2) establish the baseline conditions for determining subsequent changes in conditions due to ESF construction. Subsequently, these conditions will be monitored to detect interference with tests in the shafts, and in some cases cross-hole testing in conjunction with the LRBT's will be conducted.

- Extensive exploratory drifting and drilling, in conjunction with testing (including the MTLDBR), will be conducted in the MTL. This information will supplement that obtained from the shafts and surface boreholes, focussing on the repository horizon and possibly extending down to the Calico Hills.

- Boreholes will be drilled from the surface, with testing conducted within those boreholes, to investigate other portions of the site. Similarly, surface-based geophysics programs will be conducted. Although generally providing less detailed information than provided by the ESF, through correlations the ESF information can thus be extended across the site.

- Samples obtained from the ESF and from other boreholes will be tested in the laboratory. In this way, the geochemistry, and by inference aspects of the hydrology, of the site will be determined. Also, although at a small scale, the hydrologic and thermomechanical characteristics of the rock will be determined under carefully controlled conditions to supplement the large-scale information provided by the ESF.

3.2 OTHER REQUIREMENTS

The ESF must be designed, constructed and operated to satisfy a large set of requirements. A generic set of requirements, including those derived from the relevant federal laws, regulations (e.g., 10CFR60, 40CFR191, 30CFR57, 10CFR960, etc.) and DOE orders, is specified in Appendix E of OGR/B-2 (DOE, 1989b). A specific set of requirements is specified in the ESF Subsystem Design Requirements Document for Title II (DOE, 1989g). These requirements were reviewed as part of Task 1. In addition to the general requirements of providing a safe facility in which to conduct site characterization and design confirmation tests, which will ultimately be integrated into the repository and not adversely affect long-term performance, the following criteria are of special interest regarding the evaluation of alternative ESF shaft construction methods/test sequences:

- The ESF must be designed and constructed
  - to accommodate flexibility in the test program
  - to be robust, so that breakdowns do not significantly affect budget and/or schedule
  - using similar techniques as for the repository.
- The ESF shafts must be designed and constructed
  - using excavation techniques which control overbreak and minimize disturbance
  - with emergency egress systems which allow for the evacuation of all underground personnel within one hour
  - controlling the use of blasting agents/explosives and construction fluids so that there is no adverse effect on site characterization
  - to be stable, minimizing the potential for deleterious rock movements and/or fracturing which might result in pathways for radionuclide migration.
- Testing must be conducted
  - for ESF design verification and to determine the effects of ESF construction on site characterization and isolation
  - to initiate repository performance confirmation
  - at full-scale at the MTL only after the ESF shafts have been connected.

Table 3-1. Potential Changes to ESF Shaft Test Program (Page 1 of 2)

TEST	REQUIRED IN BOTH SHAFTS?	AFFECTED BY CONSTRUCTION?	POSSIBLE TO MODIFY?	POSSIBLE TO DEFER?	POSSIBLE TO RELOCATE?
Geologic Mapping	yes	sm	no	yes[a]	no
Rock Sampling	no[b]	mod[b]	yes[b]	yes[b]	no
Vertical Seismic Profiling	yes	no	no	yes	no
Shaft Convergence Test	no[c]	sm	no	no	no
UDBR	no	no	no	yes	yes[d]
Thermomech Testing in UDBR	no	no	no	yes	yes[d]
Excavation Effects Test	no[c]	sm	yes[e]	poss[f]	yes[d]
SRBT	no[c]	sm	no	poss[f]	no
LRBT	no	no	no	poss[f]	no
Perched Water Tests	cont	mod	no	poss[g]	no

Table 3-1. Potential Changes to ESF Shaft Test Program (Page 2 of 2)

NOTES:

sm - small effect
mod - moderate effect
cont - contingency
poss - possible

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

[b] Although not planned, samples could be obtained from both 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 shaft wall.

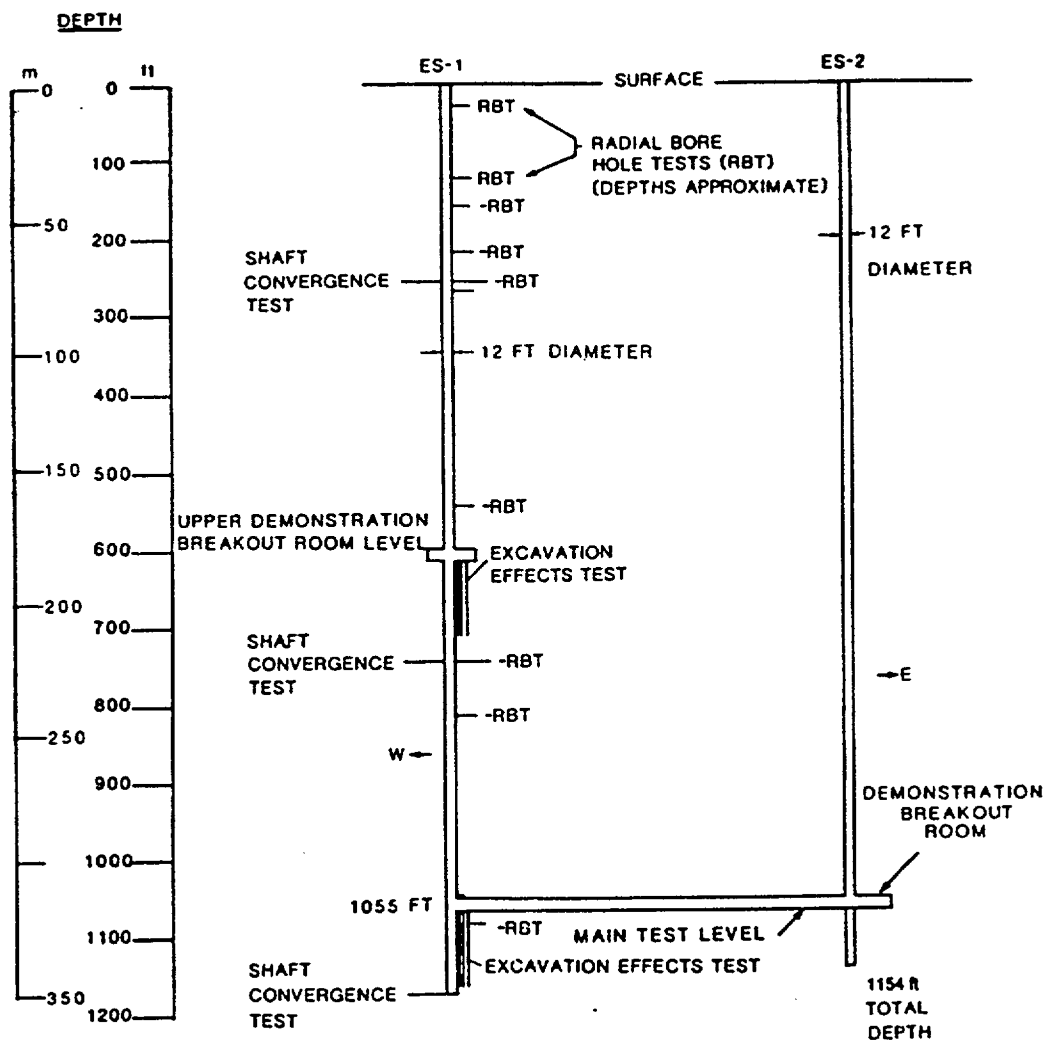
[c] If different methods are used for constructing the two ESF shafts and they are both being considered for constructing the repository shafts, then these tests should be conducted in both shafts.

[d] The UDBR, and the associated testing (including 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 hydromechanical 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 shaft construction if the transient data (i.e., feature-specific hydromechanical 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 shaft until after excavation, even though the data quality in that shaft may be reduced.



Notes: ES - Exploratory Shaft
RBT - Radial Bore Hole Tests (Depths Approximate)

Geologic mapping, rock sampling (e.g., for mineralogy, matrix hydrology, hydrochemistry, and chlorine), seismic tomography, perched water test (if encountered) and evaluation of mining methods will be conducted in shafts, but are not shown.

Additional Long Radial Borehole tests will also be conducted, but are not shown.

Testing will also be conducted in the UDBR and in the MTL, but is not shown.

Testing will be conducted in multiple purpose boreholes drilled parallel and offset to shafts, but is not shown.

(Source: DOE, 1988a)

Locations and Types of Tests in the Exploratory Shaft Facility

Figure 3-1

4.0 ALTERNATIVE ESF SHAFT CONSTRUCTION METHODS AND TESTING SEQUENCES

4.1 INTRODUCTION

The present concept for accessing the Exploratory Shaft Facility (ESF) testing horizon is to conventionally mine (drill-and-blast) both exploratory shafts and to perform all shaft testing essentially in-line with shaft construction. The broad scope of this study is to evaluate the data quality and schedule/cost impacts of employing 1) alternative testing sequences, and 2) various combinations of conventional and mechanical shaft construction methods. There are a variety of mechanical shaft construction methods, including drilling (wet), blind boring (dry), raise boring and construction with a V-Mole. As discussed in Section 2.1, previous studies have rejected some of these options because of concerns about site/test location contamination and the use of non-demonstrated technologies. Therefore, three basic mechanical shaft construction methods have been considered herein:

- Raise boring to full ESF shaft diameter with a single pass.
- Raise boring a pilot hole to 6 to 8 feet diameter, followed by top-down construction to full ESF shaft diameter using a V-Mole.
- Conventional (drill-and-blast) sinking of a pilot shaft to some reasonable small diameter (e.g., 10-12 feet), followed by top-down construction to full ESF shaft diameter using a V-Mole.

The seven combinations of shaft construction methods considered as part of this study are therefore:

- Method 1 - Conventional (drill-and-blast) construction of both shafts
- Method 2 - Conventional construction of Shaft 1 and Raise Bore Shaft 2
- Method 3 - Conventional construction of Shaft 1 and Raise Bore (pilot)/V-Mole Shaft 2
- Method 4 - Conventional construction of Shaft 1 and Drill-and-Blast (pilot)/V-Mole Shaft 2
- Method 5 - Drill-and-Blast Shaft 1 (pilot), Raise Bore Shaft 2 and finally V-Mole Shaft 1
- Method 6 - Drill-and-Blast Shaft 1 (pilot), Raise Bore (pilot)/V-Mole Shaft 2, and finally V-Mole Shaft 1
- Method 7 - Drill-and-Blast Shaft 1 (pilot), Drill-and-Blast (pilot)/V-Mole Shaft 2, and finally V-Mole Shaft 1.

It should be noted that at least one conventionally constructed shaft is common to all cases, either as a pilot shaft or as a final shaft. Such conventionally constructed shafts will employ controlled blasting, controlled use of construction fluids, and a stringent safety program.

A testing program within the exploratory shafts is planned as part of the site characterization program. Some of these tests must be performed in-line with shaft sinking, and others may be performed following the establishment of access to the MTL. It is therefore essential to consider the combination of both the shaft construction method and the shaft testing program when evaluating the schedule and data quality issues.

The planned shaft testing program has been briefly discussed in Section 3. Many of the tests are essentially non-impactive on the schedule (e.g., sampling, vertical seismic profiling, etc.). Geologic mapping must be done before the shaft is lined and, where appropriate, time has been included in the construction rates to allow for this activity. Other tests (e.g., Shaft Convergence Test) must be performed during construction and time has been explicitly allowed for these activities. There are a few testing activities which significantly affect the schedule and which have the potential for being rescheduled in whole or in part, including:

- Construction of the Upper Demonstration Breakout Room (UDBR), including essential in-line geomechanical monitoring of these openings together with the UDBR Excavation Effects Test.

- Thermomechanical tests to be performed within the UDBR

- Radial Borehole Tests (SRBT's and LRBT's)

Various combinations of shaft construction methods and testing sequences have therefore been considered as part of this study under Task 2. These are briefly outlined below and summarized in Table 4-1. More detailed information for each case is presented in Appendix B, including a schematic description of the sequence of shaft development/testing and a sequential list of activities.

Table 4-1 shows that, apart from the current base case, two basic test sequences have been considered for each of the first four construction methods. Test sequence "a" considers the case where all thermomechanical testing planned for the UDBR is delayed until after the completion of shaft sinking, the SRBT's are conducted in-line with sinking of the conventionally-mined Shaft 1 in each case, and the LRBT's are installed during shaft sinking but the majority of the testing at these locations is performed following shaft sinking. Test sequence "b" considers the case where both the UDBR thermomechanical testing and the Radial Borehole Tests are delayed until completion of shaft sinking.

In so far as the final three construction methods are concerned, only testing sequence "b" is considered relevant. Installation of the Radial Borehole Tests during construction of the small diameter, conventionally mined Shaft 1 would be difficult and would in any case result in those tests being disrupted during subsequent reaming of Shaft 1 to full ESF size. This is not considered acceptable from a test performance point of view. Furthermore, the Radial Borehole Tests cannot be conducted in-line with any of the other mechanical shaft construction methods due to lack of access to the face. Hence, the final three methods of construction are assumed incapable of accommodating testing sequence "a" (i.e., in-line performance of the Radial Borehole Tests).

It should be noted that the YMPO has not currently endorsed delaying the Radial Borehole Tests. As discussed in Section 3.1, the principal reasons for this are believed to be:

- A requirement to study the transient behavior of construction fluid ingress, in order to better understand fluid transfer phenomena under unsaturated conditions. There would appear, however, to be alternative methods for obtaining this information; e.g., instead of using water applied during construction, the same phenomena could be studied by introducing water in the vicinity of the Radial Borehole Tests following construction.

- A requirement to observe the transient hydromechanical response of the immediate shaft walls during construction, in order to calibrate predictive models. It should be noted, however, that the timing of installation of the Radial Borehole tests will not provide an "undisturbed" baseline, and that this type of information may be more appropriately obtained from the Excavation Effects Test, or equivalent.

In so far as more permanent effects (e.g., mechanical disturbance, hydrochemical contamination, etc.) in the vicinity of the shafts are concerned, it would appear that monitoring the transient response is not required. Because of the schedule impacts of in-line performance of the Radial Borehole Tests, and the authors' opinion that alternative testing strategies are available, the delayed Radial Borehole Testing sequence has been evaluated as a possible alternative.

4.2 CASE 0

This option represents the current base case in which both shafts will be conventionally sunk and simultaneously lined, all testing will be done in-line with construction in Shaft 1 (Scientific Shaft), and Shaft 2 will serve as the Access/Mucking Shaft. Following complete outfitting of Shaft 2, the two shafts will be connected by mining from Shaft 2 towards Shaft 1, and mucking through Shaft 2.

4.3 CASE 1

This option is similar to Case 0 in that both shafts will be sunk conventionally and lined, Shaft 1 will be the Scientific Shaft in which all testing is performed and Shaft 2 will serve as the Access/Mucking Shaft. For each permutation examined in this case, optimum schedule was achieved by first outfitting Shaft 2 and then mining the MTL connection between the two shafts from Shaft 2 towards Shaft 1, mucking through Shaft 2. This was not a constraint, however, and it was considered permissible to reverse the mining direction and use the Shaft 1 sinking equipment for mucking or to first equip Shaft 1 and use the permanent hoists for mucking. Two different permutations have been considered, each corresponding to a different sequence for performing the shaft testing. These are:

1a - The UDBR will be constructed during shaft sinking, but the thermomechanical testing to be performed in the UDBR will be delayed. As noted above, the Radial Borehole Tests for test sequence "a" will be performed essentially in-line with shaft construction, although some of the testing associated with the LRBT's will be delayed until shaft sinking is complete.

1b - This option is identical to 1a above, except that the Radial Borehole Tests will be delayed until shaft sinking is complete.

4.4 CASE 2

This case examines the use of one conventionally mined shaft and one mechanically mined shaft using a Single-Pass Raise Boring method. Two alternative options are examined for this case:

2a - It has been assumed that it is not practical to attempt to conduct the Radial Borehole Tests in conjunction with the raise boring of the second shaft. If transient data are required, the Radial Borehole Tests will thus have to be performed within the conventionally sunk Shaft 1. Because virtually all of the planned scientific testing is now performed in Shaft 1, it will be retained as the Scientific Shaft. The raise bored shaft will therefore be used as the Access/Mucking Shaft, with limited scientific testing restricted to perhaps the taking of "uncontaminated" samples from the shaft walls. Following Shaft 1 equipping, the shaft connecting tunnel will be driven from the Shaft 1 station to intercept the Shaft 2 pilot hole previously installed, using the Shaft 1 hoists for mucking. Shaft 2 will be developed by raise boring to full ESF shaft diameter in a single pass, again using the Shaft 1 hoists for mucking, and subsequently lined, outfitted and equipped as the Access/Mucking Shaft for subsequent MTL development.

2b - This option assumes that the Radial Borehole Tests can be deferred until shaft sinking is complete, as for option 1b above. The post-shaft construction scientific testing is assumed to be concentrated in Shaft 2 which will be mechanically mined. Therefore, Shaft 1, which will be conventionally sunk and lined, will be fully outfitted and equipped as the Access/Mucking Shaft once access to the MTL is achieved. Following this, the shaft connecting tunnel will be mined from the Shaft 1 station to intercept the previously drilled Shaft 2 pilot hole, mucking through Shaft 1. Shaft 2 will be developed by raise boring to full ESF shaft diameter in a single pass, again mucking through Shaft 1, and will be subsequently lined and outfitted. Lining and outfitting of Shaft 2 could be deferred and is not necessary to allow MTL development and testing, as long as Shaft 2 is stabilized and equipped to provide emergency egress.

4.5 CASE 3

This case is identical to Case 2, with the exception that the mechanically mined Shaft 2 will be raise bored to a small diameter (e.g., 6 ft) and then subsequently reamed with a V-Mole to full ESF size, mucking through Shaft 1. Two alternative options are again considered:

3a - As for Case 2a

3b - As for Case 2b.

4.6 CASE 4

This case is identical to Case 2, with the exception that the mechanically mined Shaft 2 will be constructed by conventionally sinking a small diameter (e.g., 10-12 ft) pilot shaft, drifting across from Shaft 2 to Shaft 1 using the Shaft 2 sinking equipment for mucking, and finally using a V-Mole to develop Shaft 2 to full ESF size after the shafts are connected, mucking through Shaft 1. Once again, the following two options have been considered for this case:

4a - As for Case 2a

4b - As for Case 2b

4.7 CASE 5

This case considers a conventionally sunk small diameter (10 to 12 feet) first shaft (Shaft 1) to gain initial access to the MTL. Shaft 1 will be initially supported but left unlined, and temporarily equipped for muck handling. Following this, the shaft connecting tunnel will be mined from the Shaft 1 station to intercept a previously drilled Shaft 2 pilot hole. Shaft 2 will then be developed by raise boring to full ESF shaft diameter in a single pass, with mucking through Shaft 1, and will be subsequently mapped (and possibly sampled), lined and outfitted as the ESF Access/Mucking Shaft. Finally, Shaft 1 will be reamed to full ESF shaft diameter using a V-Mole, mucking through Shaft 2, and will be lined and outfitted. Lining and outfitting of Shaft 1, which will be the Scientific Shaft, could be deferred providing it is stabilized and equipped to provide emergency egress in order that MTL development and testing can proceed.

Essential in-line testing (e.g., UDBR construction and associated geomechanical monitoring, Excavation Effects Test, Shaft Convergence Test) will be performed during sinking of the Shaft 1 small diameter pilot shaft. However, Radial Borehole Testing must be delayed until after reaming of Shaft 1, as previously discussed.

4.8 CASE 6

This case is identical to Case 5, with the exception that Shaft 2 will be raise-bored to a small diameter (e.g. 6 ft) and then subsequently reamed with a V-Mole to full ESF shaft diameter, mucking through Shaft 1. Mapping (and possibly sampling), lining and outfitting of Shaft 2 (the Access/Mucking Shaft) will follow the V-Mole, proceeding from the top down.

4.9 CASE 7

This case is identical to Case 5, with the exception that Shaft 2 will be constructed by conventionally sinking a small pilot shaft, drifting across from Shaft 2 to Shaft 1, using the Shaft 2 sinking equipment for mucking, and again using a V-Mole to develop Shaft 2 to full ESF size after the shafts are connected, mucking through Shaft 1. Mapping (and possibly sampling), lining and outfitting of Shaft 2 (the Access/Mucking Shaft) will follow the V-Mole, proceeding from the top down.

4.10 UPPER DEMONSTRATION BREAKOUT ROOM

As indicated in Section 4.1, the present base case includes construction of an Upper Demonstration Breakout Room (UDBR) in-line with sinking of Shaft 1. Because of logistical problems associated with mining the UDBR at this location following completion of shaft sinking, the potential disruptions to the operations of the ESF that would be associated with such an activity, and the current requirement for transient data associated with shaft sinking from the Excavation Effects Test to be performed from within the UDBR, all of the above construction methods/test sequences have assumed that the UDBR would be constructed during sinking of Shaft 1. As discussed in Section 3.1, if a suitable test horizon (i.e., high lithophysal zone) can be found in the vicinity of the MTL, it might be possible to re-locate the UDBR and remove all UDBR activities from the shaft critical path. Such relocation would, of course, be predicated on an analysis of the effects on site characterization and long-term performance. If the UDBR is relocated, it is assumed that a trial shaft section would also be constructed so that the transient mechanical/hydrological effects testing associated with the Excavation Effects Test (to be performed from the UDBR) could still be undertaken.

Alternatively, as previously discussed, the Excavation Effects Test could be modified so as to be conducted in a horizontal mode within the relocated UDBR, using the controlled introduction of construction fluids. The schedule benefits of such an option are discussed in Section 6.

Table 4-1. Alternative ESF Shaft Construction Methods/Testing Sequences (Page 1 of 2)

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
(5) Drill-and-Blast/V-Mole Shaft 1, Raise Bore Shaft 2			Case 5b
(6) Drill-and-Blast/V-Mole Shaft 1, Raise Bore/V-Mole Shaft 2			Case 6b
(7) Drill-and-Blast/V-Mole Shaft 1, Drill-and-Blast/V-Mole Shaft 2			Case 7b

Table 4-1. Alternative ESF Shaft Construction Methods/Testing Sequences (Page 2 of 2)

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 Borehole Tests until after shaft construction.

5.0 EVALUATION METHOD AND CRITERIA

5.1 EVALUATION METHOD

A methodology for the quantitative, technical evaluation of the alternative ESF shaft construction methods/test sequences has been developed as part of Task 3. This methodology consists of the following steps:

1. Identify set of evaluation criteria - A set of criteria for evaluating the alternative ESF construction methods/testing sequences has been identified. These criteria are derived from the objectives and requirements for the ESF shafts previously identified in Section 3. In some cases these criteria were quantitative (e.g., schedule in terms of months), whereas in other cases they were necessarily qualitative (e.g., occupational health and safety). These criteria are discussed further in Section 5.2.

2. Assess relevant characteristics of each construction method/test sequence - The characteristics (or attributes) of each ESF shaft construction method/test sequence relevant to the criteria have been subjectively assessed. These characteristics are readily quantifiable in some cases (e.g., schedule), but less quantifiable in other cases and can therefore be discussed only qualitatively (e.g., occupational health and safety). Because of the short time frame available for this study, these assessments are approximate, based largely on available information and on the experience and judgement of the team members. Because the relative characteristics of each alternative are of interest in the comparative evaluation, the uncertainties in the assessments have not been explicitly considered.

3. Evaluate each construction method/test sequence independently with respect to each criterion - Based on the assessed attributes of each ESF shaft construction method/test sequence, each alternative has been evaluated with respect to each of the criteria independently. First, the acceptability of each alternative with respect to each criterion has been evaluated. However, only viable and potentially acceptable alternatives were initially selected for consideration (see Section 4.0), so that any alternatives which would be unacceptable with respect to any criterion have already been screened out. The various acceptable alternatives have then been evaluated and compared with respect to satisfying each criterion independently on a relative, rather than an absolute basis. As previously noted, in some cases (e.g., schedule), the comparisons have been expressed quantitatively, whereas in other cases (e.g., health and safety) the comparisons have been stated in qualitative terms (i.e., best, good, and satisfactory). These ratings are defined in Section 5.3.

4. Evaluate each construction method/test sequence collectively with respect to the set of criteria - Based on the evaluations of each ESF shaft construction method/test sequence with respect to each criterion, each alternative can eventually be evaluated with respect to the entire set of criteria collectively. However, in the absence of an ideal alternative (i.e., one which is best with respect to all of the significant criteria), this requires that the relative importance of the various criteria be established, so that tradeoffs can be made among them.

5.2 EVALUATION CRITERIA

Based on the ESF requirements previously identified in Section 3, in conjunction with DOE guidance (DOE, 1989a) and NWTRB panel comments (TRB, 1989), a set of differentiating criteria for the evaluation of the alternative ESF shaft construction methods/test sequences has been identified as part of Task 3:

- Satisfaction of the Information Needs - The degree to which the set of information needs and testing strategies, as previously identified in the SCP (see Section 3.1), can be satisfied by the construction method and integrated testing program. This evaluation considers the ability to obtain the necessary information regarding:

  - site characteristics at appropriate locations. Suitable access must be provided to conduct testing at the appropriate horizons in the shafts and possibly for specific features. Spatial variability can be assessed for some characteristics through surface boreholes.

  - site characteristics reflecting undisturbed conditions. This requires minimal contamination/disturbance (e.g., mechanical, hydrological, or chemical) of the rock being tested. Suitable access must be provided to conduct testing either at the face during construction or beyond the effects of shaft construction (i.e., ahead of the face or at a large radial distance) to determine preconstruction conditions. Preconstruction conditions will also be assessed for some characteristics through surface boreholes (e.g., the multipurpose boreholes offset from the shafts). Of special concern is the degradation/alteration of specific features prior to sampling.

  - site characteristics expressing transient conditions. Suitable access must be provided to conduct testing/monitoring either at the face during construction or at various radial distances from the shaft to determine the change in conditions due to construction, especially to monitor the transient effects of construction fluids. Transient conditions will also be assessed during large-scale in situ testing under controlled conditions at the MTL.

[Interference with shaft construction or operation caused by providing access for such testing is considered under schedule and cost impacts. Impacts of testing on repository integration or long-term performance, and the satisfaction of other aspects of the information needs/test strategies, are discussed elsewhere.]

- Shaft Constructability and Reliability - The likelihood that the shafts can be successfully constructed and operated. This considers:

  - whether the proposed construction methodology is based on a technology that has been demonstrated under similar conditions as those anticipated at the site

  - the ability of the proposed construction methodology to adapt to unexpected conditions at the site

  - the ability of the proposed construction methodology to achieve the specified shaft verticality requirements.

- Occupational Health and Safety - The potential hazards to workers and the comfort and convenience of the working conditions associated with constructing and operating (including testing) the shafts.

- Schedule - The expected length of time (in months) from the initiation of shaft sinking until the MTL is available for development and full-scale testing. MTL availability requires that: (1) both shafts be excavated and connected at the MTL, thus establishing a ventilation circuit; (2) one shaft be lined and fully equipped as a muck handling shaft, with a loading pocket and sump; and (3) the other shaft be lined and fully equipped, or at least have an emergency hoist available capable of evacuating all underground personnel in one hour. [Although limited access to the MTL to look for fatal flaws in and between the two exploratory shafts may require less time, development and testing in the MTL cannot proceed until the above requirements are satisfied.]

- Cost - The expected cost (in 1989 US dollars) of shaft construction, from the shaft collar to the point at which the MTL is available for development and testing, including the cost of standby for testing performed in-line with construction but not including other testing costs.

Additional criteria were considered (see Section 3.2), but determined to be non-differentiating with respect to the evaluation of the given set of ESF shaft construction methods/testing sequences. These additional criteria included:

- Satisfaction of the Information Needs - Other information needs and testing strategies include consideration of:

  - repository design performance. Information must be obtained regarding shaft construction and operation, as it relates to repository shaft performance. The degree to which the information from the ESF shafts can be extrapolated to the repository shafts is a function of their similarity in design and construction methods.

  - ESF design performance. Information must be obtained regarding shaft construction and operation, for safe ESF operations and as input to the shaft maintenance program.

  - site characteristics at appropriate scale. Suitable access and space must be provided to conduct testing at the appropriate scale in the shafts. Large-scale tests will also be conducted at the MTL and between boreholes.

  - flexibility. The ESF should be designed so that the test program can be revised, if necessary, based on observed conditions (e.g., to conduct additional tests at other locations). This includes the ability to subsequently provide access to a lower test level, such as the Calico Hills.

  However, the test strategies have not been significantly revised, with only some tests being deferred, so that there will not be any significant difference among the alternatives with respect to the above.

- ESF Efficiency - The potential impact (e.g., delay in months) on ESF post-shaft construction and operation. For example, construction of the UDBR testing in the shaft might be delayed until after shaft construction is complete and the MTL is available, but such an activity would essentially shut down ESF MTL construction or operation when it is finally conducted. However, for the cases considered, there will not be any significant differences among them after construction (including lining, outfitting, and testing).

- Long-term Performance - The potential impact on long-term repository performance (i.e., radionuclide containment and isolation). For example, the total number of penetrations to the repository horizon must be limited. As another example, construction-induced disturbance around the shaft could provide

- increased access to the repository horizon for percolating fluids, thus increasing waste package degradation and release and increasing downward fluid transport

- increased access to the surface for vapors, thus increasing upward gaseous radionuclide transport.

However, the impacts of shaft disturbance on long-term repository performance have not yet been definitively assessed to the point of being able to differentiate among construction methods (Fernandez et al., 1989). Moreover, it is the DOE's position, based on analyses, that if all due care is used in excavating the shafts (i.e., using controlled blasting techniques and controlling the use of construction fluids) the disturbance associated with drill-and-blast construction is not expected to significantly affect long-term performance (DOE, 1988a). Hence, for the cases considered, there will not be any significant differences among them after construction with respect to long-term performance.

- Repository Integration - The ease of incorporating the ESF into repository design/construction/operation/reclamation/sealing. Again, for the cases considered, there will not be any significant differences among them after construction.

- Environmental Effects - The effects of shaft construction on the environment, especially considering dust, noise, air/water quality, waste, etc. For the cases considered, there will not be a significant difference among them during construction.

5.3 RATING DEFINITIONS

The degree to which each of the ESF shaft construction methods/test sequences satisfies the test data quality, constructability, and health and safety evaluation criteria has been rated qualitatively. The rating scale adopted is a relative one, with the most favorable of the methods considered in each case rated as "best". In relation to the most favorable methods(s) for each evaluation criterion, the remaining methods have been ranked using the following qualitative descriptions which constitute, in effect, a five-point rating scale:

"satisfactory" - substantially less desirable than the preferred method(s) and lowest rated within the acceptable range.

"satisfactory +" - intermediate between "satisfactory" and "good".

"good" - less desirable than the preferred method(s) and intermediate within the acceptable range.

"good +" intermediate between "good" and "best".

(As noted above, the "best" rating has been applied to those acceptable methods which are judged to be the most favorable of all the methods considered.)

The above five-point qualitative rating scale will necessarily result in somewhat unequal methods being similarly rated. Where there is an obviously preferred method within any rating category, this has also been indicated in order to provide additional refinement to the above rating system.

6.0 EVALUATION OF ALTERNATIVE ESF SHAFT CONSTRUCTION METHODS/TEST SEQUENCES

6.1 COMPARISON WITH INDIVIDUAL CRITERIA

The various ESF shaft construction methods and testing sequences, presented in Section 4.0, have been evaluated with respect to specific criteria, based on readily available information and on the authors' expertise, as part of Task 4. As discussed in Section 5.2, the principal criteria include:

- Test Data Quality - The degree to which the alternative develops the required characterization information, focusing on: 1) ability to provide access to the required test locations; 2) extent of test contamination (e.g., mechanical, hydrological or chemical disturbance) related to the method of construction; and 3) ability to provide timely data where transient effects are significant.

- Shaft Constructability - The likelihood that the shafts can be successfully constructed and operated, considering whether: 1) the method has been demonstrated under conditions similar to those expected at the site; 2) unexpected adverse conditions can be accommodated; and 3) the required verticality of the shafts can be reasonably achieved.

- Health and Safety - The relative industrial hazards and the relative comfort and convenience of the working conditions during shaft construction.

- Schedule - The relative time to construct the facility from start of construction of the shaft collar to availability of the MTL for development and testing, including stand-by time for in-line testing and requiring the shafts to be adequately equipped for mucking and emergency egress.

- Cost - The relative cost of construction from start of construction of the shaft collar to the point that the MTL is available for development and testing, including the cost of stand-by for testing performed in-line with construction but not including other testing costs.

6.1.1 Test Data Quality

For the construction methods/testing sequences considered, many of the planned tests to be performed within the exploratory shafts will be essentially non-discriminatory in terms of test data quality. These tests include the Vertical Seismic Profiling and the Shaft Convergence Testing, which will be performed in an essentially identical manner for all options considered. Similarly, the quality of test data from the thermomechanical testing to be performed in the UDBR will be unaffected by construction method or testing sequence for any of the options considered. In fact, for all options evaluated except for the current base case, the thermomechanical testing is performed upon completion of shaft sinking as there appears to be no reason to delay construction while these tests are being installed. With respect to the construction of the UDBR and the performance of associated in-line testing such as geomechanical monitoring of the excavations (including the Excavation Effects Test), two basic scenarios may be considered. The first scenario assumes that the UDBR must be situated at its present location. For this case the UDBR construction and associated testing would be performed in-line with shaft construction. The second scenario assumes that the UDBR can be relocated to a high lithophysal zone elsewhere, and that this location is relatively easily accessible from the MTL. In this case, the UDBR construction and testing moves off the shaft construction critical path. Since all construction methods considered are equally capable of addressing either scenario, the UDBR construction and testing will also be non-discriminatory in terms of test data quality. As will be noted later, however, there are schedule advantages associated with alternative locations of the UDBR, if this is technically possible.

The various ESF shaft construction methods/testing sequences are subsequently discussed with respect to each of the site characterization activities where test data quality may be influenced by the adopted methodology:

- <u>Geologic Mapping</u> - In terms of the influence of mechanical disturbance (i.e., excavation-induced fractures, etc.) on the mapping of the shaft walls, the options which include one mechanically mined shaft (Cases 2 through 7) would appear to offer some modest advantage over the options using two conventionally mined shafts. From the point of view of timely access to the shaft walls for mapping purposes, Case 2 (Raise-bored Shaft) would be rated lower than the other alternatives because of the potential significant delays between shaft construction and availability for mapping. Overall, therefore, Cases 3 through 7 (V-Mole construction of a mechanically-mined shaft) would be rated best in terms of the geologic mapping data quality, with all other methods rated good.

- <u>Rock Sampling</u> - Because of concerns about near-surface sample disturbance and contamination associated with the method of construction, the construction methods which include a mechanically mined shaft (Cases 2 through 7) would be rated somewhat higher than the remaining cases. The existence of a mechanically constructed shaft would afford the opportunity to make direct comparisons of the extent of disturbance associated with each method of construction. Those methods which allow for timely access to the shafts for sampling of specific features during construction are preferred and, in this regard, Case 2 (Raise-bored Shaft) would be rated lower than the other mechanical mining methods. However, undisturbed/uncontaminated samples can be relatively easily obtained by drilling through the zone potentially disturbed by construction and, bearing in mind that conventional shaft sinking would take particular care to limit drill fluid losses and mechanical damage, there appears to be no overwhelming advantage to any of the considered construction methods with respect to rock sampling. Cases 3 through 7 (V-Mole construction of a mechanically mined shaft) have been rated best in terms of rock sampling, with the other methods rated as good. Large bulk samples will be obtained from the conventionally mined shaft (pilot or final) for each of the options considered.

- <u>Radial Borehole Tests</u> - The current YMPO position is that the Radial Borehole Tests must be installed and testing performed in-line with the construction of a conventionally mined shaft. As noted previously in Section 3.1, the principal reason for conducting the Short Radial Borehole Tests in-line with shaft construction appears to relate to a requirement to monitor transient fluid invasion and observe the transient hydro-mechanical response at specific locations within the radial boreholes as the shaft is advanced. However, there would appear to be alternative strategies for addressing these needs. These strategies might include making provisions for the introduction of water to the vicinity of the Radial Borehole Tests, following construction. Alternatively, this aspect of the Radial Borehole Tests could be performed elsewhere in the MTL and the scope of the Radial Borehole Tests in the shafts limited to evaluating the nature of the more permanent hydro-mechanical and hydro-chemical alterations caused by shaft sinking. Similarly, the transient hydro-mechanical response could be more effectively evaluated by a mine-by type test such as the Excavation Effects Test. It is suggested that the YMPO examine whether alternative testing strategies could be adopted without significant loss of information. For example, post-construction testing at different depths into the shaft wall will provide a good indication of the extent and nature of disturbance associated with shaft sinking. In order to reflect the present YMPO position with respect to data requirements from the Radial Borehole Tests, however, the following approach has been adopted in ranking the various methodologies with respect to Radial Borehole Test quality:

  - those methods which provide for full transient test data within a conventionally mined shaft have been rated best (i.e., Cases 0, 1a, 2a, 3a and 4a)

  - those methods which provide for only non-transient data have been rated as satisfactory (i.e., Cases 1b, 2b, 3b, 4b, 5b, 6b, andf 7b).

- Perched Water Test - Perched water conditions, if encountered, can be most expeditiously evaluated by construction methods which allow essentially immediate access to the exposed face. For this reason, mechanical mining methods will severely limit the opportunity to study perched water conditions. All construction methods examined herein include at least one conventionally mined shaft (pilot or final) which will be suitable for the perched water investigations. There will be some advantage to having both shafts available for this study, because of the better spatial coverage. Therefore, those options which include two conventionally mined shafts (i.e., Cases 0, 1, 4 and 7) have been rated best, with the other options rated as good. It should also be noted that there is presently no indication that perched water conditions will be encountered in the exploratory shafts, and the planned testing is considered a contingency item (i.e., there is no explicit time allowed for this testing in the schedules).

Based on the above qualitative evaluations, each of the construction methods/testing sequences considered as part of this study has been evaluated with respect to satisfying the test data quality requirements for the entire suite of tests to be performed from within the exploratory shafts. The overall evaluations are summarized in Table 6-1. In essence, there is relatively little to differentiate in the overall sense among any of the methods that provide for timely execution of the Radial Borehole Tests (i.e., Cases 0, 1a, 2a, 3a and 4a). From a site characterization view, the drill-and-blast/V-Mole method of construction for the second shaft (i.e., Case 4a) offers the best of all alternatives, including timely access for geologic mapping and sampling of shaft walls constructed by two different methods, relatively undisturbed/uncontaminated immediate shaft walls, and an ability to study the presence of perched water in both shafts. The remaining methods (i.e., Cases 1b, 2b, 3b ,4b, 5b, 6b, and 7b) do not provide for transient data from the Radial Borehole Tests, and this is responsible in large part for their lower average rating. Of this latter group, Casees 4b and 7b (drill-and-blast/V-Mole construction of the second shaft) are the preferred options for the same reasons as outlined above.

For this evaluation, the major discriminator among the various options is the timing of the Radial Borehole Tests. If re-evaluation of the data needs by the YMPO were to downgrade the importance of transient data from these tests, there would be relatively little to choose among the various options considered in terms of the impact on test data quality.

6.1.2 Shaft Constructability

In evaluating the compatibility of the various proposed shaft construction methods with the conditions anticipated at the site, consideration has been given primarily to the rock quality and groundwater conditions expected at the locations of the exploratory shafts. Although perched water conditions may be encountered locally, groundwater is not anticipated to be a problem at this site. In order to assess the expected problems with ground control for each of the construction methodologies, preliminary rock mass classifications have been developed for the various units to be penetrated by the shafts. To develop these classifications, use was made of strength and structural data from the volcanic rocks encountered in corehole USW G-4 (Spengler and Chornack, 1984), which is located a few hundred feet from the planned location of the exploratory shafts.

The exploratory shafts will be developed entirely within four members of the Paintbrush Tuff. In descending order, these rhyolitic to quartz latitic ash-flow tuffs are the Tiva Canyon, Yucca Mountain, Pah Canyon and Topopah Spring members. The Tiva Canyon and Topopah Spring members are predominantly densely welded tuffs characterized by low primary porosities and moderate to high degrees of fracturing. The Yucca Mountain and Pah Canyon members are non- to partially welded tuffs characterized by high primary porosities, relatively low degrees of fracturing, high friability and associated poor core recoveries. The Rock Mass Rating (RMR) classification system (Bieniawski, 1976) has been used to define rock quality and considers the following elements:

- Rock Strength - Mechanical properties of intact rock, including design values of uniaxial compressive strength tests, are presented for thermal/mechanical units in the Site Characterization Plan, Table 6-12 (DOE, 1988a). Recommended design values are:

Thermal/ Mechanical Unit	Lithologic Equivalent	Design Uniaxial Compressive Strength Mpa	psi
TCw	Welded, devitrified Tiva Canyon	155	22,500
PTn	Vitric, nonwelded Tiva Canyon, Yucca Mountain, Pah Canyon, Topopah Spring	7	1,000
TSw1	Lithophysal Topopah Spring		
	- lithophysal poor	114	16,500
	- lithophysal rich	18	2,600
TSw2	Nonlithophysal Topopah Spring (potential repository horizon)	171	24,800

Low core recoveries in corehole USW G-4 through the PTn unit suggest that highly friable layers exist within this material. Uniaxial compressive strength tests conducted on recovered core may overestimate the strength of the zones from which no core was recovered.

- Rock Quality - Rock quality for corehole USW G-4 was documented using the CI (core index) descriptor. Since the RMR classification system incorporates the more widely applied RQD (rock quality designation), an estimate of RQD must be developed from available CI and fracture frequency data. There does not appear to be a single, reliable correlation between CI and RQD.

  Based on fracture frequency data for the densely welded tuffs, it is estimated that RQDs are likely to be on the order of 75% for these units. Langkopf and Gnirk (1986) calculated RQD for USW G-4 between depths of 1,112 and 1,293 feet using available drill logs. The fracture frequency within this section of the borehole appears to be typical of the lithophysal/nonlithophysal units of the Topopah Spring. Their calculated average RQD of 79.7% compares well with the estimated value of 75%. Much lower RQDs, ranging from 35% to 48%, were calculated by Langkopf and Gnirk for portions of the Topopah Spring for coreholes UE-25a #1, USW G-1, and USW GU-3, which are located at some distance from the proposed shaft sites.

  While recorded fracture frequencies are low within the non- to partially-welded tuffs, low core recoveries indicated in the drilling records and reflected in the CI values result in substantially lower estimates for RQD of 40%. This unit was not characterized by Langkopf and Gnirk.

- Fracture Frequency - Joint and shear fractures have been documented for corehole USW G-4, and the number of fractures per 10 ft interval has been recorded. Fractures have been recorded for intervals of core run rather than for lengths of core recovered, leading to an underestimate of the true fracture frequency in zones of substantial core loss. The densely welded members indicated a fracture frequency on the order of 1.3 to 2.6 fractures per foot, whereas the non-welded materials indicated a fracture frequency of less than 0.5 fractures per foot.

- Joint Condition - Fracture fillings and coatings for all natural fractures were recorded for corehole USW G-4. In general terms, manganese and iron oxides, with or without silica, form the majority of joint coatings in the members above the Topopah Spring; there are few joints recorded as having clay coatings. Within the Topopah Spring member, most joints are recorded as having no infilling, with silica being the most common infilling. Again, less than five percent of fractures are recorded as containing clay. Overall, about five percent of fractures were characterized as shear fractures based on the presence of slickensides, truncation of pumice fragments, and/or brecciation. These joint infilling characteristics are generally favorable for rock mass quality.

- Joint Orientations - Approximately 13 percent of the core from corehole USW G-4 was oriented to enable orientation of structural features. Foliation and layering within the Topopah Spring member show an average dip of 10 degrees in a direction of 075 degrees. Fracture orientations within the densely welded Tiva Canyon and Topopah Spring members show mainly steeply dipping fracture sets with average orientations of 65/292 and 89/78, respectively.

The above geotechnical information was used to assess rock mass quality for each of the relevant rock units, as indicated in Table 6.2. The data suggest that the densely welded tuffs can be classified as good quality rock, whereas the non-welded tuffs can be classified as fair quality rock. These assessments are consistent with the RMR values developed by Langkopf and Gnirk (1986) for the Topopah Spring member. They concluded that the densely welded portion of the Topopah Spring could be rated as very good to fair quality rock. They did not develop ratings for the non-welded tuffs.

For the anticipated groundwater and rock mass conditions in the vicinity of the exploratory shafts, all of the considered methods of shaft construction are feasible. Conventional (drill-and-blast) construction is the most versatile of the methods and has been rated best of all the options. Similarly, V-Mole construction with a conventionally sunk pilot shaft is well suited to the expected conditions. However, some problems could be encountered when V-Moling past the UDBR, if Shaft 1 is initially constructed to a small diameter by drill-and-blast methods. This method has been ranked slightly lower than conventional construction because of this and the requirement to use unorthodox temporary support of the shaft walls (e.g., fiberglass rock bolts) in order not to interfere with subsequent V-Moling of the shaft. Single-pass raise boring, while technically feasible and rated satisfactory, has been ranked lowest of all the options because of its inability to install support close to the face. There is some uncertainty as to the degree of lithification of parts of the non-welded materials, and there is also an indication (based on very limited data) of unfavorable steep-dipping structure in some of the welded units. Both of these conditions offer the potential for ravelling and degradation of portions of the shaft walls in a relatively large raise-bored shaft which must remain unsupported for a considerable length of time. The Raise Bore/V-Mole construction method has been ranked as good, intermediate between the Single-Pass Raise Bore approach and the drill-and-blast/V-Mole method. Similar concerns for the raise bored pilot shaft, as noted above, apply to this construction method, although any difficulties encountered would be anticipated to be less severe because of the smaller shaft size.

In terms of accommodating unanticipated groundwater conditions and ground support requirements, conventional shaft sinking offers excellent potential for early recognition and mitigation of adverse conditions during construction, and has been rated best. Similarly, the drill-and-blast/V-Mole method of construction would be well suited to controlling adverse groundwater and rock mass quality conditions, and has been rated essentially equivalent to conventional drill-and-blast construction in this regard. Raise boring (rated as satisfactory) is the least versatile of all the techniques in accommodating unanticipated conditions, and poor rock or adverse groundwater can lead to serious difficulties if encountered unexpectedly. The Raise Bore/V-Mole construction method (rated as good) has been rated somewhat more highly than the Single-Pass Raise Bore method in terms of its ability to deal with unanticipated conditions, primarily on the basis of the smaller diameter of the bored raise.

The verticality of the shaft is an important consideration in ensuring that vertical shaft guides can be installed within the confines of the dimensions of the shaft opening. In this regard, the Single-Pass Raise Bore method of construction has been rated lowest (satisfactory) because of accuracy limitations on the drilling of the pilot hole. Current technology would suggest that if extraordinary care is taken with the pilot hole drilling (e.g., frequent deviation corrections and more frequent hole surveys), it is possible to hit a two-foot diameter target at depths on the order of 1000 feet. This might require some modest oversizing of the shaft in order to install completely vertical shaft guides. All other methods of construction (i.e., conventional drill-and-blast, V-Mole) have the capability of constructing a completely vertical shaft and have been rated equally highly (best) in this regard.

Overall constructability ratings for the various combinations of construction methods considered in this study are shown in Table 6.1. Conventional shaft sinking is most highly rated in all the constructability categories, and has been rated best, with drill-and-blast/V-Mole construction rated almost as highly. The remaining construction methods have been ranked in the following order: Raise Bore/V-Mole (good); and Raise Bore (satisfactory). Because conventional shaft sinking and the drill-and-blast/V-Mole method both rank very high, the primary differentiating factor is the method used for constructing the second shaft. Also, the test sequence does not impact constructability.

6.1.3 Health and Safety

Shaft construction can be a relatively hazardous activity for the workers, with a significant likelihood of serious accidents occurring; for example:

- From 1971-1978, the mining industry suffered 44 fatalities directly related to shaft sinking (Overley, 1979).
- During 1978, on a total of 16 shaft projects for metal or nonmetal mines, there were an average of about 7 injuries/project and about 0.3 fatalities/project (Overley, 1979).
- During 1973-1975, the accident frequency rate was about 158 accidents per million man-hours worked, with an average of 14.7 days lost per accident and about 3.6% of the accidents resulting

in fatalities, on shaft sinking projects for metal or nonmetal mines (Dames and Moore, 1977).

The above statistics are primarily for drill-and-blast shaft construction methods in the mining industry, with little information available for other methods or industries. It is anticipated that the safety program implemented at Yucca Mountain will be much more stringent than is typical in the mining industry (Vieth, 1982; Gates, 1982), which should reduce although probably not eliminate the construction hazards for any method chosen. For example, REECo has experienced an accident frequency rate of about 71 accidents per million man-hours worked in drilling shafts at the Nevada Test Site (NTS), which reflects a more stringent safety program as well as possibly differences due to construction methods.

Several studies in the past have examined the differences in health and safety for different shaft construction methods. Although most of these studies evaluated construction methods not relevant to this study, they are useful nevertheless when taken as a whole. These previous studies can be summarized as follows:

- Shaft drilling vs raise boring (Bullock, 1989; Gonano et al, 1982) - Raise boring was considered to be more dangerous than shaft drilling due to the danger from mechanical hangups, inaccessibility of the bit in the hole, and having to muck from under a large raise area.

- Shaft drilling vs conventional shaft sinking (Vieth, 1982; Bertram, 1984; Gonano et al, 1982) - Shaft drilling was considered to be inherently safer, because miners must be down the shaft in conventional mining whereas they will be at the surface most of the time for shaft drilling. Also, the working conditions are better for shaft drilling than for conventional shaft sinking due to the dust and humidity at depth in the shaft.

- Shaft boring machine vs conventional shaft sinking (Irby, 1986) - Shaft boring was considered to be safer because no explosives are used, no high speed hoist is used, no men are at the face, and a protected, lighted work environment is provided, although dust, noise and heat could be worse.

Based on the above and on the experience of the team members, the health and safety associated with each shaft construction method has been subjectively evaluated:

1. Conventional (drill-and-blast) shaft sinking methods are considered to be relatively more hazardous than the mechanical methods, primarily because

   - men must work extended periods at the face under adverse conditions (heat, humidity, dust), exposed to materials possibly falling down the shaft and a short unlined section of shaft above them

- frequent trips up the hoist (where most accidents historically occur)

- explosives are used.

2. Conventional shaft sinking to a small diameter followed by a V-Mole to full ESF diameter is somewhat more hazardous than conventional shaft sinking to full ESF size, because

   - conventional mining of a small size shaft is less safe than mining of a large size shaft due to the constricted work environment and because the shaft will not be lined (only stabilized with rock bolts and possibly shotcrete) above the workers, although otherwise a smaller shaft should be more stable than a large shaft.

   - the V-Mole entails some hazards due to (a) the possibility of mechanical hangups, (b) having a large hole in the floor if workers need access to the face (e.g., to replace cutters in the bit), (c) having to muck from under a large unsupported raise, (d) the machine operator having to work under potentially adverse conditions (noise, dust, heat), and (e) the possibility of having significant sections of shaft unlined above the machine.

3. Raise boring to a small diameter followed by a V-Mole to full ESF diameter is substantially safer than conventional shaft sinking to a small diameter followed by a V-Mole to full ESF diameter, primarily because raise boring is safer than conventional shaft sinking. This is because, although raise boring entails some hazards associated with possible mechanical hangups, inaccessibility of the bit in the hole, and mucking from under a large unsupported raise, it has the following advantages: men are not at the face; no explosives are used; and men are not required in the shaft being constructed.

4. Raise boring to full ESF size is somewhat safer than raise boring to a small diameter followed by a V-Mole to full ESF diameter, primarily because

   - raise boring to a small size is only marginally safer than to a large size

   - the V-Mole entails additional hazards, as previously noted.

Based on the above considerations, the Single-Pass Raise Boring method of shaft construction was rated best of the alternatives considered, with the Raise Bore/V-Mole method rated good and the drill-and-blast method (with or without subsequent V-Mole) rated satisfactory. It should be noted, however, that all of the cases considered as part of this study include at least one of the shafts sunk by conventional drill-and-blast methods (with or without subsequent reaming by V-Mole). The individual shaft construction method assessments were therefore combined to evaluate the health and safety ratings for each of the shaft access methods considered herein. These relative ratings are indicated in Table 6-1, which shows Options 2 and 5 (Raise boring of the second shaft) rated best, Options 3 and 6 (Raise Bore/V-Mole construction of the second shaft) rated good, and the remaining cases which involve conventional drill-and-blast construction in both shafts rated satisfactory. Although it would be marginally safer to defer testing until after construction, this was not significant enough to differentiate among the alternative cases considered.

6.1.4 Schedule

Schedules for each of the 12 cases considered as part of this study are presented in Appendix B. The schedule data are summarized in Table 6-1. These schedules are approximate and are considered suitable for comparing the cited options. However, absolute schedule estimates must necessarily be based on site and project specific requirements. The progress for each case at various points in time is compared in Figures 6-1 through 6-4. As shown and as summarized in Table 6-1:

- Substantial time savings (typically 25 percent) can be made for the present shaft construction method (i.e., two conventionally sunk shafts) by delaying specific testing until completion of shaft sinking. If the Radial Borehole Testing could also be delayed until shaft construction is complete, the time required to establish access for development and testing at the MTL could be almost halved.

- All methods which involve conventional construction of the first shaft and mechanical construction of the second shaft suffer from substantial schedule impacts when compared with the conventional drill-and-blast method of construction of the second shaft, for a corresponding testing sequence, because of sequential rather than parallel shaft development. The most time consuming option is the Raise Bore/V-Mole method, with the least time consuming being the drill-and-blast/V-Mole method.

- Those methods which involve a two stage drill-and-blast/V-Mole method of construction for the first shaft are the most time consuming of all the options considered, for corresponding testing sequences and methods of construction for the second shaft. Even in terms of minimizing the time required to gain first access to the MTL (as opposed to having the shaft outfitted to support MTL development and testing, e.g., mucking, emergency egress), there are apparently no clear-cut schedule benefits associated with construction of a small-diameter pilot shaft. Insofar as excavation advance rates are concerned, for the size of ESF shaft considered, reducing the shaft diameter may actually increase the construction time (e.g, due to shorter rounds, less efficient drilling and mucking related to smaller work area). On the other hand, installing temporary support rather than a concrete liner and deferring mapping would result in some time savings early on. Overall, it is estimated that the schedule benefit in term of first access to the MTL (e.g, to look for a fatal flaw in the relatively limited excavation in and between the two exploratory shafts) would be negligible. In addition, as noted in Table 6-1, this two-stage method of construction would result ultimately in schedule delays associated with subsequent reaming and outfitting of the shaft to support MTL development and testing.

In all cases, the MTL is considered available for development and testing when both shafts are fully lined and outfitted. For testing sequence "b" with the methods which employ a mechanically mined shaft, the final shaft constructed would be used as the post-construction scientific shaft. Under these circumstances, it would not be necessary to line and equip the Scientific Shaft before the MTL could be made available. Instead, the shaft walls would be secured with bolts and mesh where required and emergency hoisting installed. Shaft lining and equipping could then proceed, together with shaft testing, concurrently with development and testing at the MTL. This would have the effect of shortening the schedules for Cases 2b, 3b, 4b, 5b, 6b and 7b by approximately two months.

If a suitable alternative location for the UDBR can be found in the vicinity of the MTL, schedules for all cases considered can be shortened. In general, a schedule savings of about three months would be achieved. For Cases 1b, 4b and 7b, the schedule savings would be somewhat less than this (typically 1.5 to 2 months), because of the flexibility of employing alternative construction sequences for these cases.

For a slower conventional shaft sinking rate than that assumed above, all cases considered would suffer essentially the same schedule delay. For a reduction in the rate of sinking/lining from 6.3 to 4.5 feet per day, the schedule would be extended by approximately two months, which would have little effect on the relative schedules for the various construction methods/testing sequences considered in this study.

6.1.5 Cost

Construction cost estimates have been prepared for each of the 12 alternative cases previously described. The unit cost basis for these estimates incorporate data from the Underground Research Laboratory (URL) project in Canada and recent construction cost estimates from the Salt Repository Project (SRP) in Texas. These unit costs are approximate and are considered suitable for comparing the cited options. However, absolute construction cost estimates must necessarily be based on site and project specific requirements.

The total cost for each alternative case includes the costs to mine, support and outfit the shafts, and approximately 450 ft of underground drifting. Standby costs for instrument installation and testing have been included, whereas the costs associated with labor and material for test installation and subsequent routine monitoring have not been included.

Costs are presented for each activity in Appendix B. Summary costs are presented in Table 6-1. Cost differences are primarily associated with standby time (e.g., between version a and b for each case), manpower savings associated with raise boring the second shaft, and the high capital cost involved with the V-Mole equipment.

6.2 COLLECTIVE EVALUATION ISSUES

In the previous section, as summarized in Table 6-1, each alternative ESF shaft construction method/test sequence has been evaluated with respect to satisfying each of a specific set of criteria independently. However, each alternative must eventually be evaluated with respect to satisfying the entire set of criteria collectively, in conjunction with the consideration of other programmatic factors, in order to make a decision among the various alternatives. If one alternative had been rated best with respect to satisfying each of the criteria, then clearly that alternative would also be best with respect to satisfying the set of criteria considered herein. However, as evidenced in Table 6-1, this was not the case. In the absence of such an ideal alternative, if one alternative had been rated best with respect to one or more criteria which dominate all of the others, then that alternative would again be best with respect to satisfying the set of criteria. For example, if test data quality was the only significant criterion, then (as shown in Table 6-1) Case 4a would be considered the best alternative. On the other hand, if schedule was the only significant criterion, then (as shown in Table 6-1) Case 1b would be considered the best alternative.

However, it is not apparent that one criterion dominates the others to the extent that they can be effectively ignored. In the previous examples, although Case 4a may be best with respect to test data quality, it is rated less desireable with respect to schedule, cost, and health and safety, i.e., improved test data quality is achieved at a price. Similarly, although Case 1b may be best with respect to schedule, it is rated less desireable with respect to test data quality and health and safety. This illustrates that the collective evaluation of alternatives cannot simply focus on satisfying any one criterion, as that approach would result in different overall rankings depending on the criterion considered. Instead, tradeoffs must be made among the attributes addressed by the criteria in order to determine on balance the degree to which the entire set of criteria considered herein are satisfied by each alternative. Such tradeoffs should consider the relative importance of the various criteria, as well as the differences among the alternatives with respect to satisfying each criterion. For example, an alternative which is ranked second best with respect to all criteria may be preferred to an alternative which is ranked best with respect to one or more criteria but substantially lower with respect to the remaining criteria.

Although this study provides the technical input necessary for such tradeoff analyses, in the form of ratings of each alternative with respect to satisfying each criterion independently (Table 6-1), the determination of the relative importance of the various criteria as well as the consideration of other programmatic factors, and thus the resulting collective evaluations of alternatives, is outside the scope of this study.

Table 6-1. Summary Evaluation of Alternative ESF Shaft Construction Methods/Testing Sequences (page 1 of 3)

SHAFT CONSTRUCTION METHOD/TEST SEQUENCE (see Table 4-1)[a]	EVALUATION CRITERIA				
	TEST DATA QUALITY[b]	CONSTRUCT-ABILITY[b]	SCHEDULE (months)[c]	HEALTH/ SAFETY[b]	COST (US$Million)[c]
Conventional (Shafts 1 and 2)					
Case 0-All Testing In Line	good+	best	26.4	satis.+	25.6
Conventional (Shafts 1 and 2)					
Case 1a-Delay Thermo/ LRBT (Part)	good+	best	18.7	satis.+	21.9
Case 1b-Delay Thermo/ all RBT	good	best	13.5	satis.+	19.1
Conventional (Shaft 1), Single-Pass Raise Bore (Shaft 2)					
Case 2a-Delay Thermo/ LRBT (Part)	good+	satis.	27.3	best	20.7
Case 2b-Delay Thermo/ all RBT	good	satis.	22.0	best	18.1
Conventional (Shaft 1), Raise Bore/V-Mole (Shaft 2)					
Case 3a-Delay Thermo/ LRBT (Part)	best	good	29.2	good	24.4
Case 3b-Delay Thermo/ all RBT	good	good	24.0	good	21.7

Table 6-1. Summary Evaluation of Alternative ESF Shaft Construction Methods/Testing Sequences (page 2 of 3)

Conventional (Shaft 1), Conventional/V-Mole (Shaft 2)					
Case 4a-Delay Thermo/ LRBT (part)	best	best	26.3	satis.+	27.1
Case 4b-Delay Thermo/ all RBT	good	best	19.5	satis.+	24.5
Conventional/V-Mole (Shaft 1), Single-Pass Raise Bore (Shaft 2)					
Case 5b-Delay Thermo/ all RBT	good	satis.	26.7	best	22.7
Conventional/V-Mole (Shaft 1), Raise Bore/V-Mole (Shaft 2)					
Case 6b-Delay Thermo/ all RBT	good	good	28.6	good	25.3
Conventional/V-Mole (Shaft 1), Conventional/V-Mole (Shaft 2)					
Case 7b-Delay Thermo/ all RBT	good	best	25.8	satis.+	27.9

Notes:

[a] In both versions "a" and "b," the UDBR is constructed in-line, but the thermomechanical testing in the UDBR is delayed. In version "a," the SRBT's are conducted and the LRBT's are installed in-line, but the additional LRBT testing is delayed. In version "b," all the RBT's are delayed.

Table 6-1. Summary Evaluation of Alternative ESF Shaft Construction Methods/Testing Sequences (page 3 of 3)

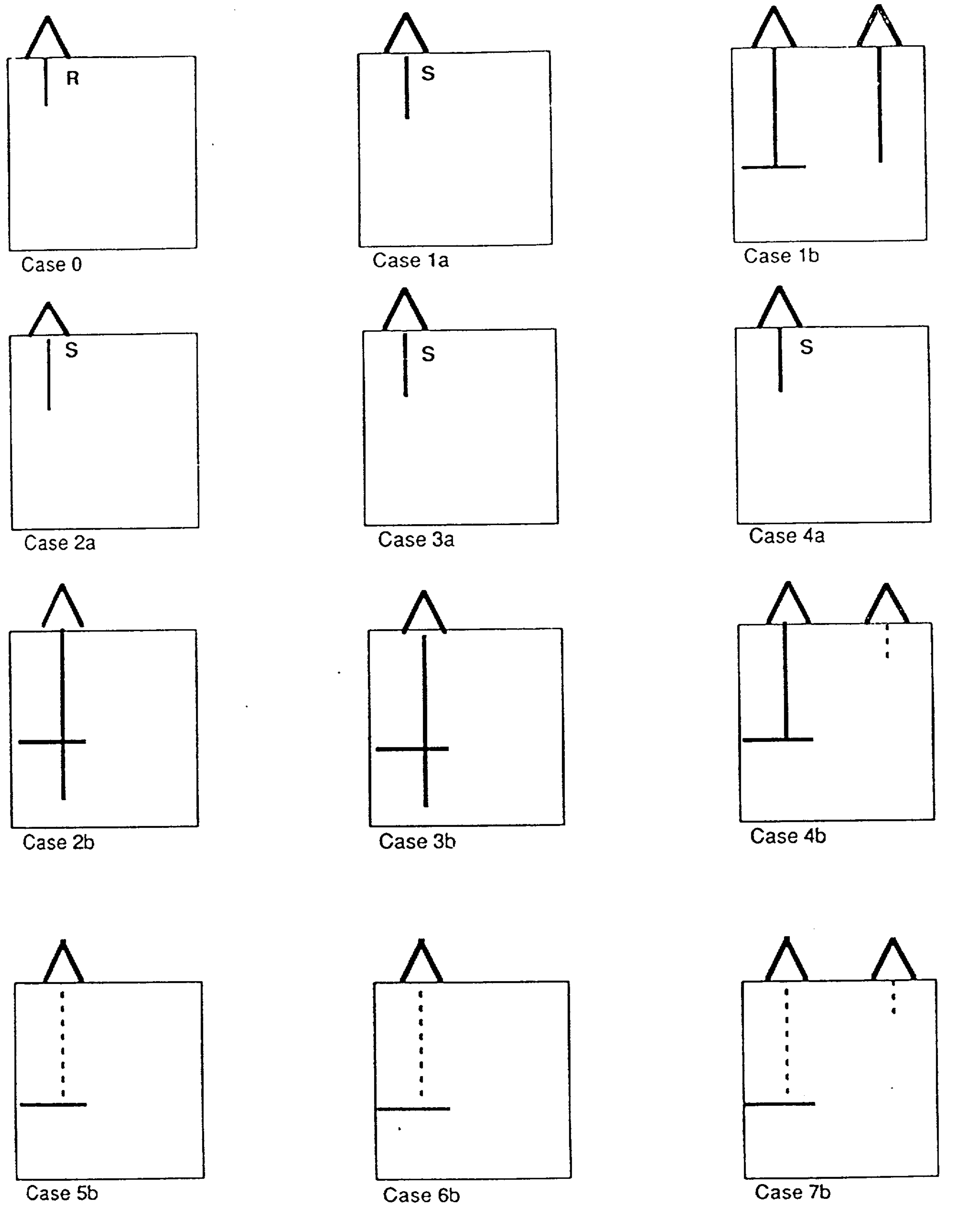
(b) Each case is rated qualitatively with respect to satisfying the criterion in terms of best, good or satisfactory (see Section 5.3). It should be noted that all of the cases evaluated were considered to be acceptable with respect to satisfying each of the above criteria. A "+" indicates that the case is rated between this and the next higher rating (i.e., "good+" rates between good and best). Additional detail is given in Table 7-1, which also indicates the preferred methods, if any, within each of the qualitative ratings.

(c) Cost and schedule should be considered to be approximately correct, only in a relative and not in an absolute manner. Comparisons of construction methods should be made among cases 1a, 2a, 3a, and 4a (or 1b, 2b, 3b, 4b, 5b, 6b and 7b), whereas comparisons of testing sequences should be made among versions 0, a, and b.

Table 6-2. Rock Mass Quality

DENSELY WELDED TIVA CANYON MEMBER (41-118 ft depth)	RATING
Strength (22,500 psi estimated)	12
RQD (75% estimated)	15
Joint Spacing (2.6/ft)	8
Joint Condition	20
Groundwater (dry)	10
Joint Attitude Adjustment	-5
RMR	60
	Good Rock, Class II
NON-WELDED TUFF (118-239 ft depth)	**RATING**
Strength (500 psi estimated)	0
RQD (40% estimated)	8
Joint Spacing (<0.5/ft)	20
Joint Condition	20
Groundwater (dry)	10
Joint Attitude Adjustment	-5
RMR	53
	Fair Rock, Class III
DENSELY WELDED TOPOPAH SPRING MEMBER (239-1345 ft depth)	**RATING**
Strength (16,500 psi, assumed to be mostly lithophysal poor)	10
RQD (75% estimated)	15
Joint Spacing (1.3/ft)	10
Joint Condition	20
Groundwater (dry)	10
Joint Attitude Adjustment	-3
RMR	62
	Good Rock, Class II

Note: The rock mass classification system is based on Bieniawski (1976).



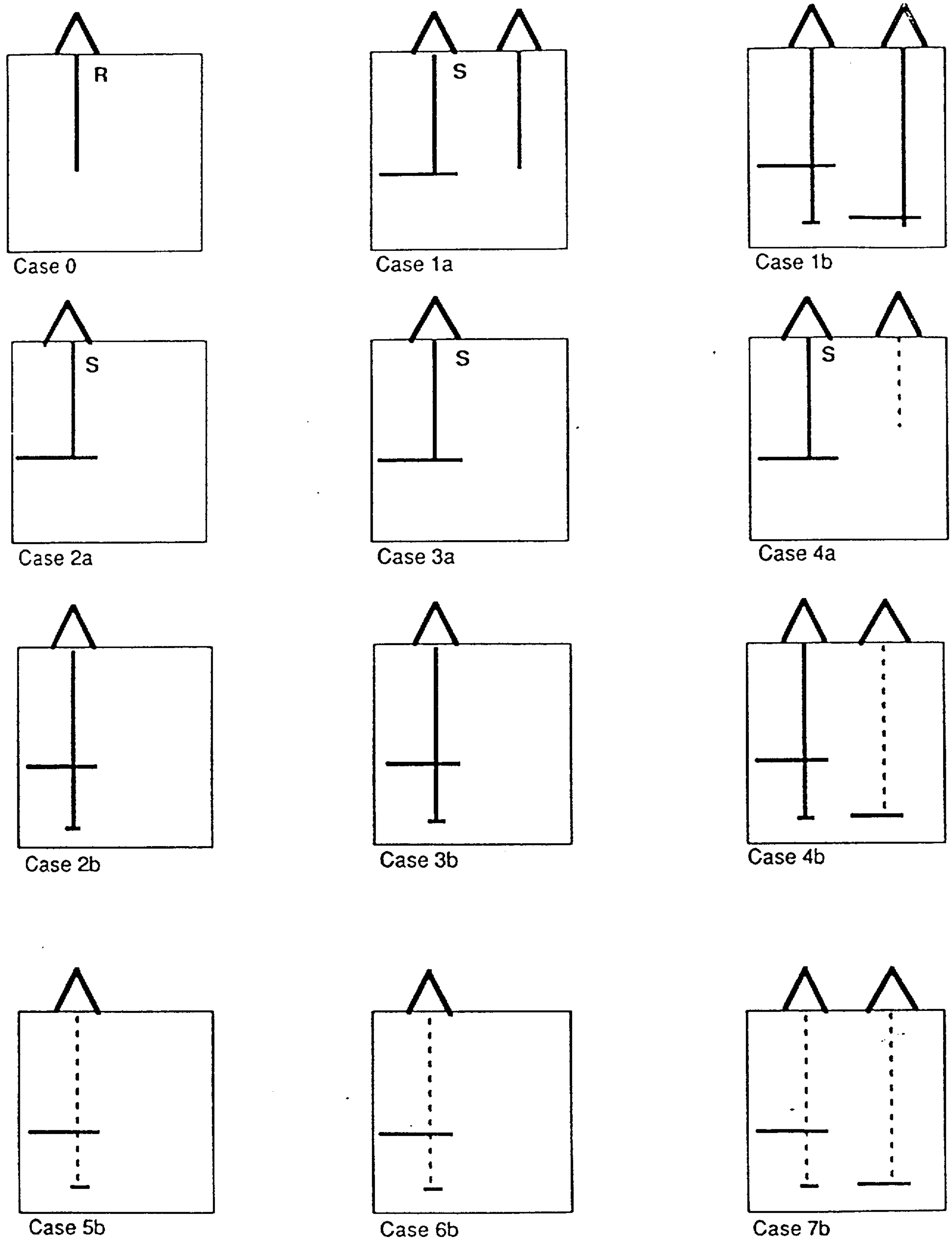
Key:
T - Thermomechanical Testing In UDBR
R - All Radial Borehole Tests (LRBTs and SRBTs)
S - SRBTs and part of LRBTs
- - - - Excavated, but unlined
—— Lined and equipped

NOT TO SCALE

FIGURE 6.1
COMPARISON OF PROGRESS OF ALTERNATIVE ESF CONSTRUCTION METHODS/TEST SEQUENCES AT 6 MONTHS

PROJECT NO. 833-1017.116 DWG. NO. 20067 DATE 8/31/89 DRAWN DC APPROVED WR

Golder Associates Inc.



Key:

T - Thermomechanical Testing in UDBR

R - All Radial Borehole Tests (LRBTs and SRBTs)

S - SRBTs and part of LRBTs

- - - - Excavated, but unlined

—— Lined and equipped

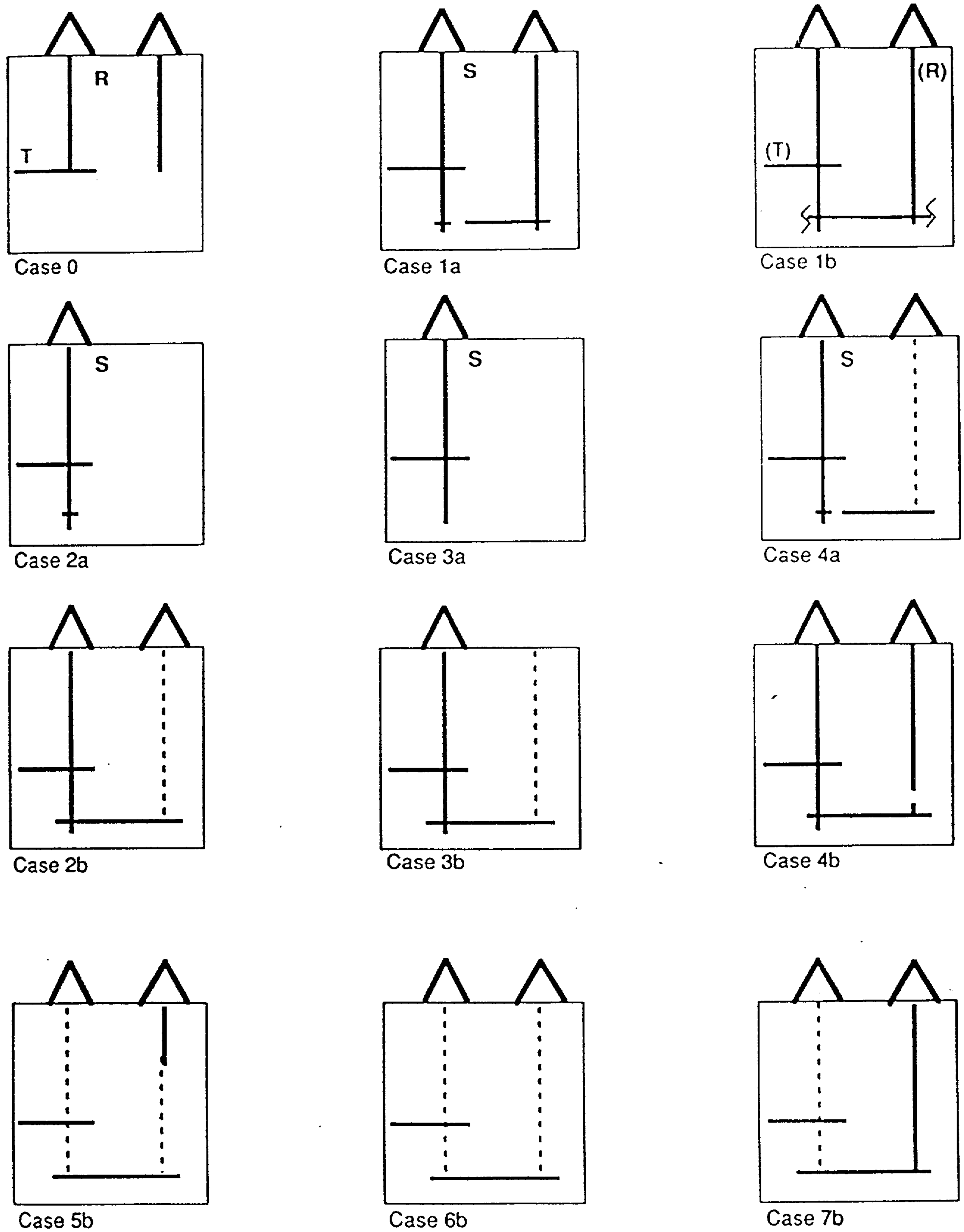
NOT TO SCALE

FIGURE 6.2

COMPARISON OF PROGRESS OF ALTERNATIVE ESF CONSTRUCTION METHODS/TEST SEQUENCES AT 12 MONTHS

PROJECT NO. 833-1017.118 DWG. NO. 20088 DATE 8/31/89 DRAWN DC APPROVED WR

Golder Associates Inc.



NOT TO SCALE

Key:

T - Thermomechanical Testing in UDBR

R - All Radial Borehole Tests (LRBTs and SRBTs)

S - SRBTs and part of LRBTs

- - - - - Excavated, but unlined

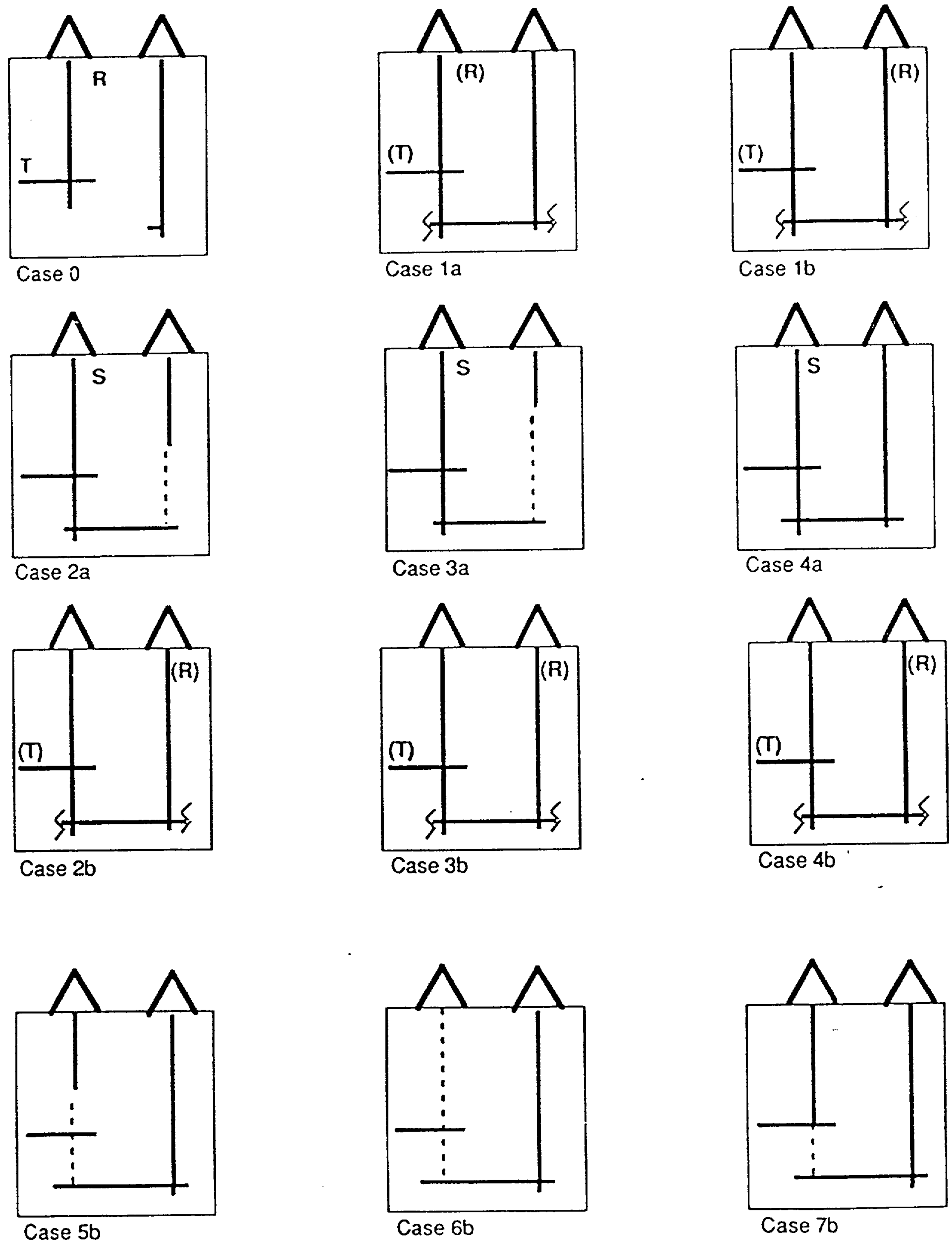
——— Lined and equipped

FIGURE 6.3

COMPARISON OF PROGRESS OF ALTERNATIVE ESF CONSTRUCTION METHODS/TEST SEQUENCES AT 18 MONTHS

PROJECT NO. 833-1017.116 DWG. NO. 20089 DATE 8/31/89 DRAWN DC APPROVED WR

Golder Associates Inc.



NOT TO SCALE

Key:

T - Thermomechanical Testing in UDBR

R - All Radial Borehole Tests (LRBTs and SRBTs)

S - SRBTs and part of LRBTs

- - - - - Excavated, but unlined

——— Lined and equipped

FIGURE 6.4

COMPARISON OF PROGRESS OF ALTERNATIVE ESF CONSTRUCTION METHODS/TEST SEQUENCES AT 24 MONTHS

PROJECT NO. 833-1017.116 DWG. NO. 20088 DATE 8/31/89 DRAWN DC APPROVED WR

Golder Associates Inc.

7.0 CONCLUSIONS AND RECOMMENDATIONS

A representative set of potentially viable alternative methods for constructing the two ESF shafts and of test sequences at Yucca Mountain have been identified and systematically evaluated with respect to a project-specific set of criteria, consistent with the suggestions of the Structural Geology and Geoengineering Panel of the Nuclear Waste Technical Review Board (NWTRB panel) in their meeting of April 11-12, 1989.

The primary conclusions of this study regarding the evaluation of each alternative with respect to each criterion are summarized in Table 7-1. The conclusions are as follows:

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

- All permutations of shaft construction methods considered are capable of generating good quality test data. The primary discriminator among the various options evaluated is the ability to provide early-time transient test data (including monitoring construction fluid invasion) for the Radial Borehole Tests. There are significant schedule and cost penalties associated with a requirement to perform the Radial Borehole Tests in-line with shaft construction. On the other hand, if such data are critical, testing sequences which delay the Radial Borehole Tests must be considered to provide significantly lower quality test data.

- All construction methods evaluated are considered technically feasible (i.e., based on demonstrated technologies) for anticipated ground conditions at the planned location for the exploratory shafts. From a constructability viewpoint, the conventional drill-and-blast method of construction is considered the most reliable while single-pass raise boring is considered to be the method subject to most uncertainty.

- From a health and safety perspective, conventional drill-and-blast shaft construction (with or without subsequent V-Moling) is rated as satisfactory but lowest of the methods considered, whereas raise boring (assuming no access to face is attempted) is considered to be best. For all methods of accessing the MTL considered in this study, however, at least one of the shafts is constructed conventionally (with or without subsequent V-Moling). This fact tends to dampen the inherent construction method health and safety differences among the various options evaluated.

- There are significant schedule differences among the methods considered, and these derive from both the construction method itself and the associated testing sequencing. The most significant points with respect to schedule are:

- For comparable testing sequences, conventional shaft sinking for both shafts results in significantly shorter schedules (i.e., time required before the MTL is available for development and testing) because the two shafts can be developed in parallel rather than sequentially.

- Delaying all in-line testing for which transient data are not an issue will result in relatively large construction time savings.

- The Radial Borehole Tests, which are presently assumed to be carried out in-line with shaft construction, have a relatively large adverse effect on the construction schedule.

- If an alternative location for the UDBR and associated testing (including the Excavation Effects Test) can be found such that the UDBR can be removed from the shaft construction critical path, further significant schedule reductions can be achieved. If the UDBR must be accessed from one of the exploratory shafts, as presently envisaged, it is considered preferable to construct the UDBR in-line with shaft construction and suffer the associated schedule delays, rather than attempt to construct the UDBR following shaft construction. The latter approach would suffer additional construction difficulties and would probably result in disruption to MTL activities in any case. Notwithstanding the scheduling of the UDBR construction, all testing within the UDBR for which transient data are not an issue should be delayed until completion of shaft construction.

- There is the potential for further schedule savings if the Radial Borehole Tests can be delayed until completion of shaft sinking and if these tests can be performed in a mechanically mined shaft. In this case, it has been assumed that most post-construction scientific testing would be performed in a mechanically mined shaft and that it would not therefore be necessary to line and equip this shaft (except for emergency egress) before the MTL could be made available.

- There appears to be no schedule benefit to a two-stage construction of the first shaft, involving conventional construction of a smaller diameter pilot shaft followed by reaming to full ESF shaft size. In terms of completion of the shafts to the stage where they can support MTL development, the two-stage first shaft scenario suffers typically a 20 to 25 percent increase in schedule compared to corresponding access methods involving a first shaft conventionally sunk to full size. It is also unlikely that conventionally sinking a smaller diameter pilot shaft will result in faster initial access to the MTL, for the sizes of shaft considered, as a result of construction inefficiencies associated with such small-sized openings.

The schedule effects of construction methods and of test sequences are summarized in Table 7-2.

- There is a substantial spread in the estimated relative costs for the various construction methods/test sequences evaluated. The current base case (conventional shaft construction with all testing performed in-line) and options involving use of the V-Mole lie towards the upper end of the cost spectrum. Conventional drill-and-blast construction of both shafts and raise boring of one of the shafts (both with delayed testing, wherever possible) represent the lower cost alternatives, with some cost advantage to the Raise Bore option.

- With respect to the NWTRB panel's suggestions regarding alternative ESF shaft construction methods/test sequences:

  - Substantial schedule and cost benefits, and marginal health and safety benefits, can be achieved by delaying and possibly relocating specific aspects of the test program, without a significant adverse impact on test data quality.

  - Although mechanical excavation of the second shaft offers benefits with regard to improving test data quality and health and safety, it has a significant schedule penalty due to sequential (rather than parallel) development with the first shaft.

  - Subsequent reaming of a conventionally sunk small diameter first shaft offers no significant benefit in terms of early limited access to the MTL (because an unlined small diameter shaft would take about as long to sink as a lined larger diameter shaft) or in terms of test data quality (because there is no additional testing), and instead results in increased costs and a schedule delay in terms of availability of the MTL for testing and development (because the shaft must first be reamed, lined, and equipped).

- The optimum construction method/testing sequence, from the point of view of maximizing satisfaction of the various criteria considered herein, will depend on the relative importance assigned to each of the criteria.

Based on the above conclusions, the following recommendations are made:

- Regarding test data quality

  - The requirement for conducting the Short Radial Borehole Tests in-line with shaft construction should be reconsidered in light of the significant impact this test has on schedule.

  - The possible relocation of the UDBR (and the associated testing) out of the shaft (e.g., accessed from a ramp from the MTL) should be considered in light of the significant impact its construction has on schedule.

- The various alternatives should be re-evaluated if the information needs or the criteria change.

- The relative importance of the various criteria should be established so that, in conjunction with the technical evaluations contained in this study regarding the degree to which each alternative satisfies each criterion independently, tradeoffs among the criteria evaluated herein can be made and considered with other programmatic factors, and a collective evaluation of each alternative can be performed.

Table 7-1. Simple Ranking of Alternative ESF Shaft Construction Methods/ Testing Sequences with Respect to Each Criterion (Page 1 of 2)

a) Qualitative Criteria[a]

	TEST DATA QUALITY	CONSTRUCTABILITY	HEALTH AND SAFETY
Best	Cases 3a, 4a*	Cases 0*, 1a*, 1b*, 4a, 4b, 7b	Cases 2a, 2b, 5b
Good+	Cases 0*, 1a*, 2a		
Good	Cases 1b, 2b, 3b, 4b*, 5b, 6b, 7b*	Cases 3a, 3b, 6b	Cases 3a, 3b, 6b
Satisfactory+			Cases 0, 1a, 1b, 4a, 4b, 7b
Satisfactory		Cases 2a, 2b, 5b	

b) Quantitative Criteria[b]

SCHEDULE (Months)	COST (Million $)
Case 1b (13.5)	Case 2b (18.1)
Case 1a (18.7)	Case 1b (19.1)
Case 4b (19.5)	Case 2a (20.7)
Case 2b (22.0)	Case 3b (21.7)
Case 3b (24.0)	Case 1a (21.9)
Case 7b (25.8)	Case 5b (22.7)
Case 4a (26.3)	Case 3a (24.4)
Case 0 (26.4)	Case 4b (24.5)
Case 5b (26.7)	Case 6b (25.3)
Case 2a (27.3)	Case 0 (25.6)
Case 6b (28.6)	Case 4a (27.1)
Case 3a (29.2)	Case 7b (27.9)

Table 7-1. Simple Ranking of Alternative ESF Shaft Construction Methods/ Testing Sequences with Respect to Each Criterion (Page 2 of 2)

Note: See Tables 4-1 and 6-1 for a description and evaluation of each case, respectively.

[a] All of the cases were considered to be acceptable with respect to each of the above criteria. A "*" indicates a preference within a category, and thus additional detail in the ratings.

[b] Schedules and cost estimates are approximate and suitable for comparisons only; they are not intended to be accurate absolute estimates.

Table 7-2. Comparison of Schedules for Alternative ESF Shaft Construction Methods/Testing Sequences (Page 1 of 2)

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) 26.4	(Case 1a) 18.7	(Case 1b) 13.5
(2) Drill-and-Blast Shaft 1, Raise Bore Shaft 2	35.0	(Case 2a) 27.3	(Case 2b) 22.0
(3) Drill-and-Blast Shaft 1, Raise Bore/ V-Mole Shaft 2	36.9	(Case 3a) 29.2	(Case 3b) 24.0
(4) Drill-and-Blast Shaft 1, Drill-and-Blast/V-Mole Shaft 2	34.0	(Case 4a) 26.3	(Case 4b) 19.5
(5) Drill-and Blast/ V-Mole Shaft 1, Raise Bore Shaft 2	--	--	(Case 5b) 26.7
(6) Drill-and-Blast/ V-Mole Shaft 1, Raise Bore/V-Mole Shaft 2	--	--	(Case 6a) 28.6
(7) Drill-and-Blast/ V-Mole Shaft 1, Drill-and-Blast/V-Mole Shaft 2	--	--	(Case 7b) 25.8

Table 7-2. Comparison of Schedules for Alternative ESF Shaft Construction Methods/Testing Sequences (Page 2 of 2)

Notes: Schedule is expressed in terms of the expected length of time (in months) from initiation of shaft sinking until MTL is available for development and full-scale testing. These schedules are approximate and suitable for comparisons only; they are not intended to be accurate absolute estimates. The schedules for Cases 2, 3, and 4 with all testing conducted in-line were developed by adding the time associated with the mechanical testing in the UDBR and the retesting of the long radial boreholes (i.e., 7.7 months) to the schedule for version "a." Additional schedule savings would result if the UDBR were relocated out of the shaft (i.e., on the order of 1.5 to 3 months) or if lining of the scientific shaft could be delayed for Cases 2b, 3b, 4b, 5b, 6b or 7b (i.e., on the order of 2 months).

(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 Borehole Tests until after shaft construction.

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APPENDIX A

IMPLEMENTATION PLAN AND QUALITY ASSURANCE PROGRAM PLAN

Golder Associates Inc's Implementation Plan, incorporating a Quality Assurance Program Plan, under which the study described in this report was conducted is attached.

Golder Associates Inc.
CONSULTING ENGINEERS

May 10, 1989

Our ref: 833-1017.116

Battelle Project Management Division
Office of Waste Technology Development
7000 S. Adams Street
Willowbrook, IL 60521

ATTENTION: Mr. Alan Yonk

RE: PLANS FOR EVALUATION OF ALTERNATIVE
ESF ACCESS CONSTRUCTION METHODS

Dear Alan:

I have attached revised drafts of our implementation plan and report outline for the subject task. The QAPP previously submitted on May 5, 1989 remains unchanged. The implementation plan and report outline have been revised based on discussions held with the following people in our office on May 9, 1989:

D. Stucker - DOE/OFSD
R. Lark - DOE/RTP
C. Quan - DOE/OSIR
P. Kumar - Weston
W. Haslebacher - Weston

The plan and outline have not yet been revised to reflect discussions during a conference call with Ram Lahoti and representatives of the project this morning. In those discussions emphasis was placed on following the TRB suggestions explicitly and not considering ramps as an option for accessing the repository horizon at this time. Please call if you have questions or comments.

Sincerely,

GOLDER ASSOCIATES INC.

Donald M. Caldwell

Donald M. Caldwell

DMC/keh

Attachment

cc: R. Lahoti, DOE, Washington
D. Stucker, DOE, Washington
S. Webster, DOE, Chicago
R. Lark, DOE, Chicago
J. Robson, DOE, Las Vegas
A. Girdley, DOE, Las Vegas
M. Cline, Weston, Washington
W. Haslebacher, Weston, Washington
P. Kumar, Weston, Washington

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EVALUATION OF ALTERNATIVE ESF ACCESS CONSTRUCTION METHODS

IMPLEMENTATION PLAN

PURPOSE/SCOPE

The purpose of this study is to identify alternative ESF access construction methods, and to then evaluate them technically with respect to a defined set of criteria using an established methodology. As a first step in the study, the information needs and related test programs identified in the SCP as relevant to the ESF access ways will be reviewed. It will be assumed that the site characterization and repository design information needs must be satisfied, and that the tests for satisfying these information needs are thus required. However, in some cases, these information needs might not have to be satisfied immediately (during ESF access construction) and can be deferred until later (after ESF access construction has been completed). Some of the other information needs are related to assessing the impacts of ESF access construction. These construction related information needs might change if the construction method changes. Hence, in addition to possibly deferring some tests, other tests may be modified or even eliminated if the construction method changes.

A representative set of alternative construction methods for developing the two ESF access ways will be identified, and a methodology for evaluating each potential combination of construction methods will be developed. In essence, each feasible combination of construction methods will be evaluated with respect to a specific set of criteria. First and foremost, each combination must be able to satisfy the testing requirements, possibly as redefined above. Other criteria (e.g., regarding schedule, cost, safety, quality of information, site integrity, program flexibility, repository integration, etc.) will also be identified.

A knowledgeable group will be assembled, whose members (1) are independent of the original analyses and decisions which lead to the current ESF construction method, (2) have expertise in mining engineering and earth sciences, and (3) have sufficient knowledge of the SCP and underlying regulatory framework. This group will then evaluate each identified alternative construction method with respect to the criteria, using the established evaluation methodology.

WORK TASKS

The work described above will be conducted under five separate tasks.

Task 1 - Review SCP ESF Shaft Information Needs and Testing Requirements

The initial activity will involve a review of the information needs to be addressed from the access ways (shafts, ramps), and the currently planned testing program to satisfy these information needs, as specified in the SCP and supporting documents (see Figure 1). The information needs and related tests will be subsequently classified according to whether they are concerned with basic site characterization and/or repository design, or with determining the effects related to the particular method of constructing the ESF access way. It will be assumed that the information needs related to site characterization and/or repository design are valid and must be satisfied by testing in the ESF access ways. The tests will be further classified according to flexibility with respect to timing and location. In the case of tests designed to evaluate a particular method of construction, the potential for eliminating or modifying the test if the method of construction is changed will be assessed. These information needs and related tasks will be discussed with DOE/YMPO staff.

Task 2 - Identify Alternative ESF Access Construction Methods

A wide variety of construction methods is available for developing the two ESF access ways. Clearly, the first access way must be constructed from the top-down, whereas the second access way could be constructed either from the top-down (in parallel with the first) or from the bottom-up (in sequence with the first). The various possible combinations of the two ESF access ways are shown in the matrix of Table 1, with the alternative construction method for the first access listed down the left hand side and the alternative construction method for the second access listed across the top. Some methods, which would clearly not be suitable, have not been listed, including: (1) raise boring a shaft on a second pass; (2) drill-and-blast a small size shaft followed by slashing to full ESF size; and (3) drilling or blind boring a shaft to a small size followed by enlarging to full ESF size. Various combinations of the identified shaft and/or ramp construction methods are possible, although some of these combinations may be obviously inferior and should not be considered further. For example: (1) shaft drilling (wet) should not be considered further due to possible contamination of the site; (2) shaft blind boring should not be considered further because it has not been demonstrated under similar conditions; (3) ramps should not be considered for the second access way, because at least one shaft should be used and, if a ramp is used, it should be the first access way so that the shaft can be raised; and (4) raising the second shaft with enlarging by drill-and-blast is not as good as using mechanical methods.

Intuitively, based on experience and a knowledge of the relevant objectives for the ESF access ways, the following combinations of construction methods for ES-1 and ES-2 appear to offer the most advantages, and are thus proposed for further evaluation:

1. Sink two full size ESF shafts by drill-and-blast in parallel.

   a) Virtually all testing is conducted in ES-1 during construction. This is the current base case.

   b) Only immediate access (in-line) testing is performed during shaft sinking, whereas the remaining testing is undertaken in the shaft after access to the repository horizon has been achieved.

2. Sink ES-1 to either full size ESF diameter or possibly to some minimum diameter (e.g., 9 feet) by drill-and-blast, without any testing. After access to the repository horizon has been achieved, raise bore ES-2 to a suitable diameter to permit inspection and conduct scientific testing.

Finally, enlarge ES-1 and ES-2 (if they were not initially constructed to full ESF size) by mechanical means (e.g., V-mole). This is essentially the alter native suggested by the TRB.

3. Construct a ramp (as designed for the repository) with a TBM (or mechanical miner), conducting only immediate access testing and testing that does not impact the ramp construction schedule (e.g., in test adits constructed off the ramp). Raise bore a shaft to suitable diameter to permit inspection and conduct scientific testing. Finally, enlarge the shaft to ESF full size diameter (if it was not initially constructed to full size ESF diameter) by mechanical means (e.g., V-mole).

Approval for the ESF access way construction methods to be evaluated will be obtained from DOE/OFSD on May 12, 1989. Subsequently, they will be discussed with DOE/YMPO staff.

Task 3 - Develop Evaluation Methodology and Criteria

A methodology for evaluating the various ESF access way construction methods will be developed. This methodology will consist of first identifying specific criteria, related to the ESF access way objectives/requirements. These criteria will include those previously identified by DOE/OFSD and those identified in the SCP and supporting documents, as well as in 10 CFR 60. Based on this information, and on our experience and knowledge of the program, the following criteria appear to be most significant in evaluating the ESF access way construction methods:

- o Ability to satisfy the information needs - quality of the test data.

  According to the particular information need and associated test being considered, this may involve consideration of some or all of the following factors (from Task 1):

  - potential for timely access to make direct observations of conditions or performance, install instrumentation in a timely manner, and take representative samples.
  - ability to permit testing at appropriate locations in order to provide data which is representative of the site in general.
  - ability to provide repository design information.
  - potential for adverse impacts (construction/operation to test interference) of the construction method on the quality of the data, i.e., ability to characterize the site.

- o Compatibility with site conditions - the extent to which the construction methodology is based on a technology which has been demonstrated under similar conditions to those anticipated at the site.

- o Schedule - construction time required to access the repository horizon, taking into consideration those tests that must be performed in-line with construction (note: project delays due to changes in the program will be considered elsewhere as a programmatic impact).

- o Degree of disturbance to the rock around the ESF access way due to the construction methodology.

- o Efficiency in construction/operation of the ESF.

- o Flexibility for changes or additions to testing related to the licensing process (per Regulatory Guide 4.17), including providing subsequent access to a lower test level (200 ft below repository horizon) in the Calico Hills formation where construction induced disturbance would be of greater concern.

- o Potential for (1) integration into the repository design/construction/operation/reclamation/sealing (including the possible continued use of the ESF for long-term performance confirmation testing), (2) repository development schedule impacts, and (3) limiting the total number of penetrations (associated with both the ESF and the repository) to the repository horizon.

- o Occupational health and safety (including consideration of ground support).

- o Cost (ballpark, including consideration of construction, ground support, and outfitting).

Approval for the criteria to be used in evaluating the ESF access way construction methods will be obtained from DOE/OFSD on May 12, 1989.

Once the criteria have been established, the various ESF access way construction methods will be technically evaluated with respect to satisfying each criterion (see Task 4). This evaluation will be accomplished by assessing and summarizing the likely characteristics of each method vis a vis the criteria. Due to the short time frame available, these assessments will be based largely on available information and on the experience and judgement of the team members. In some cases (where scales do not readily exist), scores (e.g., on a scale of 0-10) will be assigned to each method which reflect how well each criterion is satisfied relative to the other methods. For example, a score of ten for one method with respect to one criterion would suggest that it satisfies that criterion completely, whereas a score of five for a different method with respect to the same criterion would suggest that it satisfies that criterion only half as well. Both the criteria and their scales will be clearly documented in the report (see Task 5).

The determination of the relative importance of the various criteria involves tradeoffs among competing objectives. This is a "value" rather than a technical assessment, which will be necessary to evaluate each method with respect to satisfying the <u>collective</u> set of criteria and to then rank the methods on this basis. Such "value" judgments should be made by DOE rather than the consultant, who should be restricted to technical assessments. Hence, the technical input required to make such collective evaluations will be provided to DOE/OFSD, so that they can then apply their "value" judgements.

Task 4 - Evaluate Alternatives with Respect to Criteria

The various ESF access way construction methods (from Task 2) will be technically evaluated with respect to satisfying each criterion (from Task 3). These assessments will be developed by qualified technical staff in a workshop environment. The logic used in making these assessments, including any relevant references, will be documented in the report (see Task 5).

Task 5 - Management and Prepare Report

This study will be managed as discussed under the following sections entitled SCHEDULE, ORGANIZATION and QUALITY ASSURANCE. Weekly status reports, focussing on deviations from this plan and on workarounds, will be submitted to the DOE/OFSD Lead Representative. All integration meetings and correspondence will be controlled through the DOE/OFSD Lead Representative. As noted under SCHEDULE, several such meetings are planned.

A report will be prepared which documents the results of Tasks 1 - 4. A draft outline for this report is presented as an attachment to this plan. Approval for this draft outline will be obtained from DOE/OFSD on May 12, 1989.

The draft report will be less than 50 pages (exclusive of appendices) and will be submitted to DOE/OFSD by June 2, 1989. Subsequent to review and revision (as required), the final report will be submitted to DOE/OFSD by June 21, 1989. This final report will require acceptance by the DOE/OFSD Director.

SCHEDULE

Date	Activity
Every Thursday	Status Report to DOE/OFSD
5/3-5/89	Contractor Develops Plan
5/9/89	Contractor Presents Plan at Meeting in Seattle
5/12/89	DOE/OFSD Approves Contractor Plan
5/10-17/89	Task 1 - Review ESF Access Information Needs/Testing
5/10-17/89	Task 2 - Identify ESF Access Construction Methods
5/10-17/89	Task 3 - Develop Evaluation Methodology/Criteria
5/16/89	Meeting with Project in Las Vegas, if necessary

5/18-26/89	Task 4 - Evaluate ESF Access Construction Methods
5/29-6/1/89	Task 5 - Develop Draft Report
6/2/89	Contractor Submits Draft Report
6/5-8/89	DOE/OFSD Reviews Draft Report
6/9/89	Review meeting in Denver
6/12-15/89	Contractor Finalizes Draft Report
6/16/89	Meeting in Washington DC: Contractor Briefs DOE Management DOE Accepts Draft Final Report
6/21/89	Contractor Submits Final Report
6/26-27/89	Contractor Attends TRB Meeting in Las Vegas

ORGANIZATION

The following Golder Associates Inc. staff, with the noted responsibilities, are planned to be utilized on this project; others may be involved as the need arise:

Person	Responsibility
D. Caldwell	Project Manager Contributor - Task 5
J. Byrne	Manager - Task 2, 4. Contributor - Tasks 1, 3, 5
W. Roberds	Manager - Tasks 1, 3, 5 Contributor - Tasks 2, 4
D. Pentz	Contributor - Tasks 1-5
C. Breeds	Contributor - Tasks 1, 2, 4
K. Mathews	Contributor - Tasks 2, 4
J. Conway	Contributor - Task 4
F. Shuri	Contributor - Task 4
G. Elliot	Contributor - Task 4
C. Wilson	Contributor - Tasks 1,4

QUALITY ASSURANCE

This evaluation has been designated by the client as Quality Level III. Elements of Golder Associates' QA Program, which is designed to meet the requirements of 10 CFR 50 Appendix B as interpreted by ANSI/ASME NQA-1 and the NRC Review Plan, will be selected and applied as appropriate for the designated level of quality and required activities. A Quality Assurance

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Program Plan (QAPP) describing the appropriate QA program elements and identifying the implementing QA Procedures will be prepared and approved within Golder Associates, and then submitted to the client for final approval. Implementing Golder Associates QA Procedures will be as follows:

P-2.0-1, "Training and Orientation"
P-3.0-2, "Specific Work Instructions"
P-5.0-1, "Distribution and Control of Golder Associates Procedures
P-6.0-2, "Control of Correspondence and Communications"
P-10.0-1, "Technical Review"
P-17.0-1, "Quality Assurance Records Management"

Controlled copies of the QAPP and implementing QA procedures will be issued to project personnel performing or supervising the work.

TABLE 1

COMBINATIONS OF ALTERNATIVE ESF ACCESS CONSTRUCTION METHODS

Methods to Construct First Access	Methods to Construct Second Access										
	Shaft-Drill & Blast Full Size	Shaft-Raise Bore Full Size	Shaft-Raise Bore Small Size/V-Mole Full Size	Shaft-Drill & Blast Small Size/V-Mole Full Size	Ramp-Drill & Blast	Ramp-TBM	Ramp-Mech. Miner	Shaft-Alimak Raise	Shaft-Raise Bore Small Size/Slash Full Size	Shaft-Drilling (Wet) Full Size	Shaft-Blind Boring (Dry) Full Size
Shaft-Drill & Blast Full Size	■	Δ	Δ								
Shaft-Drill & Blast Small Size/V-Mole Full Size		Δ	Δ								
Ramp-TBM		•	•								
Ramp-Mech. Miner		•	•								
Ramp-Drill & Blast											
Shaft-Drilling (Wet)											
Shaft-Blind Boring (Dry)											

Key:
- ■ current base case
- Δ TRB suggestion
- · feasible alternative
- • secondary alternative

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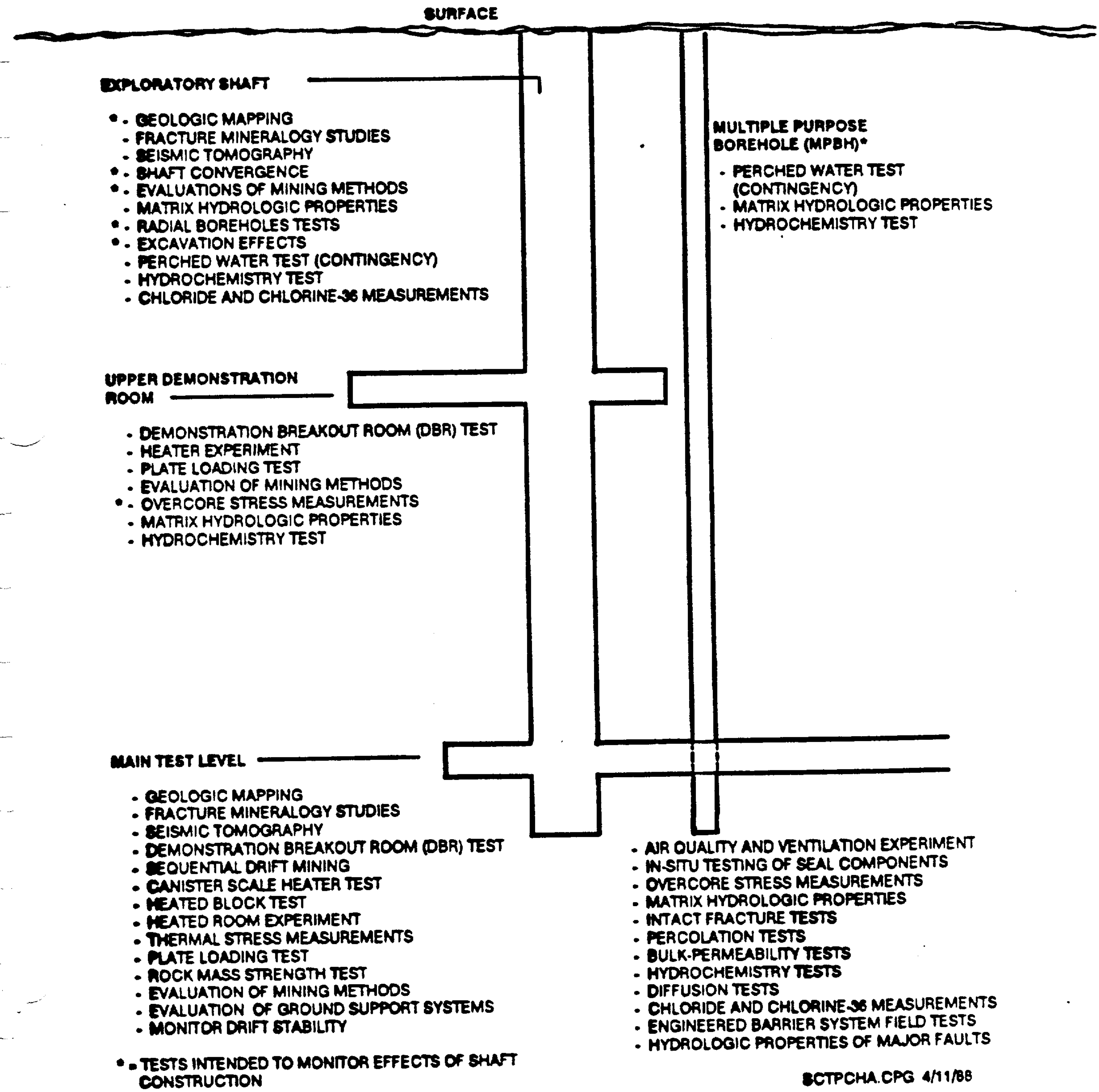
Figure 1

LOCATION AND TYPE OF TEST IN THE EXPLORATORY SHAFT FACILITY



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EVALUATION OF ALTERNATIVE ESF ACCESS CONSTRUCTION METHODS

DRAFT OUTLINE FOR REPORT

EXECUTIVE SUMMARY

1.0 INTRODUCTION
- 1.1 Purpose/Objectives
- 1.2 Scope
- 1.3 Implementation (incl. QA - ref. App. A)

2.0 BACKGROUND
- 2.1 Current ESF Design Concept (ref. SCP)
  - 2.1.1 Design Basis
  - 2.1.2 Design Concept
- 2.2 Need for Evaluation (ref. TRB transcript)

3.0 REVIEW OF ESF REQUIREMENTS (results of Task 1)
- 3.1 Information Needs (ref. App. B)
- 3.2 Test Sequence/Duration Requirements (ref. App. C)
- 3.3 Other Requirements (e.g., 10 CFR 60, two access ways - ref. App. D)

4.0 ALTERNATIVE ACCESS CONSTRUCTION METHODS (results of Task 2 - ref. App. E)
- 4.1 Access Ways (i.e., shafts, raises, ramps)
- 4.2 Construction Methods (i.e., drill-and-blast, mechanical)
- 4.3 Combinations

5.0 EVALUATION METHOD AND CRITERIA (results of Task 3)
- 5.1 Evaluation Method
- 5.2 Development of Criteria

6.0 EVALUATION OF ACCESS CONSTRUCTION METHODS (results of Task 4)
- 6.1 Comparison with Individual Criteria (ref. App. F and G)
- 6.2 Collective Evaluation Issues

7.0 CONCLUSIONS AND RECOMMENDATIONS (e.g., (1) conclusions regarding how well each of the methods satisfy individual criteria, not collective evaluation or ranking; (2) does not include programmatic issues; (3) recommend how to make collective evaluation; (4) recommend items for further study, if any)

8.0 REFERENCES

APPENDIX A - IMPLEMENTATION PLAN
APPENDIX B - INFORMATION NEEDS
APPENDIX C - TEST METHODS
APPENDIX D - OTHER ESF REQUIREMENTS (e.g., 10 CFR 60)
APPENDIX E - CONSTRUCTION METHODS
APPENDIX F - RESUMES OF EVALUATORS
APPENDIX G - DOCUMENTATION OF EVALUATIONS

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CONTROLLED DOCUMENT

QUALITY ASSURANCE PROGRAM PLAN
FOR
EVALUATION OF ALTERNATIVE SHAFT CONSTRUCTION METHODS
CONTRACT E512-09100

REVISION -0-

Prepared For
Battelle Project Management Division
Office Of Waste Technology Development

833-1017.116

Golder Associates Inc.
Seattle (Redmond), Washington

Reviewed and approved by:

Donald M. Caldwell
Donald M. Caldwell, Project Manager

C.W. Lockhart for
Glenn Mills, Corporate QA Officer

David Pentz, Project Sponsor

May 5, 1989

TABLE OF CONTENTS

1. INTRODUCTION

1.1 Quality Policy

This task has been designated by the client as Quality Level III. It is Golder Associates' policy to conduct all work on projects related to nuclear waste repository studies in accordance with 10 CFR 50 Appendix "B" requirements as interpreted by the latest edition of ANSI/ASME NQA-1 and the NRC Standard Review Plan. Golder Associates' Quality Assurance (QA) program is designed to meet these requirements; this Quality Level III QA Program Plan (QAPP) has been written to select and describe the application of program elements appropriate for the quality level and activities undertaken in this task. The individual implementing procedures discussed in the plan are listed in Figure 1-1.

1.2 Objective

The primary objective of this plan is to establish a procedural framework that will assure that the research activities, reports, and recommendations made or completed as part of this task are fully documented and defensible in terms of compliance with regulatory requirements and good scientific practice.

2. PROGRAM DESCRIPTION

2.1 Organization

The QA organization has direct access to the Project Sponsor, Project Manager, and supporting technical staff. It has the necessary organizational independence and authority to assure the proper implementation of the QA requirements discussed in this plan. Primary responsibility for the implementation of the QA program lies with the Project Manager and the project organization. The Project Manager reports to the Project Sponsor and is responsible for overall technical and budgetary performance. Verification of proper program implementation is the responsibility of Golder Associates' QA Manager/Corporate QA Officer, who reports directly to the President of Golder Associates' U.S. operations. The QA Manager is responsible for the preparation and revision of this QAPP and its implementing procedures as well as the overall monitoring of project performance to plan requirements.

2.2 Training and Qualification of Project Personnel

All personnel assigned to the project shall be trained in the specific application of QAPP elements and implementing procedures to their work activities in accordance with procedure P-2.0-1, "Training and Orientation." Technical qualification of project personnel to perform their task assignments will be based on an appropriate combination of physical training, reading assignments, and academic and professional qualifications. Training and qualification records for all technical personnel shall be maintained in the project QA files.

Figure 1-1

PROJECT QA PROCEDURES LIST

P-2.0-1 "Training and Orientation"

P-3.0-2 "Specific Work Instructions"

P-5.0-1 "Distribution and Control of Golder Associates Procedures"

P-6.0-2 "Control of Correspondence and Communications"

P-10.0-1 "Technical Review"

P-17.0-1 "Quality Assurance Records Management"

3. ACTIVITY CONTROL

All task activities shall be planned and directed through the use of this QAPP and by Specific Work Instructions (SWIs). SWI issue and use is described in detail in P-3.0-2, "Specific Work Instructions." QA personnel shall review and approve all SWIs to assure incorporation of appropriate QA program elements and proper review procedures. All deliverable reports shall be formally reviewed in accordance with procedure P-10.0-1, "Technical Review." All reviews shall be performed by qualified personnel who are independent from the authorship of the document. Definition of quality standards, client interfaces, reporting requirements, and other details of individual work assignments shall be provided to project staff by SWIs.

4. DISTRIBUTION AND CONTROL OF PROCEDURES

All procedures shall be reviewed, approved, and controlled as described in P-5.0-1, "Distribution and Control of Golder Associates Procedures," by the QA Manager, an independent reviewer, and the Office Manager. Controlled copies of this Plan and appropriate implementing procedures shall be distributed in accordance with procedure P-5.0-1 to project personnel performing or supervising the work.

5. DOCUMENT PREPARATION AND CONTROL

The QAPP, SWIs, and individual QA or technical procedures all specify QA requirements and prescribe activities affecting quality. In each case, procedures control the preparation, distribution, revision control, and approval of such documents. SWIs shall be controlled by procedure P-3.0-2, "Specific Work Instructions"; individual Golder Associates QA and Technical Procedures shall be controlled by procedure P-5.0-1, "Distribution and Control of Golder Associates Procedures." Procedure P-6.0-2, "Control of Correspondence and Communications", shall be implemented to ensure that project communications affecting project quality are distributed as required, systematically filed, and are available for review.

6. TECHNICAL REVIEW

As stated above, independent technical reviews of all deliverables shall be performed utilizing the methodology described in procedure P-10.0-1, "Technical Review". Independent technical reviews are in-depth critical reviews that verify calculations, examine applicability and technical adequacy of references, and examine the validity of the technical approach; technical reviews of final documents shall emphasize evaluation of judgements, conclusions, or recommendations, especially in areas that are beyond the existing "state of the art" or where technical criteria may be in the process of development or may not exist. All reviews shall be performed by qualified personnel with similar technical expertise who are independent from the authorship of the document. QA personnel shall perform a final review and approval of the technical review package prior to submittal of the deliverable to the client.

7. PROJECT QA RECORDS

All project QA records shall be maintained in accordance with procedure P-17.0-1, "Quality Assurance Records Management." Records shall provide documentary evidence of report development, independent technical reviews, and associated correspondence and communications. Files will be organized and indexed to provide positive identification and retrievability of records. Storage methods shall effectively prevent damage, deterioration, loss, and misuse as described in P-17.0-1. Original records shall be turned over to the client as directed by the client's Technical Administrator.

APPENDIX B

ESF SHAFT CONSTRUCTION METHODS/TESTING SEQUENCES

Each of the alternative ESF shaft construction method/testing sequences, as presented in Section 4 of the main text, are described in detail in this appendix, in terms of:

- A schematic description of the sequence of shaft development/testing.
- A schedule of activities, in terms of time elapsed since initiation of shaft construction.
- A sequential list of activities, with durations for each (consistent with the schedule)
- A cost estimate, including the cost for each activity as well as the total cost; these costs include all costs for construction-related work (including construction crew stand-by time during test installation), but do not include costs for actual testing.

The schedule and estimated costs are based on the Title I design for the Yucca Mountain Project (YMP) and assume that the mining operation will be conducted in accordance with general industry practice, using standard equipment and techniques. These schedule and cost estimates are approximate and suitable for relative comparisons among the cited options. However, absolute estimates must necessarily be based on site- and project-specific requirements.

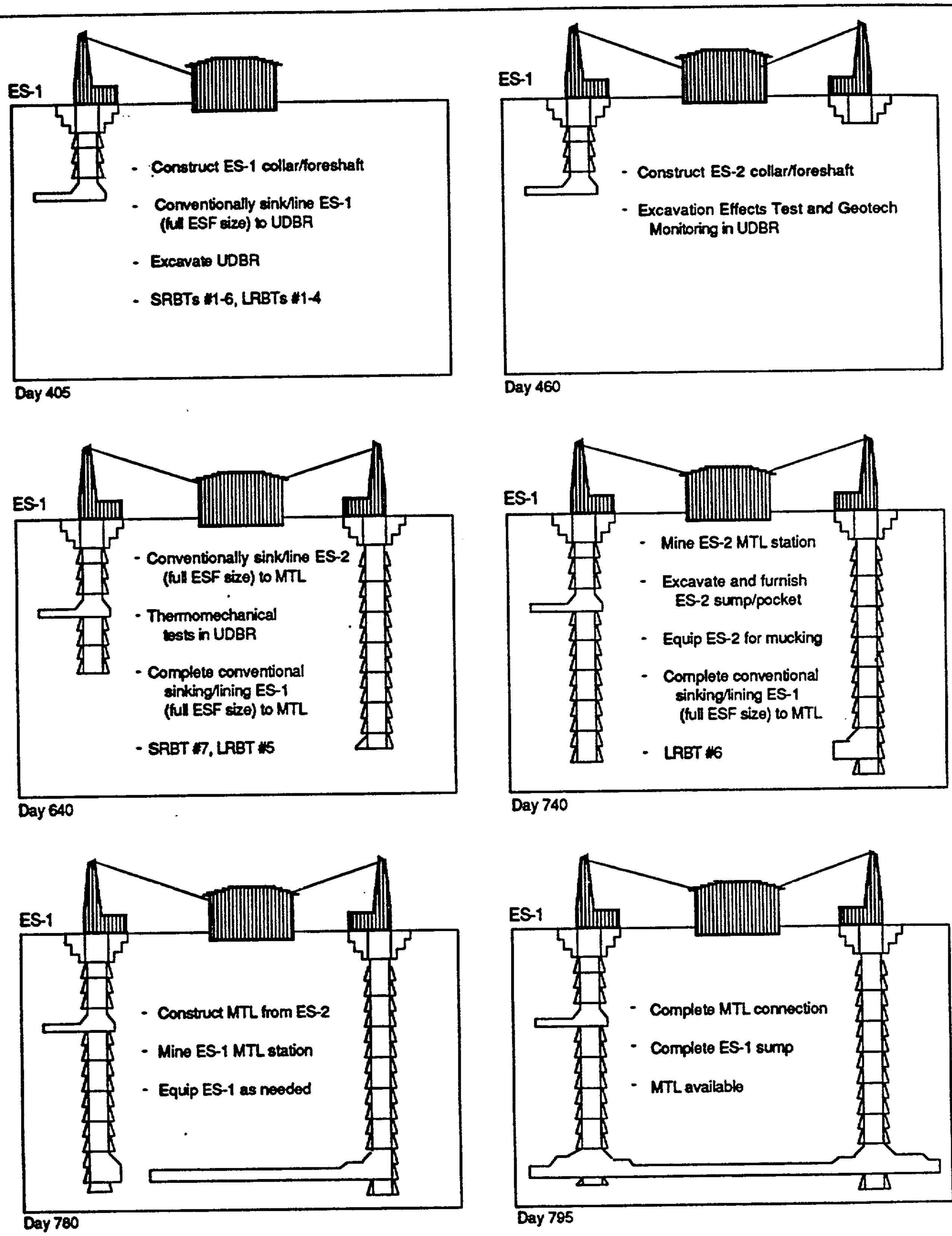
The basis for the schedule estimates is shown on the attached tables. Some of the key assumptions are as follows:

- Conventional shaft advance rate (includes sinking, lining, and mapping but no outfitting) of 6.2 ft/day, based on industry averages, modified to provide time for geologic mapping and QA related activities, and on shaft sinking at the Underground Research Laboratory (URL) for the Canadian high level waste program. A sensitivity analysis was performed to determine the effects of changing this rate (i.e., to 4.5 ft/day). A similar range of shaft sinking advance rates (sinking and supporting, but no lining, outfitting or mapping) was assumed for construction of a smaller diameter pilot shaft.
- Drift excavation rate of 9 ft/day.
- Raise boring rate of 35 ft/day for full size (e.g., 14 ft), and 60 ft/day for pilot size (e.g., 6 to 8 ft).
- Time to V-Mole, map, sample, line and equip a mechanically mined shaft of 90 days.

- LRBT duration of 30 days/test, with 10 days/test in-line.
- SRBT duration of 14 days/test.
- Shaft Convergence Test duration of 20 days/test.
- Excavation Effects Test duration of 45 days/test.
- Geoengineering testing duration in the UDBR of 10 days in-line.
- Thermomechanical testing duration in the UDBR of 110 days.

The basis for the cost estimates is shown on the attached tables. Some of the key assumptions are as follows:

- Drifting cost (3 shift/day, 7 days per week) of $1,200/ft at 9 ft/day, or $8,100/day.
- Conventional sinking costs (includes stand-by during mapping and sampling, 3-shift/day) of $25,000/day in ES-1 and $15,000/day in ES-2; the difference in costs between the two shafts is due to assignment of overhead items (e.g., common surface facilities and support) to ES-1.
- Standby costs (3 shifts/day) of $16,000/day in ES-1 and $8,500/day in ES-2.
- Costs of lining the 14 ft shaft of $1,400/ft and supporting (e.g., using spot bolting) the 10-12 ft diameter shaft of $200/ft.
- Raisebore pilot hole drilling cost (including rig, crew, survey crew, downhole drill rental, etc.) of $300/ft.
- Cost to raisebore 8 ft and 14 ft diameter shaft of $187,500 and $312,500, respectively.
- V-moling cost of $22,500/day; this assumes an approximate 40% capital equipment cost recovery per shaft.



ES-1 (Scientific) and ES-2 (Mucking) Conventional (Drill-and-Blast) Construction
All testing in-line.

Not to Scale

SCHEMATIC DESCRIPTION OF THE SEQUENCE OF SHAFT DEVELOPMENT/TESTING FOR BASE CASE 0

PROJECT NO. 833-1017.116 DWG. NO. 13422 DATE 8/18/89 DRAWN CW APPROVED CB

Golder Associates

Schedule Name: Yucca Mtn ESF Schedule Base Case 0
Project Manager:
As of date: 14-Jun-89 2:06pm Schedule File: A:ESBASE

ES-1 Conventional
ES-2 Conventional

	Status	12 (months) 24
Start ES-1 Shaft Construction	C	M
Construct ES-1 Collar	C	===
Preassemble Sinking Equipment	C	=====
SRBT#1 in ES-1 Collar	C	===
ES-1 Foreshaft Construction	C	===
ES-1 Hoist and Hoist House	C	======
Install Sinking Plant in ES-1	C	=====
Sink/Line ES-1 to UDBR	C	============
Shaft Conv. Test #1 in ES-1	C	====
SRBTs #2-#6, LRBT #1-#4	C	============================
Excavate UDBR in ES-1	C	======
Excavation Effects,Geotech Mon	C	=========
Start ES-2 Construction	C	M
Construct ES-2 Collar	C	====
Preassemble ES-2 Sinking Equip	C	=====
Construct ES-2 Foreshaft	C	===
ES-2 Hoist and Hoisthouse	pC	======
Install ES-2 Sinking Plant	C	=====
Thermomechanical UDBR Tests	C	=================
Sink/Line ES-2 to MTL	C	======================
Sink/Line ES-1 to MTL	C	===========
Excavate ES-2 MTL Station	C	======
Shaft Convergence Test #2 ES-1	C	====
SRBT #7, LRBTs #5 & #6 in ES-1	C	============
Excavate ES-2 to Shaft Bottom	C	===
Furnish Sump / Pockets	C	====
Lower ESF Excavation Equipment	C	=
Equip ES-2 Shaft	C	====
Changeover to Permanent Hoist	C	===
Equip ES-1	C	===
Start MTL Const. from ES-2	C	M
Develop ESF to ES-1	pC	========
Mine ES-1 MTL Station	C	======
MTL Available	C	M

Schedule Name: Yucca Mtn ESF Schedule Base Case 0
Project Manager:
As of date: 31-May-89 3:19pm Schedule File: A:ESBASE

ES-1 Conventional
ES-2 Conventional

This is a selective report. All items shown in bold
* Notes (1) contains "ES1"

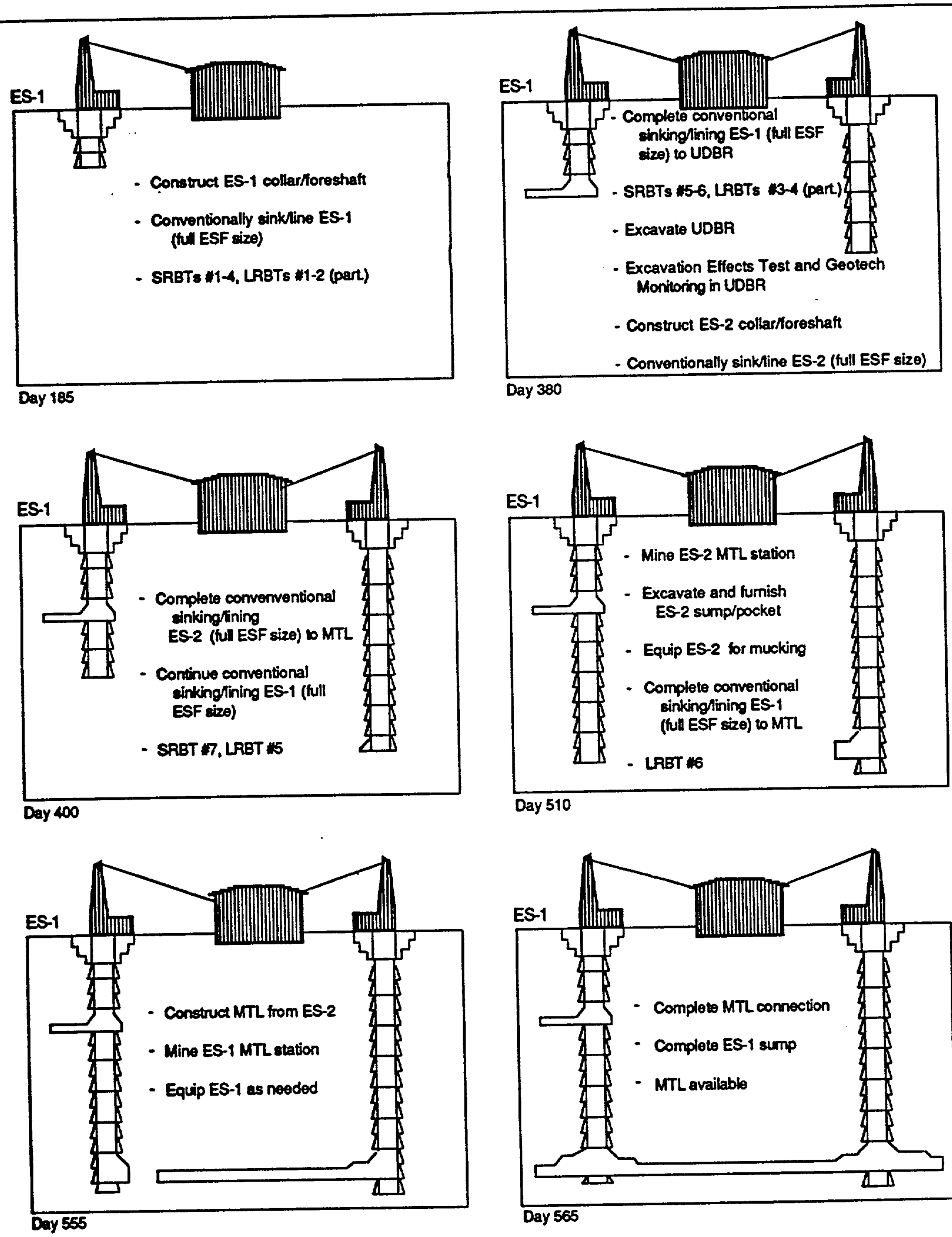
Task	How Long
Start ES-1 Shaft Construction	**0 days**
Construct ES-1 Collar	**20 days**
Preassemble Sinking Equipment	**30 days**
SRBT#1 in ES-1 Collar	**14 days**
ES-1 Foreshaft Construction	**13 days**
ES-1 Hoist and Hoist House	**40 days**
Install Sinking Plant in ES-1	**30 days**
Sink/Line ES-1 to UDBR	**81 days**
Shaft Conv. Test #1 in ES-1	**20 days**
SRBTs #2-#6, LRBT #1-#4	**190 days**
Excavate UDBR in ES-1	**35 days**
Excavation Effects,Geotech Mon	**55 days**
Start ES-2 Construction	0 days
Construct ES-2 Collar	20 days
Preassemble ES-2 Sinking Equip	30 days
Construct ES-2 Foreshaft	13 days
ES-2 Hoist and Hoisthouse	40 days
Install ES-2 Sinking Plant	30 days
Thermomechanical UDBR Tests	**110 days**
Sink/Line ES-2 to MTL	154 days
Sink/Line ES-1 to MTL	**74 days**
Excavate ES-2 MTL Station	37 days
Shaft Convergence Test #2 ES-1	**20 days**
SRBT #7, LRBTs #5 & #6 in ES-1	**74 days**
Excavate ES-2 to Shaft Bottom	16 days
Furnish Sump / Pockets	20 days
Lower ESF Excavation Equipment	3 days
Equip ES-2 Shaft	20 days
Changeover to Permanent Hoist	12 days
Equip ES-1	**20 days**
Start MTL Const. from ES-2	0 days
Develop ESF to ES-1	50 days
Mine ES-1 MTL Station	**37 days**
MTL Available	0 days
Excavate DBOR	0 days
SCT#3 and Lower Exc. Effects	0 days
Complete ES-1 Sump	**10 days**

TIME LINE Task Table Report

Schedule Name: Yucca Mtn ESF Schedule Base Case 0
Project Manager:
As of date: 31-May-89 3:28pm Schedule File: A:ESBASE

ES-1 Conventional
ES-2 Conventional

TASK	TOTAL
Start ES-1 Shaft Construction	0
Construct ES-1 Collar	300,000
Preassemble Sinking Equipment	200,000
SRBT#1 in ES-1 Collar	224,000
ES-1 Foreshaft Construction	400,000
ES-1 Hoist and Hoist House	1,300,000
Install Sinking Plant in ES-1	500,000
Sink/Line ES-1 to UDBR	2,725,000
Shaft Conv. Test #1 in ES-1	320,000
SRBTs #2-#6, LRBT #1-#4	3,040,000
Excavate UDBR in ES-1	875,000
Excavation Effects,Geotech Mon	880,000
Start ES-2 Construction	0
Construct ES-2 Collar	100,000
Preassemble ES-2 Sinking Equip	100,000
Construct ES-2 Foreshaft	200,000
ES-2 Hoist and Hoisthouse	600,000
Install ES-2 Sinking Plant	250,000
Thermomechanical UDBR Tests	1,760,000
Sink/Line ES-2 to MTL	3,612,000
Sink/Line ES-1 to MTL	2,452,000
Excavate ES-2 MTL Station	555,000
Shaft Convergence Test #2 ES-1	320,000
SRBT #7, LRBTs #5 & #6 in ES-1	1,184,000
Excavate ES-2 to Shaft Bottom	240,000
Furnish Sump / Pockets	400,000
Lower ESF Excavation Equipment	45,000
Equip ES-2 Shaft	520,000
Changeover to Permanent Hoist	180,000
Equip ES-1	720,000
Start MTL Const. from ES-2	0
Develop ESF to ES-1	405,000
Mine ES-1 MTL Station	925,000
MTL Available	0
Excavate DBOR	0
SCT#3 and Lower Exc. Effects	0
Complete ES-1 Sump	250,000
TOTALS	25,582,000



ES-1 (Scientific) and ES-2 (Mucking) Conventional (Drill-and-Blast) Construction
Thermomechanical testing in UDBR and additional testing in LRBTs (in ES-1) delayed until after MTL is available.

Not to Scale

SCHEMATIC DESCRIPTION OF THE SEQUENCE OF SHAFT DEVELOPMENT/TESTING FOR CASE 1(a)

PROJECT NO. 833-1017.116 DWG. NO. 13161 DATE 6/18/89 DRAWN CW APPROVED CB

Golder Associates

Schedule Name: Yucca Mtn ESF Schedule Case No. 1.(a)
Project Manager:
As of date: 14-Jun-89 2:09pm Schedule File: A:ESCS#1A

ES-1 Conventional [Mine UDBR, Delay Thermomech tests, inc. SRBTs inst LRBTs
ES-2 Conventional [Mucking Shaft]

Task	Status	Schedule (months: 12 ... 24)
Start ES-1 Shaft Construction	C	M.
Construct ES-1 Collar	C	===
Preassemble ES-1 Sinking Equip	C	.=====
SRBT #1 in ES-1 Collar	C	.===
Construct ES-1 Foreshaft	C	===
ES-1 Hoist and Hoist House	C	======
Install ES-1 Sinking Plant	C	=====
Sink/Line ES-1 to UDBR	C	.=============.
Shaft Conv. Test #1 in ES-1	C	====
SRBT#2-6, inst LRBT#1-4 ES-1	C	==================
Start ES-2 Construction	C	M.
Construct ES-2 Collar	C	====
Preassemble ES-2 Sinking Equip	C	=====.
Construct ES-2 Foreshaft	C	===.
ES-2 Hoist and Hoisthouse	pC	======.
Install ES-2 Sinking Plant	C	=====.
Sink/Line ES-2 to MTL	C	========================.
Excavate UDBR in ES-1	C	.======
Exc. Effects, Geot. Mon ES-1	C	.========
Sink/Line ES-1 to MTL	C	.===========
Excavate ES-2 MTL Station	C	=======
Excavate ES-2 to Shaft Bottom	C	.===
Shaft Convergence Test #2 ES-1	C	====
Furnish ES-2 Sump / Pockets	C	====
SRBT#7, inst LRBT#5-6 ES-1	C	======
Lower ESF Exc. Equip. in ES-2	C	.=
Equip ES-2 Shaft	C	.====
Changeover to Permanent Hoist	C	===
Equip ES-1	C	.====
Start MTL Const. from ES-2	C	M
Develop ESF to ES-1	C	========
Mine ES-1 MTL Station	C	======
MTL Available	C	M

Schedule Name: Yucca Mtn ESF Schedule Case No. 1.(a)
Project Manager:
As of date: 31-May-89 3:31pm Schedule File: A:ESCS#1A

ES-1 Conventional [Mine UDBR, Delay Thermomech tests, inc. SRBTs inst LR
ES-2 Conventional [Mucking Shaft]

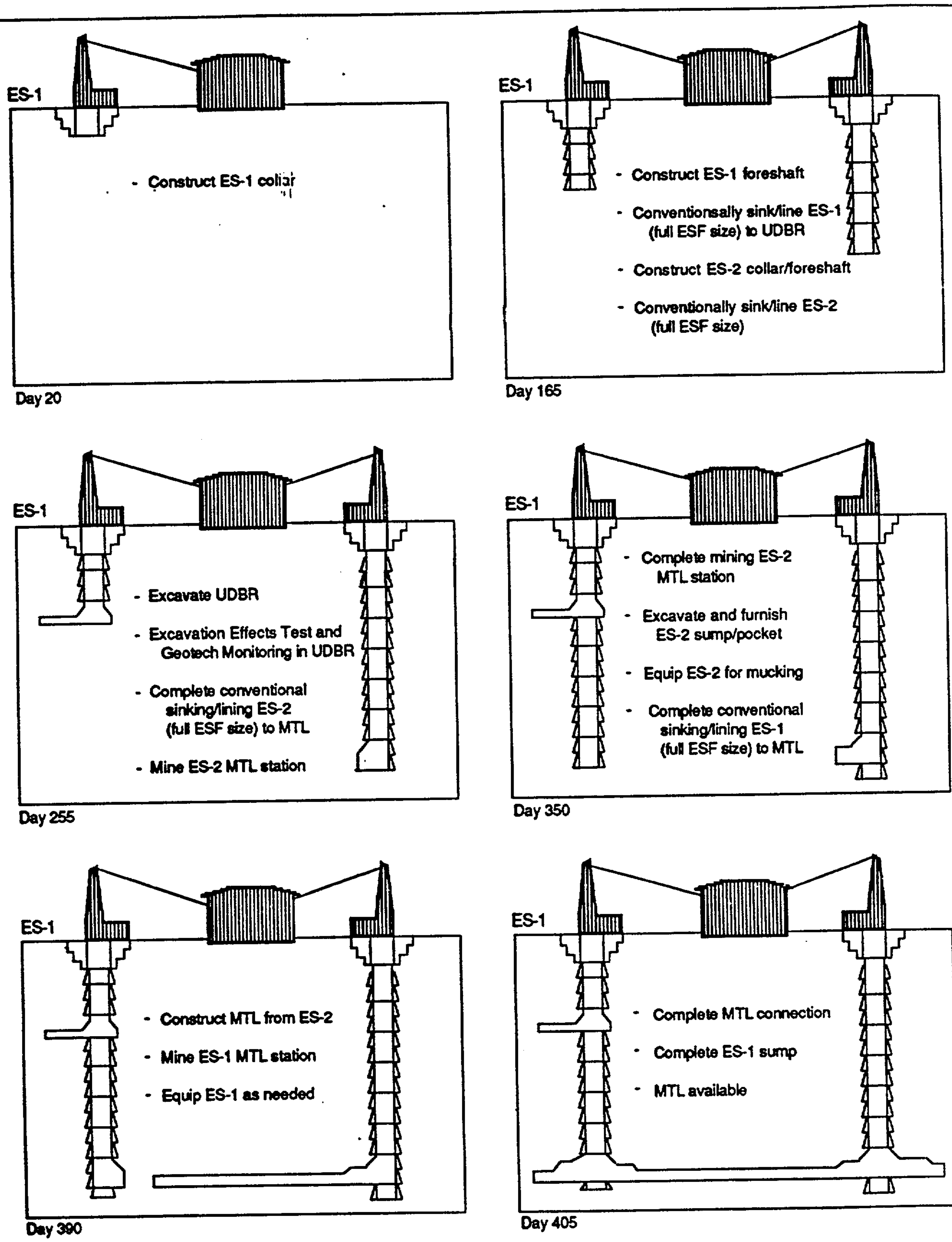
This is a selective report. All items shown in bold
* Notes (1) contains "ES1"

Task	How Long
Start ES-1 Shaft Construction	**0 days**
Construct ES-1 Collar	**20 days**
Preassemble ES-1 Sinking Equip	**30 days**
SRBT #1 in ES-1 Collar	**14 days**
Construct ES-1 Foreshaft	**13 days**
ES-1 Hoist and Hoist House	**40 days**
Install ES-1 Sinking Plant	**30 days**
Sink/Line ES-1 to UDBR	**81 days**
Shaft Conv. Test #1 in ES-1	**20 days**
SRBT#2-6, inst LRBT#1-4 ES-1	**110 days**
Start ES-2 Construction	0 days
Construct ES-2 Collar	20 days
Preassemble ES-2 Sinking Equip	30 days
Construct ES-2 Foreshaft	13 days
ES-2 Hoist and Hoisthouse	40 days
Install ES-2 Sinking Plant	30 days
Sink/Line ES-2 to MTL	154 days
Excavate UDBR in ES-1	**35 days**
Exc. Effects, Geot. Mon ES-1	**55 days**
Sink/Line ES-1 to MTL	**74 days**
Excavate ES-2 MTL Station	37 days
Excavate ES-2 to Shaft Bottom	16 days
Shaft Convergence Test #2 ES-1	**20 days**
Furnish ES-2 Sump / Pockets	20 days
SRBT#7, inst LRBT#5-6 ES-1	**34 days**
Lower ESF Exc. Equip. in ES-2	3 days
Equip ES-2 Shaft	20 days
Changeover to Permanent Hoist	12 days
Equip ES-1	**20 days**
Start MTL Const. from ES-2	0 days
Develop ESF to ES-1	50 days
Mine ES-1 MTL Station	**37 days**
MTL Available	0 days
Complete UDBR Tests in ES-1	**0 days**
Excavate DBOR	0 days
SCT#3 and Lower Exc. Effects	0 days
Complete ES-1 Sump	**10 days**

Schedule Name: Yucca Mtn ESF Schedule Case No. 1.(a)
Project Manager:
As of date: 31-May-89 3:31pm Schedule File: A:ESCS#1A

ES-1 Conventional [Mine UDBR, Delay Thermomech tests, inc. SRBTs inst L
ES-2 Conventional [Mucking Shaft]

TASK	TOTAL
Start ES-1 Shaft Construction	0
Construct ES-1 Collar	300,000
Preassemble ES-1 Sinking Equip	200,000
SRBT #1 in ES-1 Collar	224,000
Construct ES-1 Foreshaft	400,000
ES-1 Hoist and Hoist House	1,300,000
Install ES-1 Sinking Plant	500,000
Sink/Line ES-1 to UDBR	2,725,000
Shaft Conv. Test #1 in ES-1	320,000
SRBT#2-6, inst LRBT#1-4 ES-1	1,760,000
Start ES-2 Construction	0
Construct ES-2 Collar	100,000
Preassemble ES-2 Sinking Equip	100,000
Construct ES-2 Foreshaft	200,000
ES-2 Hoist and Hoisthouse	600,000
Install ES-2 Sinking Plant	250,000
Sink/Line ES-2 to MTL	3,612,000
Excavate UDBR in ES-1	875,000
Exc. Effects, Geot. Mon ES-1	880,000
Sink/Line ES-1 to MTL	2,452,000
Excavate ES-2 MTL Station	555,000
Excavate ES-2 to Shaft Bottom	240,000
Shaft Convergence Test #2 ES-1	320,000
Furnish ES-2 Sump / Pockets	400,000
SRBT#7, inst LRBT#5-6 ES-1	544,000
Lower ESF Exc. Equip. in ES-2	45,000
Equip ES-2 Shaft	520,000
Changeover to Permanent Hoist	180,000
Equip ES-1	720,000
Start MTL Const. from ES-2	0
Develop ESF to ES-1	405,000
Mine ES-1 MTL Station	925,000
MTL Available	0
Complete UDBR Tests in ES-1	0
Excavate DBOR	0
SCT#3 and Lower Exc. Effects	0
Complete ES-1 Sump	250,000
TOTALS	21,902,000



ES-1 (Scientific) and ES-2 (Mucking) Conventional (Drill-and-Blast) Construction
Thermomechanical Testing in UDBR and all RBTs (in ES-1) delayed until after
MTL is available.

Not to Scale

SCHEMATIC DESCRIPTION OF THE SEQUENCE OF SHAFT DEVELOPMENT/TESTING FOR CASE 1(b)

PROJECT NO. 833-1017.116 DWG. NO. 13422 DATE 6/18/89 DRAWN CW APPROVED CB

Golder Associates

Schedule Name: Yucca Mtn ESF Schedule Case No. 1.(b)
Project Manager:
As of date: 14-Jun-89 2:11pm Schedule File: A:ESCS#1B

ES-1 Conventional [Mine UDBR, Delay Thermomech tests and all RBTs
ES-2 Conventional [Mucking Shaft]

	Status	12 (months) 24
Start ES-1 Shaft Construction	C	M
Construct ES-1 Collar	C	===
Preassemble ES-1 Sinking Equip	C	=====
Start ES-2 Construction	C	M
Construct ES-2 Collar	C	====
Construct ES-1 Foreshaft	C	===
Preassemble ES-2 Sinking Equip	C	=====
ES-1 Hoist and Hoist House	C	======
Install ES-1 Sinking Plant	C	=====
Construct ES-2 Foreshaft	C	===
ES-2 Hoist and Hoisthouse	pC	======
Install ES-2 Sinking Plant	C	=====
Sink/Line ES-1 to UDBR	C	=============
Sink/Line ES-2 to MTL	C	=======================
Shaft Conv. Test #1 in ES-1	C	====
Excavate UDBR in ES-1	C	======
Exc. Effects, Geot. Mon ES-1	C	=========
Excavate ES-2 MTL Station	C	=======
Sink/Line ES-1 to MTL	C	===========
Excavate ES-2 to Shaft Bottom	C	===
Furnish Sump / Pockets	C	====
Lower ESF Exc. Equip. in ES-2	C	=
Equip ES-2 Shaft	C	====
Shaft Convergence Test #2 ES-1	C	====
Changeover to Permanent Hoist	C	===
Start MTL Const. from ES-2	C	M
Develop ESF to ES-1	C	========
Equip ES-1	C	====
Mine ES-1 MTL Station	C	======
MTL Available	C	M

Schedule Name: Yucca Mtn ESF Schedule Case No. 1.(b)
Project Manager:
As of date: 31-May-89 3:33pm Schedule File: A:ESCS#1B

ES-1 Conventional [Mine UDBR, Delay Thermomech tests and all RBTs
ES-2 Conventional [Mucking Shaft]

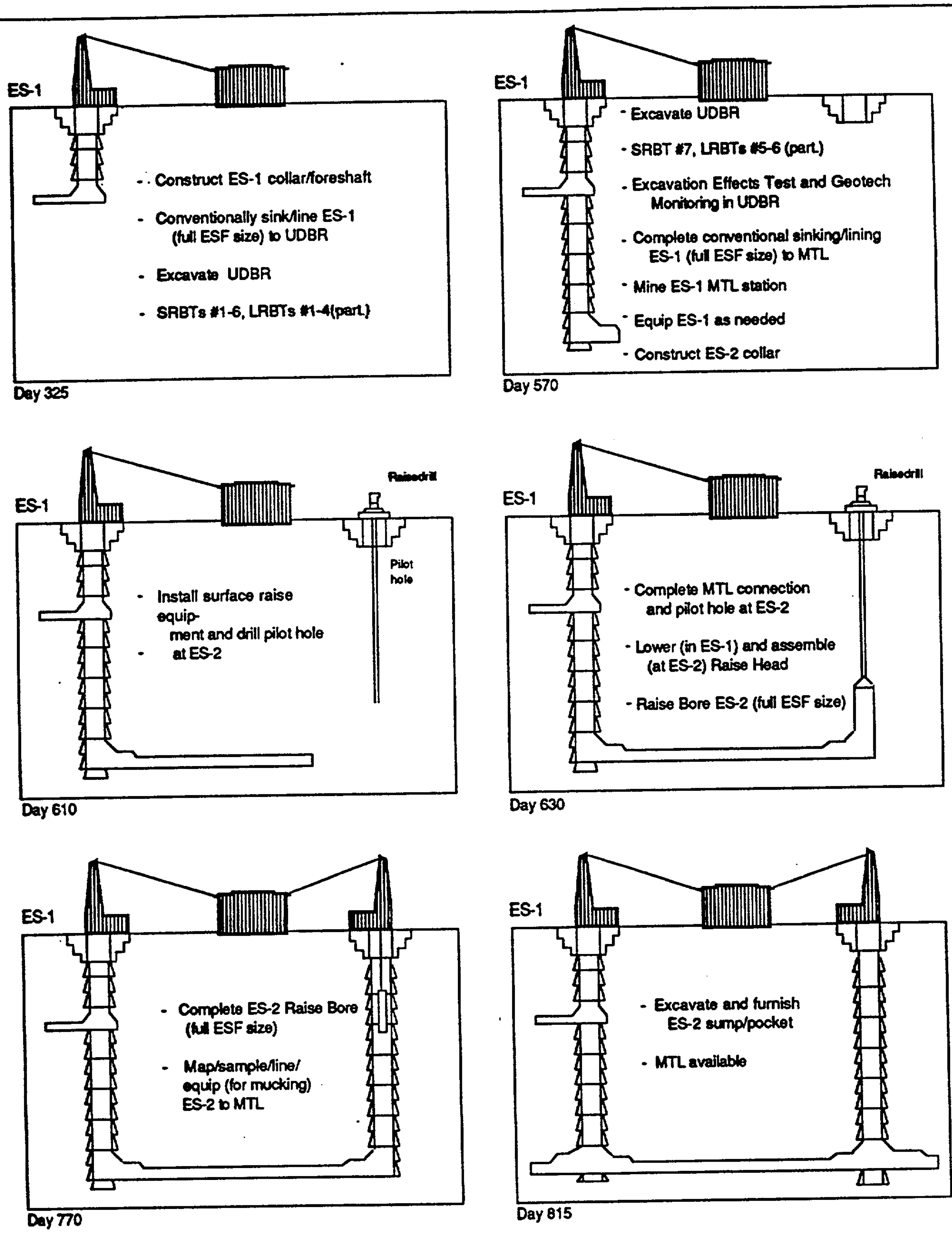
This is a selective report. All items shown in bold
* Notes (1) contains "ES1"

Task	How Long
Start ES-1 Shaft Construction	**0 days**
Construct ES-1 Collar	**20 days**
Preassemble ES-1 Sinking Equip	**30 days**
Start ES-2 Construction	0 days
Construct ES-2 Collar	20 days
Construct ES-1 Foreshaft	**13 days**
Preassemble ES-2 Sinking Equip	30 days
ES-1 Hoist and Hoist House	**40 days**
Install ES-1 Sinking Plant	**30 days**
Construct ES-2 Foreshaft	13 days
ES-2 Hoist and Hoisthouse	40 days
Install ES-2 Sinking Plant	30 days
Sink/Line ES-1 to UDBR	**81 days**
Sink/Line ES-2 to MTL	154 days
Shaft Conv. Test #1 in ES-1	**20 days**
Excavate UDBR in ES-1	**35 days**
Exc. Effects, Geot. Mon ES-1	**55 days**
Excavate ES-2 MTL Station	37 days
Sink/Line ES-1 to MTL	**74 days**
Excavate ES-2 to Shaft Bottom	16 days
Furnish Sump / Pockets	20 days
Lower ESF Exc. Equip. in ES-2	3 days
Equip ES-2 Shaft	20 days
Shaft Convergence Test #2 ES-1	**20 days**
Changeover to Permanent Hoist	12 days
Start MTL Const. from ES-2	0 days
Develop ESF to ES-1	50 days
Equip ES-1	**20 days**
Mine ES-1 MTL Station	**37 days**
MTL Available	0 days
Complete UDBR Tests in ES-1	**0 days**
Excavate DBOR	0 days
Install RBTs in ES-1	**0 days**
SCT#3 and Lower Exc. Effects	0 days
Complete ES-1 Sump	**10 days**

Schedule Name: Yucca Mtn ESF Schedule Case No. 1.(b)
Project Manager:
As of date: 31-May-89 3:33pm Schedule File: A:ESCS#1B

ES-1 Conventional [Mine UDBR, Delay Thermomech tests and all RBTs
ES-2 Conventional [Mucking Shaft]

TASK	TOTAL
Start ES-1 Shaft Construction	0
Construct ES-1 Collar	300,000
Preassemble ES-1 Sinking Equip	200,000
Start ES-2 Construction	0
Construct ES-2 Collar	100,000
Construct ES-1 Foreshaft	400,000
Preassemble ES-2 Sinking Equip	100,000
ES-1 Hoist and Hoist House	1,300,000
Install ES-1 Sinking Plant	500,000
Construct ES-2 Foreshaft	200,000
ES-2 Hoist and Hoisthouse	600,000
Install ES-2 Sinking Plant	250,000
Sink/Line ES-1 to UDBR	2,725,000
Sink/Line ES-2 to MTL	3,612,000
Shaft Conv. Test #1 in ES-1	320,000
Excavate UDBR in ES-1	875,000
Exc. Effects, Geot. Mon ES-1	880,000
Excavate ES-2 MTL Station	555,000
Sink/Line ES-1 to MTL	2,452,000
Excavate ES-2 to Shaft Bottom	240,000
Furnish Sump / Pockets	400,000
Lower ESF Exc. Equip. in ES-2	45,000
Equip ES-2 Shaft	520,000
Shaft Convergence Test #2 ES-1	320,000
Changeover to Permanent Hoist	180,000
Start MTL Const. from ES-2	0
Develop ESF to ES-1	405,000
Equip ES-1	720,000
Mine ES-1 MTL Station	925,000
MTL Available	0
Complete UDBR Tests in ES-1	0
Excavate DBOR	0
Install RBTs in ES-1	0
SCT#3 and Lower Exc. Effects	0
Complete ES-1 Sump	250,000
TOTALS	19,374,000



ES-1 (Scientific) Conventional (Drill-and-Blast) Construction
ES-2 (Mucking) Single-Pass Raise Bore
Thermomechanical testing in UDBR and additional testing in LRBTs (in ES-1) delayed until after MTL is available

Not to Scale

SCHEMATIC DESCRIPTION OF THE SEQUENCE OF SHAFT DEVELOPMENT/TESTING FOR CASE 2(a)

PROJECT NO. 833-1017.116 DWG. NO. 12406 DATE 6/20/89 DRAWN CW APPROVED CB

Golder Associates

Schedule Name: Yucca Mtn ESF Schedule Case No. 2.(a)
Project Manager:
As of date: 14-Jun-89 2:12pm Schedule File: A:ESCS#2A

ES-1 Conventional [UDBR, Delay Thermomech, SRBTs and install LRBTs
ES-2 Raise Bore [Mucking Shaft]

(months) — scale marks: 12, 24

Activity	Status	Schedule
Start ES-1 Shaft Construction	C	M
Construct ES-1 Collar	C	===
Preassemble ES-1 Sinking Equip	C	=====
SRBT#1 in ES-1 Collar	C	===
Construct ES-1 Foreshaft	C	===
ES-1 Hoist and Hoist House	C	======
Install ES-1 Sinking Plant	C	=====
Sink/Line ES-1 to UDBR	C	============
Shaft Conv. Test #1 in ES-1	C	====
SRBT#2-6, inst LRBT#1-4 ES-1	C	=================
Excavate UDBR in ES-1	C	======
ES-1 Exc. Effects, Geotech Mon	C	========
Sink/Line ES-1 to MTL	C	===========
Shaft Convergence Test #2 ES-1	C	====
SRBT#7, inst LRBTs #5-6 ES-1	C	======
Mine ES-1 MTL Station	C	======
Start ES-2 Construction	C	M
Construct ES-2 Collar	C	====
Lower ESF Exc. Equip. in ES-1	C	=
Equip ES-1	C	===
Install Surface Raise Equipmet	C	===
Start ESF Const. from ES-1	C	M
Develop ESF to ES-2	C	========
Drill Pilot Bhole/Instl String	C	=======
Lower raisebore Equip in ES-1	C	=
Assemble Raisehead at ES-2	pC	=
Preassemble ES-2 Lining Equip	C	=====
Raisebore ES-2	pC	=====
Install ES-2 Hoist	C	=======
Demobilize Raise Equipment	C	=
Install Lining Plant in ES-2	C	======
Map/Smpl/Line/Eqp ES-2 to MTL	C	=============
Excavate ES-2 to Shaft Bottom	C	===
Furnish ES-2 Sump / Pockets	C	====
Changeover to Permanent Hoist	C	==
MTL Available	C	M

Schedule Name: Yucca Mtn ESF Schedule Case No. 2.(a)
Project Manager:
As of date: 31-May-89 3:36pm Schedule File: A:ESCS#2A

ES-1 Conventional [UDBR, Delay Thermomech, SRBTs and install LRBTs
ES-2 Raise Bore [Mucking Shaft]

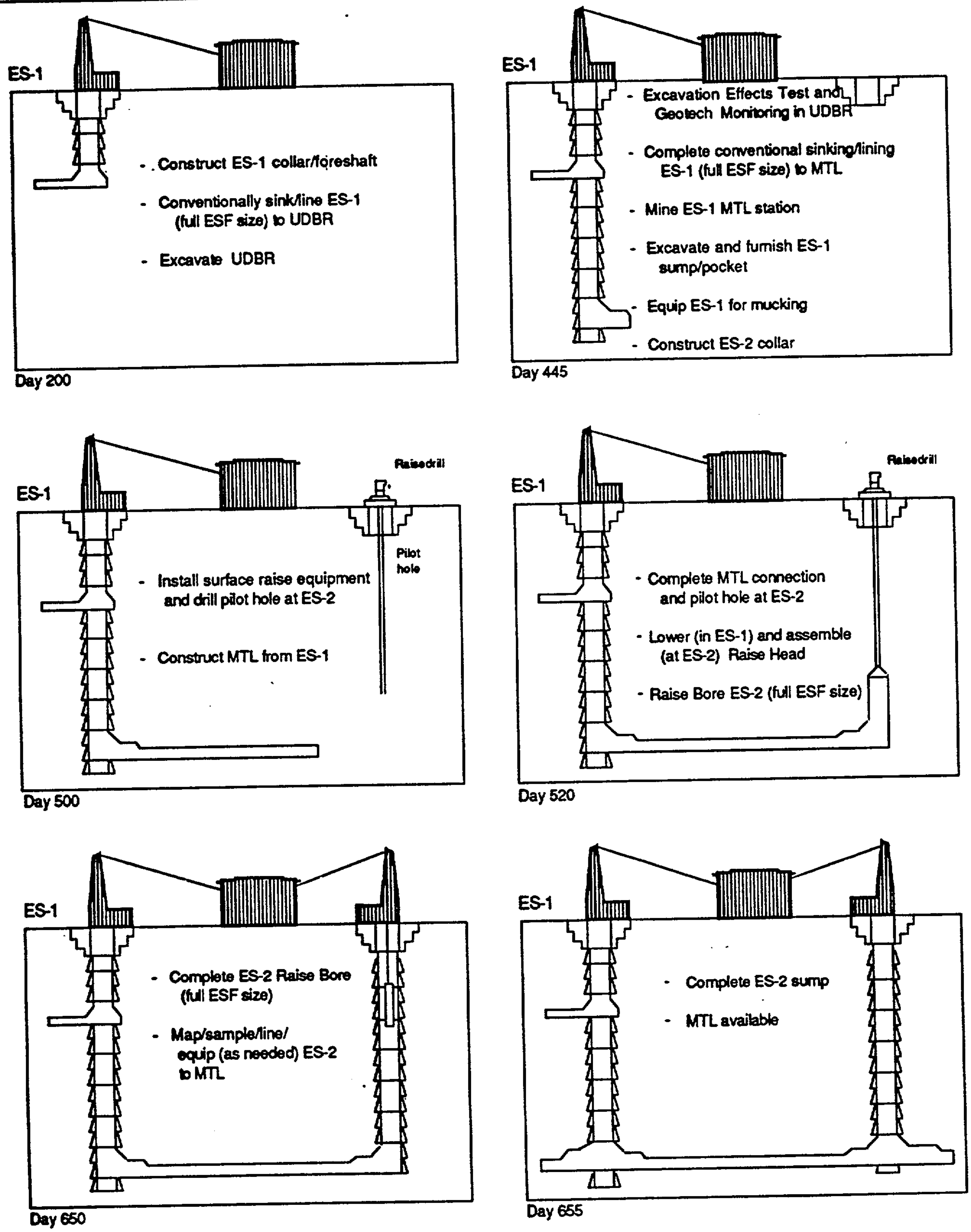
This is a selective report. All items shown in bold
* Notes (1) contains "ES1"

Task	How Long
Start ES-1 Shaft Construction	**0 days**
Construct ES-1 Collar	**20 days**
Preassemble ES-1 Sinking Equip	**30 days**
SRBT#1 in ES-1 Collar	**14 days**
Construct ES-1 Foreshaft	**13 days**
ES-1 Hoist and Hoist House	**40 days**
Install ES-1 Sinking Plant	**30 days**
Sink/Line ES-1 to UDBR	**81 days**
Shaft Conv. Test #1 in ES-1	**20 days**
SRBT#2-6, inst LRBT#1-4 ES-1	**110 days**
Excavate UDBR in ES-1	**35 days**
ES-1 Exc. Effects, Geotech Mon	**55 days**
Sink/Line ES-1 to MTL	**74 days**
Shaft Convergence Test #2 ES-1	**20 days**
SRBT#7, inst LRBTs #5-6 ES-1	**34 days**
Mine ES-1 MTL Station	**37 days**
Start ES-2 Construction	0 days
Construct ES-2 Collar	20 days
Lower ESF Exc. Equip. in ES-1	**3 days**
Equip ES-1	**20 days**
Install Surface Raise Equipmet	10 days
Start ESF Const. from ES-1	**0 days**
Develop ESF to ES-2	**50 days**
Drill Pilot Bhole/Instl String	45 days
Lower raisebore Equip in ES-1	**2 days**
Assemble Raisehead at ES-2	3 days
Preassemble ES-2 Lining Equip	30 days
Raisebore ES-2	25 days
Install ES-2 Hoist	40 days
Demobilize Raise Equipment	3 days
Install Lining Plant in ES-2	30 days
Map/Smpl/Line/Eqp ES-2 to MTL	90 days
Excavate ES-2 to Shaft Bottom	16 days
Furnish ES-2 Sump / Pockets	20 days
Changeover to Permanent Hoist	12 days
MTL Available	0 days
Complete UDBR Tests in ES-1	**0 days**
SCT #3 and Lower Exc. Effects	0 days
Construct ES-1 Sump	**10 days**
Excavate DBOR	0 days

Schedule Name: Yucca Mtn ESF Schedule Case No. 2.(a)
Project Manager:
As of date: 31-May-89 3:35pm Schedule File: A:ESCS#2A

ES-1 Conventional [UDBR, Delay Thermomech, SRBTs and install LRBTs
ES-2 Raise Bore [Mucking Shaft]

TASK	TOTAL
Start ES-1 Shaft Construction	0
Construct ES-1 Collar	300,000
Preassemble ES-1 Sinking Equip	200,000
SRBT#1 in ES-1 Collar	224,000
Construct ES-1 Foreshaft	400,000
ES-1 Hoist and Hoist House	1,300,000
Install ES-1 Sinking Plant	500,000
Sink/Line ES-1 to UDBR	2,725,000
Shaft Conv. Test #1 in ES-1	320,000
SRBT#2-6, inst LRBT#1-4 ES-1	1,760,000
Excavate UDBR in ES-1	875,000
ES-1 Exc. Effects, Geotech Mon	880,000
Sink/Line ES-1 to MTL	2,452,000
Shaft Convergence Test #2 ES-1	320,000
SRBT#7, inst LRBTs #5-6 ES-1	544,000
Mine ES-1 MTL Station	925,000
Start ES-2 Construction	0
Construct ES-2 Collar	100,000
Lower ESF Exc. Equip. in ES-1	75,000
Equip ES-1	720,000
Install Surface Raise Equipmet	200,000
Start ESF Const. from ES-1	0
Develop ESF to ES-2	405,000
Drill Pilot Bhole/Instl String	300,000
Lower raisebore Equip in ES-1	50,000
Assemble Raisehead at ES-2	10,000
Preassemble ES-2 Lining Equip	100,000
Raisebore ES-2	312,500
Install ES-2 Hoist	600,000
Demobilize Raise Equipment	200,000
Install Lining Plant in ES-2	250,000
Map/Smpl/Line/Eqp ES-2 to MTL	2,145,000
Excavate ES-2 to Shaft Bottom	400,000
Furnish ES-2 Sump / Pockets	600,000
Changeover to Permanent Hoist	300,000
MTL Available	0
Complete UDBR Tests in ES-1	0
SCT #3 and Lower Exc. Effects	0
Construct ES-1 Sump	250,000
Excavate DBOR	0
TOTALS	20,742,500



ES-1 (Mucking) Conventional (Drill-and-Blast) Construction
ES-2 (Scientific) Single-Pass Raise Bore
Thermomechanical testing in UDBR and all RBTs (in ES-2) delayed until after MTL is available.

Not to Scale

SCHEMATIC DESCRIPTION OF THE SEQUENCE OF SHAFT DEVELOPMENT/TESTING FOR CASE 2(b)

PROJECT NO. 833-1017.116 DWG. NO. 12406 DATE 8/20/89 DRAWN CW APPROVED CB

Golder Associates

Schedule Name: Yucca Mtn ESF Schedule Case No. 2.(b)
Project Manager:
As of date: 14-Jun-89 2:13pm Schedule File: A:ESCS#2B

ES-1 Conventional [UDBR, Delay Thermomech, Mucking Shaft]
ES-2 Raise Bored [Delay RBTs, Scientific Shaft]

Activity	Status	Schedule (months: 12 ... 24)
Start ES-1 Shaft Construction	C	M
Construct ES-1 Collar	C	===
Preassemble ES-1 Sinking Equip	C	=====
Construct ES-1 Foreshaft	C	===
ES-1 Hoist and Hoist House	C	======
Install ES-1 Sinking Plant	C	=====
Sink/Line ES-1 to UDBR	C	============
Shaft Conv. Test #1 in ES-1	C	====
Excavate UDBR in ES-1	C	======
ES-1 Exc. Effects, Geotech Mon	C	=========
Sink/Line ES-1 to MTL	C	===========
Shaft Convergence Test #2 ES-1	C	====
Mine ES-1 MTL Station	C	======
Excavate ES-1 to Shaft Bottom	C	===
Furnish Sump / Pockets	C	====
Lower ESF Exc. Equip. in ES-1	C	=
Equip ES-1 Shaft	C	====
Start ES-2 Construction	C	M
Construct ES-2 Collar	C	===
Changeover to Permanent Hoist	C	===
Install Surface Raise Equipmet	C	==
Start ESF Const. from ES-1	C	M
Develop ESF to ES-2	C	========
Drill Pilot Bhole/Instl String	C	=======
Lower raisebore Equip in ES-1	C	=
Assemble Raisehead at ES-2	pC	=
Preassemble ES-2 Lining Equip	C	======
Raisebore ES-2	pC	====
Install ES-2 Hoist	C	=======
Demobilize Raise Equipment	C	==
Install ES-2 Lining Plant	pC	=====
Map/Smpl/Line/Equp ES-2 to MTL	C	==============
MTL Available	C	M

Schedule Name: Yucca Mtn ESF Schedule Case No. 2.(b)
Project Manager:
As of date: 31-May-89 3:37pm Schedule File: A:ESCS#2B

ES-1 Conventional [UDBR, Delay Thermomech, Mucking Shaft]
ES-2 Raise Bored [Delay RBTs, Scientific Shaft]

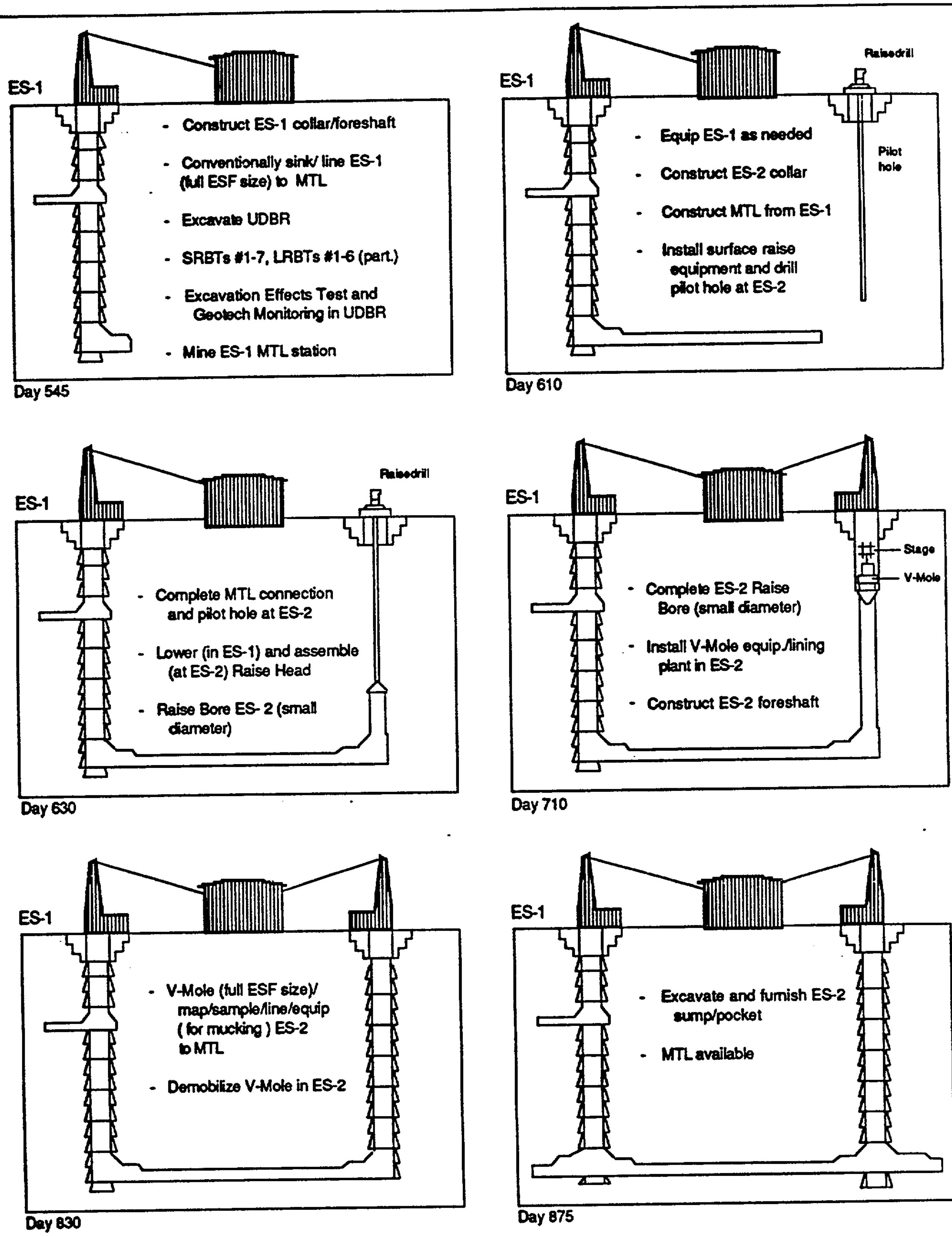
This is a selective report. All items shown in bold
* Notes (1) contains "ES1"

Task	How Long
Start ES-1 Shaft Construction	**0 days**
Construct ES-1 Collar	**20 days**
Preassemble ES-1 Sinking Equip	**30 days**
Construct ES-1 Foreshaft	**13 days**
ES-1 Hoist and Hoist House	**40 days**
Install ES-1 Sinking Plant	**30 days**
Sink/Line ES-1 to UDBR	**81 days**
Shaft Conv. Test #1 in ES-1	**20 days**
Excavate UDBR in ES-1	**35 days**
ES-1 Exc. Effects, Geotech Mon	**55 days**
Sink/Line ES-1 to MTL	**74 days**
Shaft Convergence Test #2 ES-1	**20 days**
Mine ES-1 MTL Station	**37 days**
Excavate ES-1 to Shaft Bottom	**16 days**
Furnish Sump / Pockets	**20 days**
Lower ESF Exc. Equip. in ES-1	**3 days**
Equip ES-1 Shaft	**20 days**
Start ES-2 Construction	0 days
Construct ES-2 Collar	20 days
Changeover to Permanent Hoist	**12 days**
Install Surface Raise Equipmet	10 days
Start ESF Const. from ES-1	**0 days**
Develop ESF to ES-2	**50 days**
Drill Pilot Bhole/Instl String	45 days
Lower raisebore Equip in ES-1	**2 days**
Assemble Raisehead at ES-2	3 days
Preassemble ES-2 Lining Equip	30 days
Raisebore ES-2	25 days
Install ES-2 Hoist	40 days
Demobilize Raise Equipment	3 days
Install ES-2 Lining Plant	30 days
Map/Smpl/Line/Equp ES-2 to MTL	90 days
MTL Available	0 days
Complete UDBR Tests in ES-1	**0 days**
Excavate DBOR	0 days
Install RBTs in ES-2	0 days
SCT #3 and Lower Exc. Effects	0 days
Construct ES-2 Sump	10 days

Schedule Name: Yucca Mtn ESF Schedule Case No. 2.(b)
Project Manager:
As of date: 31-May-89 3:38pm Schedule File: A:ESCS#2B

ES-1 Conventional [UDBR, Delay Thermomech, Mucking Shaft]
ES-2 Raise Bored [Delay RBTs, Scientific Shaft]

TASK	TOTAL
Start ES-1 Shaft Construction	0
Construct ES-1 Collar	300,000
Preassemble ES-1 Sinking Equip	200,000
Construct ES-1 Foreshaft	400,000
ES-1 Hoist and Hoist House	1,300,000
Install ES-1 Sinking Plant	500,000
Sink/Line ES-1 to UDBR	2,725,000
Shaft Conv. Test #1 in ES-1	320,000
Excavate UDBR in ES-1	875,000
ES-1 Exc. Effects, Geotech Mon	880,000
Sink/Line ES-1 to MTL	2,452,000
Shaft Convergence Test #2 ES-1	320,000
Mine ES-1 MTL Station	925,000
Excavate ES-1 to Shaft Bottom	400,000
Furnish Sump / Pockets	600,000
Lower ESF Exc. Equip. in ES-1	75,000
Equip ES-1 Shaft	720,000
Start ES-2 Construction	0
Construct ES-2 Collar	100,000
Changeover to Permanent Hoist	300,000
Install Surface Raise Equipmet	200,000
Start ESF Const. from ES-1	0
Develop ESF to ES-2	405,000
Drill Pilot Bhole/Instl String	300,000
Lower raisebore Equip in ES-1	50,000
Assemble Raisehead at ES-2	10,000
Preassemble ES-2 Lining Equip	100,000
Raisebore ES-2	312,500
Install ES-2 Hoist	600,000
Demobilize Raise Equipment	200,000
Install ES-2 Lining Plant	250,000
Map/Smpl/Line/Equp ES-2 to MTL	2,145,000
MTL Available	0
Complete UDBR Tests in ES-1	0
Excavate DBOR	0
Install RBTs in ES-2	0
SCT #3 and Lower Exc. Effects	0
Construct ES-2 Sump	150,000
TOTALS	18,114,500



ES-1 (Scientific) Conventional (Drill-and-Blast) Construction
ES-2 (Mucking) Raise Bore/V-Mole
Thermomechanical testing in UDBR and additional testing in LRBTs (in ES-1) delayed until after MTL is available.

Not to Scale

SCHEMATIC DESCRIPTION OF THE SEQUENCE OF SHAFT DEVELOPMENT/TESTING FOR CASE 3(a)

PROJECT NO. 833-1017.118 DWG. NO. 12407 DATE 6/20/89 DRAWN CW APPROVED CB

Golder Associates

Schedule Name: ..cca Mtn ESF Schedule Case No. 3.(a)
Project Manager:
As of date: 14-Jun-89 2:14pm Schedule File: A:ESCS#3A

ES-1 Conventional (UDBR, Delay Thermomech, SRBTs and install LRBTs
ES-2 Raise/V-Mole (Mucking Shaft)

	Status	12 (months) 24
Start ES-1 Shaft Construction	C	M
Construct ES-1 Collar	C	===
Preassemble ES-1 Sinking Equip	C	=====
SRBT#1 in ES-1 Collar	C	===
Construct ES-1 Foreshaft	C	===
ES-1 Hoist and Hoist House	C	======
Install ES-1 Sinking Plant	C	=====
Sink/Line ES-1 to UDBR	C	=============
Shaft Conv. Test #1 in ES-1	C	====
SRBT#2-6, inst LRBT#1-4 ES-1	C	=================
Excavate UDBR in ES-1	C	======
ES-1 Exc. Effects, Geotech Mon	C	========
Sink/Line ES-1 to MTL	C	###########
Shaft Convergence Test #2 ES-1	C	====
SRBT#7, inst LRBTs #5-6 ES-1	C	======
Mine ES-1 MTL Station	C	======
Start ES-2 Construction	C	M
Construct ES-2 Collar	C	====
Lower ESF Exc. Equip. in ES-1	C	=
Equip ES-1	C	===
Install Surface Raise Equipmet	C	===
Start ESF Const. from ES-1	C	M
Develop ESF to ES-2	C	========
Drill Pilot Bhole/Instl String	C	=======
Preassemble V-Mole	C	=====
Lower raisebore Equip in ES-1	C	=
Assemble Raisehead at ES-2	pC	=
Raisebore ES-2 to 8 ft	pC	===
Demobilize Raise Equipment	C	=
Install ES-2 Hoist	C	======
Install V-Mole equipment	C	=====
Preassemble ES-2 Lining Equip	C	=====
Construct ES-2 Foreshaft	C	==
Install Lining Plant in ES-2	C	=====
VMole/Map/Smpl/Line/Eqp to MTL	C	==============
Demobilize V-Mole Equipment	C	=====
Excavate ES-2 to Shaft Bottom	C	===
Furnish ES-2 Sump / Pockets	C	====
Changeover to Permanent Hoist	C	===
MTL Available	C	M

Schedule Name: Yucca Mtn ESF Schedule Case No. 3.(a)
Project Manager:
As of date: 31-May-89 3:40pm Schedule File: A:ESCS#3A

ES-1 Conventional [UDBR, Delay Thermomech, SRBTs and install LRBTs
ES-2 Raise/V-Mole [Mucking Shaft]

This is a selective report. All items shown in bold
* Notes (1) contains "ES1"

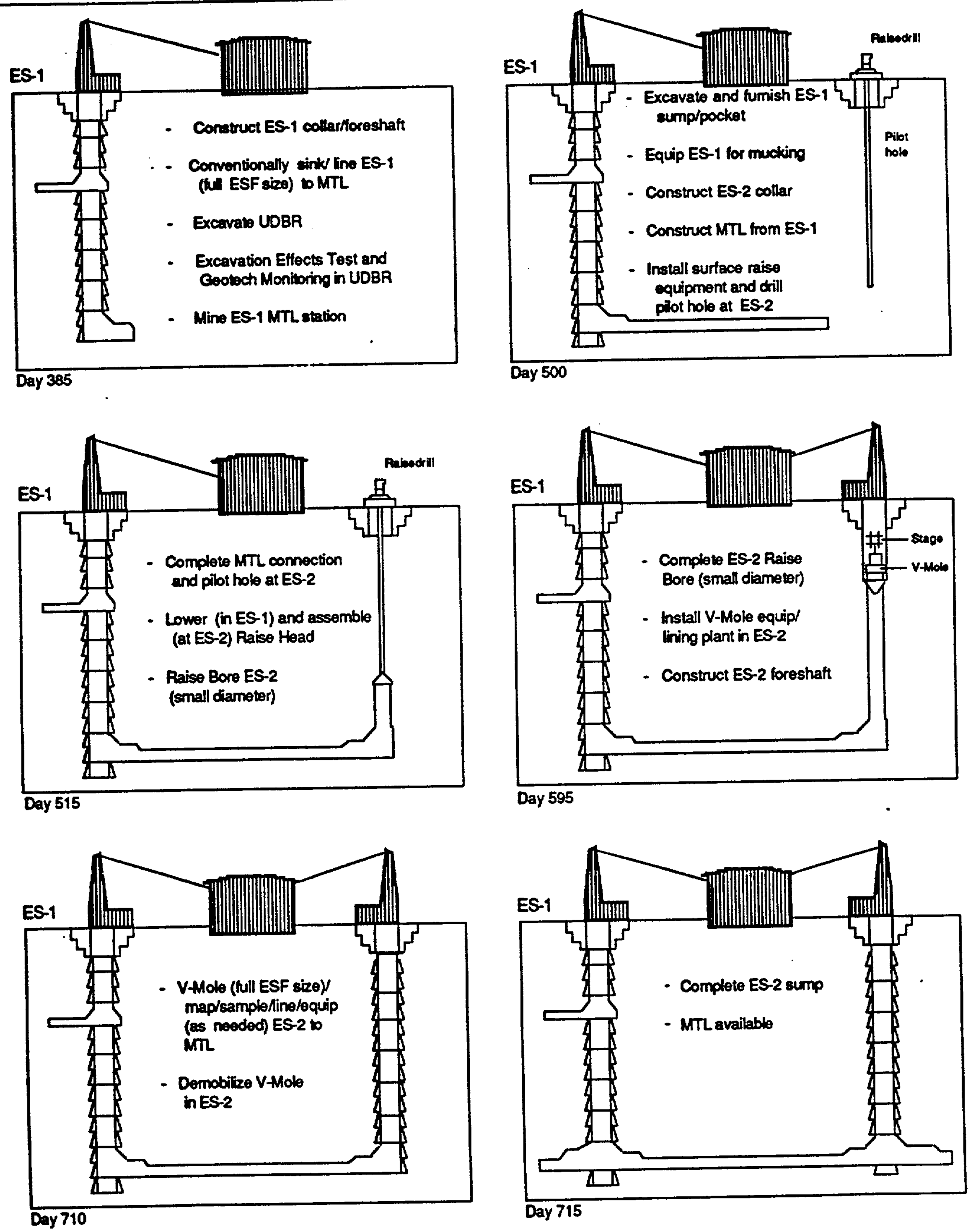
Task	How Long
Start ES-1 Shaft Construction	**0 days**
Construct ES-1 Collar	**20 days**
Preassemble ES-1 Sinking Equip	**30 days**
SRBT#1 in ES-1 Collar	**14 days**
Construct ES-1 Foreshaft	**13 days**
ES-1 Hoist and Hoist House	**40 days**
Install ES-1 Sinking Plant	**30 days**
Sink/Line ES-1 to UDBR	**81 days**
Shaft Conv. Test #1 in ES-1	**20 days**
SRBT#2-6, inst LRBT#1-4 ES-1	**110 days**
Excavate UDBR in ES-1	**35 days**
ES-1 Exc. Effects, Geotech Mon	**55 days**
Sink/Line ES-1 to MTL	**74 days**
Shaft Convergence Test #2 ES-1	**20 days**
SRBT#7, inst LRBTs #5-6 ES-1	**34 days**
Mine ES-1 MTL Station	**37 days**
Start ES-2 Construction	0 days
Construct ES-2 Collar	20 days
Lower ESF Exc. Equip. in ES-1	**3 days**
Equip ES-1	**20 days**
Install Surface Raise Equipmet	10 days
Start ESF Const. from ES-1	**0 days**
Develop ESF to ES-2	**50 days**
Drill Pilot Bhole/Instl String	45 days
Preassemble V-Mole	30 days
Lower raisebore Equip in ES-1	**2 days**
Assemble Raisehead at ES-2	3 days
Raisebore ES-2 to 8 ft	15 days
Demobilize Raise Equipment	2 days
Install ES-2 Hoist	40 days
Install V-Mole equipment	30 days
Preassemble ES-2 Lining Equip	30 days
Construct ES-2 Foreshaft	10 days
Install Lining Plant in ES-2	30 days
VMole/Map/Smpl/Line/Eqp to MTL	90 days
Demobilize V-Mole Equipment	30 days
Excavate ES-2 to Shaft Bottom	16 days
Furnish ES-2 Sump / Pockets	20 days
Changeover to Permanent Hoist	12 days
MTL Available	0 days
Excavate ES-1 Sump	**0 days**
Complete UDBR Tests in ES-1	**0 days**
SCT #3 and Lower Exc. Effects	0 days
Excavate DBOR	0 days
Construct ES-1 Sump	**10 days**

Schedule Name: Yucca Mtn ESF Schedule Case No. 3.(a)
Project Manager:
As of date: 31-May-89 3:39pm Schedule File: A:ESCS#3A

ES-1 Conventional [UDBR, Delay Thermomech, SRBTs and install LRBTs
ES-2 Raise/V-Mole [Mucking Shaft]

TASK	TOTAL
Start ES-1 Shaft Construction	0
Construct ES-1 Collar	300,000
Preassemble ES-1 Sinking Equip	200,000
SRBT#1 in ES-1 Collar	224,000
Construct ES-1 Foreshaft	400,000
ES-1 Hoist and Hoist House	1,300,000
Install ES-1 Sinking Plant	500,000
Sink/Line ES-1 to UDBR	2,725,000
Shaft Conv. Test #1 in ES-1	320,000
SRBT#2-6, inst LRBT#1-4 ES-1	1,760,000
Excavate UDBR in ES-1	875,000
ES-1 Exc. Effects, Geotech Mon	880,000
Sink/Line ES-1 to MTL	2,452,000
Shaft Convergence Test #2 ES-1	320,000
SRBT#7, inst LRBTs #5-6 ES-1	544,000
Mine ES-1 MTL Station	925,000
Start ES-2 Construction	0
Construct ES-2 Collar	100,000
Lower ESF Exc. Equip. in ES-1	75,000
Equip ES-1	720,000
Install Surface Raise Equipmet	200,000
Start ESF Const. from ES-1	0
Develop ESF to ES-2	405,000
Drill Pilot Bhole/Instl String	300,000
Preassemble V-Mole	675,000
Lower raisebore Equip in ES-1	50,000
Assemble Raisehead at ES-2	10,000
Raisebore ES-2 to 8 ft	187,500
Demobilize Raise Equipment	200,000
Install ES-2 Hoist	600,000
Install V-Mole equipment	675,000
Preassemble ES-2 Lining Equip	100,000
Construct ES-2 Foreshaft	225,000
Install Lining Plant in ES-2	250,000
VMole/Map/Smpl/Line/Eqp to MTL	3,645,000
Demobilize V-Mole Equipment	675,000
Excavate ES-2 to Shaft Bottom	400,000
Furnish ES-2 Sump / Pockets	600,000
Changeover to Permanent Hoist	300,000
MTL Available	0
Excavate ES-1 Sump	0
Complete UDBR Tests in ES-1	0
SCT #3 and Lower Exc. Effects	0
Excavate DBOR	0
Construct ES-1 Sump	250,000
TOTALS	24,367,500

TIME LINE Cost Report by Period vs Task



ES-1 (Mucking) Conventional (Drill-and-Blast) Construction
ES-2 (Scientific) Raise Bore/V-Mole
Thermomechanical testing in UDBR and all RBTs (in ES-2) delayed until after MTL is available.

Not to Scale

SCHEMATIC DESCRIPTION OF THE SEQUENCE OF SHAFT DEVELOPMENT/TESTING FOR CASE 3(b)

PROJECT NO. 833-1017.118 DWG. NO. 12407 DATE 6/20/89 DRAWN CW APPROVED CB

Golder Associates

Schedule Name: Yucca Mtn ESF Schedule Case No. 3.(b)
Project Manager:
As of date: 14-Jun-89 2:16pm Schedule File: A:ESCS#3B

ES-1 Conventional [UDBR, Delay Thermomech, Mucking Shaft]
ES-2 Raise/V-Mole [Delay RBTs, Scientific Shaft]

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                                Status                          12              (months)              24

Start ES-1 Shaft Construction    C M . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
Construct ES-1 Collar            C ===  . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
Preassemble ES-1 Sinking Equip   C ===== . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
Construct ES-1 Foreshaft         C   === . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
ES-1 Hoist and Hoist House       C  .====== . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
Install ES-1 Sinking Plant       C  . ===== . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
Sink/Line ES-1 to UDBR           C  .  . ============ . . . . . . . . . . . . . . . . . . . . . . . .
Shaft Conv. Test #1 in ES-1      C  . . . . . .====. . . . . . . . . . . . . . . . . . . . . . . . .
Excavate UDBR in ES-1            C  . . . . . . . ====== . . . . . . . . . . . . . . . . . . . . . .
ES-1 Exc. Effects, Geotech Mon   C  . . . . . . . . =========. . . . . . . . . . . . . . . . . . . .
Sink/Line ES-1 to MTL            C  . . . . . . . . . . =========== . . . . . . . . . . . . . . . .
Shaft Convergence Test #2 ES-1   C  . . . . . . . . . . . .====. . . . . . . . . . . . . . . . . . .
Mine ES-1 MTL Station            C  . . . . . . . . . . . . ====== . . . . . . . . . . . . . . . . .
Excavate ES-1 to Shaft Bottom    C  . . . . . . . . . . . . . . .===. . . . . . . . . . . . . . . .
Furnish ES-1 Sump / Pockets      C  . . . . . . . . . . . . . . . ==== . . . . . . . . . . . . . . .
Lower ESF Exc. Equip. in ES-1    C  . . . . . . . . . . . . . . . . = . . . . . . . . . . . . . . .
Equip ES-1 Shaft                 C  . . . . . . . . . . . . . . . . ==== . . . . . . . . . . . . . .
Start ES-2 Construction          C  . . . . . . . . . . . . . . . . M . . . . . . . . . . . . . . .
Construct ES-2 Collar            C  . . . . . . . . . . . . . . . . === . . . . . . . . . . . . . .
Changeover to Permanent Hoist    C  . . . . . . . . . . . . . . . . . === . . . . . . . . . . . . .
Install Surface Raise Equipmet   C  . . . . . . . . . . . . . . . . . .== . . . . . . . . . . . . .
Start ESF Const. from ES-1       C  . . . . . . . . . . . . . . . . . . M . . . . . . . . . . . . .
Develop ESF to ES-2              C  . . . . . . . . . . . . . . . . . . ======== . . . . . . . . . .
Drill Pilot Bhle/Instal String   C  . . . . . . . . . . . . . . . . . . =======. . . . . . . . . . .
Preassemble V-Mole               C  . . . . . . . . . . . . . . . . . . . . =====. . . . . . . . . .
Lower raisebore Equip in ES-1    C  . . . . . . . . . . . . . . . . . . . . = . . . . . . . . . . .
Assemble Raisehead at ES-2      pC  . . . . . . . . . . . . . . . . . . . . = . . . . . . . . . . .
Raisebore ES-2 to 8 ft          pC  . . . . . . . . . . . . . . . . . . . .===. . . . . . . . . . .
Demobilize Raise Equipment       C  . . . . . . . . . . . . . . . . . . . . . =. . . . . . . . . . .
Install V-Mole Equipment ES-2    C  . . . . . . . . . . . . . . . . . . . . . =====. . . . . . . . .
Preassemble ES-2 Lining Equip    C  . . . . . . . . . . . . . . . . . . . . . .===== . . . . . . . .
Install ES-2 Hoist               C  . . . . . . . . . . . . . . . . . . . . . . ======= . . . . . . .
Construct ES-2 Foreshaft         C  . . . . . . . . . . . . . . . . . . . . . . === . . . . . . . . .
Install ES-2 Lining Equip       pC  . . . . . . . . . . . . . . . . . . . . . . .===== . . . . . . .
VMole/Map/Smpl/Line/Eqp to MTL   C  . . . . . . . . . . . . . . . . . . . . . . . . ============== .
Demobilize V-Mole equipment      C  . . . . . . . . . . . . . . . . . . . . . . . . . . . ===== . . .
MTL Available                    C  . . . . . . . . . . . . . . . . . . . . . . . . . . . . M . . . .
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Schedule Name: Yucca Mtn ESF Schedule Case No. 3.(b)
Project Manager:
As of date: 31-May-89 3:41pm Schedule File: A:ESCS#3B

ES-1 Conventional [UDBR, Delay Thermomech, Mucking Shaft]
ES-2 Raise/V-Mole [Delay RBTs, Scientific Shaft]

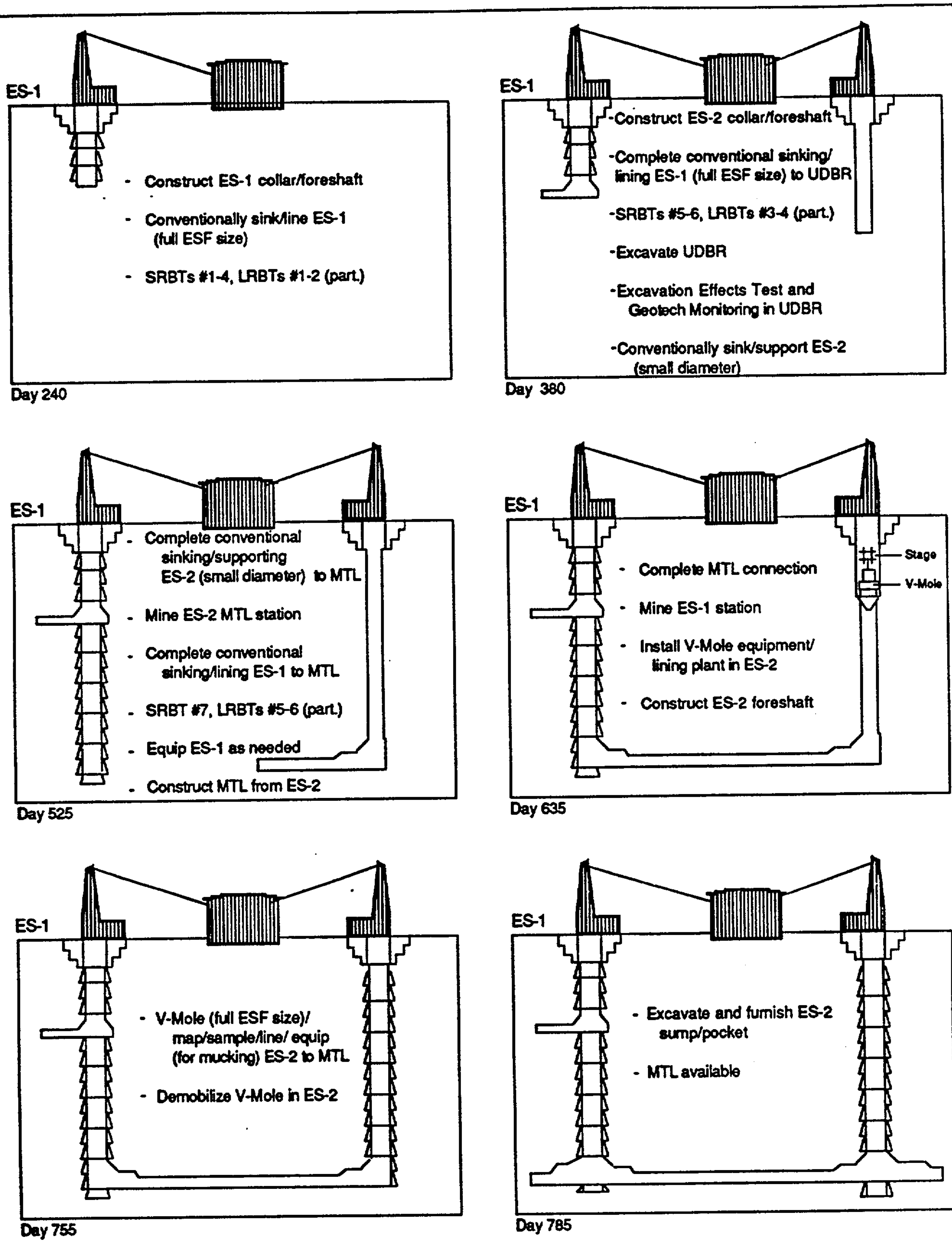
This is a selective report. All items shown in bold
 * Notes (1) contains "ES1"

Task	How Long
Start ES-1 Shaft Construction	**0 days**
Construct ES-1 Collar	**20 days**
Preassemble ES-1 Sinking Equip	**30 days**
Construct ES-1 Foreshaft	**13 days**
ES-1 Hoist and Hoist House	**40 days**
Install ES-1 Sinking Plant	**30 days**
Sink/Line ES-1 to UDBR	**81 days**
Shaft Conv. Test #1 in ES-1	**20 days**
Excavate UDBR in ES-1	**35 days**
ES-1 Exc. Effects, Geotech Mon	**55 days**
Sink/Line ES-1 to MTL	**74 days**
Shaft Convergence Test #2 ES-1	**20 days**
Mine ES-1 MTL Station	**37 days**
Excavate ES-1 to Shaft Bottom	**16 days**
Furnish ES-1 Sump / Pockets	**20 days**
Lower ESF Exc. Equip. in ES-1	**3 days**
Equip ES-1 Shaft	**20 days**
Start ES-2 Construction	0 days
Construct ES-2 Collar	20 days
Changeover to Permanent Hoist	**12 days**
Install Surface Raise Equipmet	10 days
Start ESF Const. from ES-1	**0 days**
Develop ESF to ES-2	**50 days**
Drill Pilot Bhle/Instal String	45 days
Preassemble V-Mole	30 days
Lower raisebore Equip in ES-1	**2 days**
Assemble Raisehead at ES-2	3 days
Raisebore ES-2 to 8 ft	15 days
Demobilize Raise Equipment	2 days
Install V-Mole Equipment ES-2	30 days
Preassemble ES-2 Lining Equip	30 days
Install ES-2 Hoist	40 days
Construct ES-2 Foreshaft	10 days
Install ES-2 Lining Equip	30 days
VMole/Map/Smpl/Line/Eqp to MTL	90 days
Demobilize V-Mole equipment	30 days
MTL Available	**0 days**
Complete UDBR Tests	0 days
Excavate DBOR	0 days
Install RBTs in ES-2	0 days
SCT #3 and Lower Exc. Effects	0 days
Complete ES-2 Sump	10 days

Schedule Name: Yucca Mtn ESF Schedule Case No. 3.(b)
Project Manager:
As of date: 31-May-89 3:42pm Schedule File: A:ESCS#3B

ES-1 Conventional [UDBR, Delay Thermomech, Mucking Shaft]
ES-2 Raise/V-Mole [Delay RBTs, Scientific Shaft]

TASK	TOTAL
Start ES-1 Shaft Construction	0
Construct ES-1 Collar	300,000
Preassemble ES-1 Sinking Equip	200,000
Construct ES-1 Foreshaft	400,000
ES-1 Hoist and Hoist House	1,300,000
Install ES-1 Sinking Plant	500,000
Sink/Line ES-1 to UDBR	2,725,000
Shaft Conv. Test #1 in ES-1	320,000
Excavate UDBR in ES-1	875,000
ES-1 Exc. Effects, Geotech Mon	880,000
Sink/Line ES-1 to MTL	2,452,000
Shaft Convergence Test #2 ES-1	320,000
Mine ES-1 MTL Station	925,000
Excavate ES-1 to Shaft Bottom	400,000
Furnish ES-1 Sump / Pockets	600,000
Lower ESF Exc. Equip. in ES-1	75,000
Equip ES-1 Shaft	720,000
Start ES-2 Construction	0
Construct ES-2 Collar	100,000
Changeover to Permanent Hoist	300,000
Install Surface Raise Equipmet	200,000
Start ESF Const. from ES-1	0
Develop ESF to ES-2	405,000
Drill Pilot Bhle/Instal String	300,000
Preassemble V-Mole	675,000
Lower raisebore Equip in ES-1	50,000
Assemble Raisehead at ES-2	10,000
Raisebore ES-2 to 8 ft	187,500
Demobilize Raise Equipment	200,000
Install V-Mole Equipment ES-2	675,000
Preassemble ES-2 Lining Equip	100,000
Install ES-2 Hoist	600,000
Construct ES-2 Foreshaft	225,000
Install ES-2 Lining Equip	250,000
VMole/Map/Smpl/Line/Eqp to MTL	3,645,000
Demobilize V-Mole equipment	675,000
MTL Available	0
Complete UDBR Tests	0
Excavate DBOR	0
Install RBTs in ES-2	0
SCT #3 and Lower Exc. Effects	0
Complete ES-2 Sump	150,000
TOTALS	21,739,500



ES-1 (Scientific), Conventional (Drill-and-Blast) Construction
ES-2 (Mucking), Conventional/V-Mole Construction
Thermomechancial testing in UDBR and additional testing in LRBTs (in ES-1) delayed until after MTL is available.

Not to Scale

SCHEMATIC DESCRIPTION OF THE SEQUENCE OF SHAFT DEVELOPMENT/TESTING FOR CASE 4(a)

PROJECT NO. 833-1017.116 DWG. NO. 12408 DATE 6/20/89 DRAWN CW APPROVED CB

Golder Associates

Schedule Name: Yucca Mtn ESF Schedule Case No. 4(a)
Project Manager:
As of date: 14-Jun-89 2:17pm Schedule File: A:ESCS#4A

ES-1 Conventional [Mine UDBR, Delay Thermomech tests, Scientific Shaft]
ES-2 Conventional and V-Mole [Delay RBTs, Mucking Shaft]

12 (months) 24

	Status
Start ES-1 Shaft Construction	C
Construct ES-1 Collar	C
Preassemble ES-1 Sinking Equip	C
SRBT#1 in ES-1 Collar	C
Construct ES-1 Foreshaft	C
ES-1 Hoist and Hoist House	C
Install ES-1 Sinking Plant	C
Sink/Line ES-1 to UDBR	C
Shaft Conv. Test #1 in ES-1	C
SRBT#2-6, Inst LRBT#1-4 ES-1	C
Start ES-2 Construction	C
Construct ES-2 Collar	C
Preassemble ES-2 Sinking Equip	C
Construct ES-2 Foreshaft	C
ES-2 Hoist and Hoisthouse	pC
Install ES-2 Sinking Plant	C
Excavate UDBR in ES-1	C
Sink / Support ES-2 to MTL	C
Exc. Effects, Geot. Mon ES-1	C
Sink/Line ES-1 to MTL	C
Shaft Convergence Test #2 ES-1	C
Excavate ES-2 MTL Station	C
SRBT#7, Inst LRBT#5-6 in ES-1	C
Lower ESF Exc. Equip. in ES-2	C
Equip ES-1	C
Start MTL Const. from ES-2	C
Develop ESF to ES-1	C
Mine ES-1 MTL Station	C
Preassemble V-Mole	C
Remove Shaft Sinking Equipment	C
Install V-Mole equipment	C
Preassemble ES-2 Lining Equip	C
V-Mole ES-2 Foreshaft	C
Install ES-2 Lining Equipment	C
VMole/Map/Smpl/Line/Eqp to MTL	C
Demobilize V-Mole	C
Excavate ES-2 to Shaft Bottom	pC
Furnish Sump / Pockets	C
Install Permanent Hoist in ES2	C
MTL Available	C

Schedule Name: Yucca Mtn ESF Schedule Case No. 4(a)
Project Manager:
As of date: 31-May-89 3:44pm Schedule File: A:ESCS#4A

ES-1 Conventional [Mine UDBR, Delay Thermomech tests, Scientific Shaft]
ES-2 Conventional and V-Mole [Delay RBTs, Mucking Shaft]

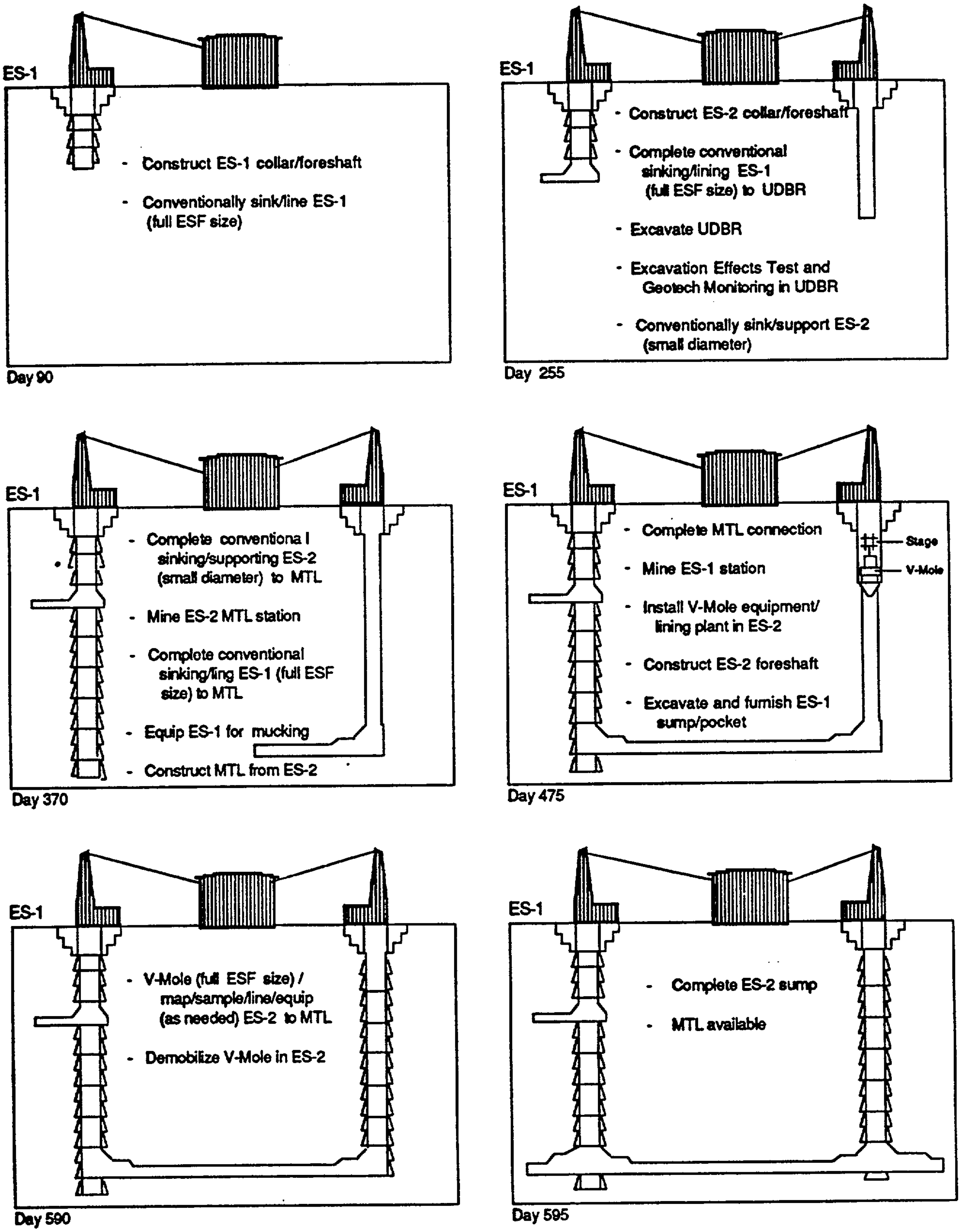
This is a selective report. All items shown in bold
* Notes (1) contains "ES1"

Task	How Long
Start ES-1 Shaft Construction	**0 days**
Construct ES-1 Collar	**20 days**
Preassemble ES-1 Sinking Equip	**30 days**
SRBT#1 in ES-1 Collar	**14 days**
Construct ES-1 Foreshaft	**13 days**
ES-1 Hoist and Hoist House	**40 days**
Install ES-1 Sinking Plant	**30 days**
Sink/Line ES-1 to UDBR	**81 days**
Shaft Conv. Test #1 in ES-1	**20 days**
SRBT#2-6, Inst LRBT#1-4 ES-1	**110 days**
Start ES-2 Construction	0 days
Construct ES-2 Collar	20 days
Preassemble ES-2 Sinking Equip	30 days
Construct ES-2 Foreshaft	13 days
ES-2 Hoist and Hoisthouse	40 days
Install ES-2 Sinking Plant	30 days
Excavate UDBR in ES-1	**35 days**
Sink / Support ES-2 to MTL	154 days
Exc. Effects, Geot. Mon ES-1	**55 days**
Sink/Line ES-1 to MTL	**74 days**
Shaft Convergence Test #2 ES-1	**20 days**
Excavate ES-2 MTL Station	37 days
SRBT#7, Inst LRBT#5-6 in ES-1	**34 days**
Lower ESF Exc. Equip. in ES-2	3 days
Equip ES-1	**20 days**
Start MTL Const. from ES-2	0 days
Develop ESF to ES-1	50 days
Mine ES-1 MTL Station	**37 days**
Preassemble V-Mole	30 days
Remove Shaft Sinking Equipment	5 days
Install V-Mole equipment	30 days
Preassemble ES-2 Lining Equip	30 days
V-Mole ES-2 Foreshaft	10 days
Install ES-2 Lining Equipment	30 days
VMole/Map/Smpl/Line/Eqp to MTL	90 days
Demobilize V-Mole	30 days
Excavate ES-2 to Shaft Bottom	16 days
Furnish Sump / Pockets	20 days
Install Permanent Hoist in ES2	12 days
MTL Available	0 days
Complete UDBR Tests in ES-1	**0 days**
Excavate DBOR	0 days
Install RBTs in ES-1	**0 days**
SCT#3 and Lower Exc. Effects	0 days
Complete ES-1 Sump	**10 days**

Schedule Name: Yucca Mtn ESF Schedule Case No. 4(a)
Project Manager:
As of date: 31-May-89 3:43pm Schedule File: A:ESCS#4A

ES-1 Conventional [Mine UDBR, Delay Thermomech tests, Scientific Shaft]
ES-2 Conventional and V-Mole [Delay RBTs, Mucking Shaft]

TASK	TOTAL
Start ES-1 Shaft Construction	0
Construct ES-1 Collar	300,000
Preassemble ES-1 Sinking Equip	200,000
SRBT#1 in ES-1 Collar	224,000
Construct ES-1 Foreshaft	400,000
ES-1 Hoist and Hoist House	1,300,000
Install ES-1 Sinking Plant	500,000
Sink/Line ES-1 to UDBR	2,725,000
Shaft Conv. Test #1 in ES-1	320,000
SRBT#2-6, Inst LRBT#1-4 ES-1	1,760,000
Start ES-2 Construction	0
Construct ES-2 Collar	100,000
Preassemble ES-2 Sinking Equip	100,000
Construct ES-2 Foreshaft	200,000
ES-2 Hoist and Hoisthouse	600,000
Install ES-2 Sinking Plant	250,000
Excavate UDBR in ES-1	875,000
Sink / Support ES-2 to MTL	2,510,000
Exc. Effects, Geot. Mon ES-1	880,000
Sink/Line ES-1 to MTL	2,452,000
Shaft Convergence Test #2 ES-1	320,000
Excavate ES-2 MTL Station	555,000
SRBT#7, Inst LRBT#5-6 in ES-1	544,000
Lower ESF Exc. Equip. in ES-2	45,000
Equip ES-1	720,000
Start MTL Const. from ES-2	0
Develop ESF to ES-1	405,000
Mine ES-1 MTL Station	925,000
Preassemble V-Mole	675,000
Remove Shaft Sinking Equipment	75,000
Install V-Mole equipment	675,000
Preassemble ES-2 Lining Equip	100,000
V-Mole ES-2 Foreshaft	225,000
Install ES-2 Lining Equipment	250,000
VMole/Map/Smpl/Line/Eqp to MTL	3,645,000
Demobilize V-Mole	675,000
Excavate ES-2 to Shaft Bottom	400,000
Furnish Sump / Pockets	600,000
Install Permanent Hoist in ES2	300,000
MTL Available	0
Complete UDBR Tests in ES-1	0
Excavate DBOR	0
Install RBTs in ES-1	0
SCT#3 and Lower Exc. Effects	0
Complete ES-1 Sump	250,000
TOTALS	27,080,000



ES-1 (Mucking) Conventional (Drill-and-Blast) Construction
ES-2 (Scientific) Conventional/V-Mole Construction
Thermomechancial testing in UDBR and all RBTs (in ES-2) delayed until after MTL is available.

Not to Scale

SCHEMATIC DESCRIPTION OF THE SEQUENCE OF SHAFT DEVELOPMENT/TESTING FOR CASE 4(b)

PROJECT NO. 833-1017.116 DWG. NO. 12408 DATE 6/20/89 DRAWN CW APPROVED CB

Golder Associates

Schedule Name: Yucca Mtn ESF Schedule Case No. 4(b)
Project Manager:
As of date: 14-Jun-89 2:18pm Schedule File: A:ESCS#4B

ES-1 Conventional [Mine UDBR, Delay Thermomech tests, Mucking Shaft]
ES-2 Conventional and V-Mole [Delay RBTs, Scientific Shaft]

Activity	Status	(months: 12 … 24)
Start ES-1 Shaft Construction	C	M.
Construct ES-1 Collar	C	===
Preassemble ES-1 Sinking Equip	C	=====
Construct ES-1 Foreshaft	C	.===
ES-1 Hoist and Hoist House	C	======
Install ES-1 Sinking Plant	C	=====
Sink/Line ES-1 to UDBR	C	============
Start ES-2 Construction	C	M
Construct ES-2 Collar	C	====
Preassemble ES-2 Sinking Equip	C	=====
Construct ES-2 Foreshaft	C	.==
ES-2 Hoist and Hoisthouse	pC	.=======.
Install ES-2 Sinking Plant	C	=====.
Shaft Conv. Test #1 in ES-1	C	.====
Sink / Support ES-2 to MTL	C	=======================.
Excavate UDBR in ES-1	C	======
Exc. Effects, Geot. Mon ES-1	C	=========
Sink/Line ES-1 to MTL	C	===========
Excavate ES-2 MTL Station	C	======
Shaft Convergence Test #2 ES-1	C	.====
Lower ESF Exc. Equip. in ES-2	C	=
Equip ES-1	C	====
Start MTL Const. from ES-2	C	.M
Develop ESF to ES-1	C	.========.
Mine ES-1 MTL Station	C	======.
Preassemble V-Mole	C	=====.
Remove ES-2 Sinking Equipment	C	=.
Install V-Mole Equip in ES-2	C	======
Preassemble ES-2 Lining Equip	C	.=====
Excavate ES-1 to Shaft Bottom	C	===
V-Mole ES-2 Foreshaft	C	==
Furnish ES-1 Sump / Pockets	C	.====.
Install ES-2 Lining Equipment	C	.=====
Changeover ES-1 to Permt Hoist	C	==
VMole/Map/Smpl/Line/Eqp to MTL	C	==============
Demobilize V-Mole	C	=====
MTL Available	C	.M

Schedule Name: Yucca Mtn ESF Schedule Case No. 4(b)
Project Manager:
As of date: 31-May-89 3:45pm Schedule File: A:ESCS#4B

ES-1 Conventional [Mine UDBR, Delay Thermomech tests, Mucking Shaft]
ES-2 Conventional and V-Mole [Delay RBTs, Scientific Shaft]

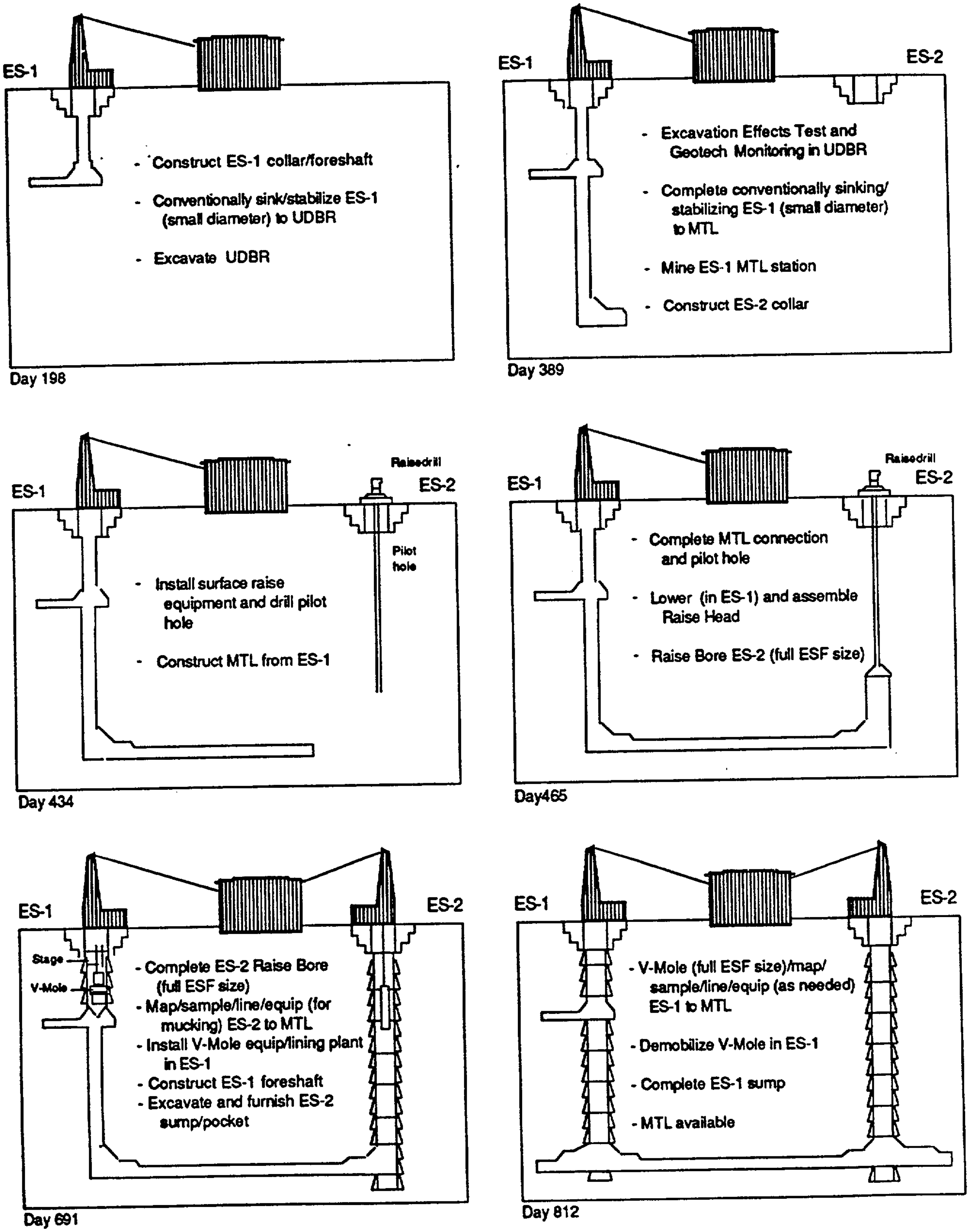
This is a selective report. All items shown in bold
* Notes (1) contains "ES1"

Task	How Long
Start ES-1 Shaft Construction	**0 days**
Construct ES-1 Collar	**20 days**
Preassemble ES-1 Sinking Equip	**30 days**
Construct ES-1 Foreshaft	**13 days**
ES-1 Hoist and Hoist House	**40 days**
Install ES-1 Sinking Plant	**30 days**
Sink/Line ES-1 to UDBR	**81 days**
Start ES-2 Construction	0 days
Construct ES-2 Collar	20 days
Preassemble ES-2 Sinking Equip	30 days
Construct ES-2 Foreshaft	13 days
ES-2 Hoist and Hoisthouse	40 days
Install ES-2 Sinking Plant	30 days
Shaft Conv. Test #1 in ES-1	**20 days**
Sink / Support ES-2 to MTL	154 days
Excavate UDBR in ES-1	**35 days**
Exc. Effects, Geot. Mon ES-1	**55 days**
Sink/Line ES-1 to MTL	**74 days**
Excavate ES-2 MTL Station	37 days
Shaft Convergence Test #2 ES-1	**20 days**
Lower ESF Exc. Equip. in ES-2	3 days
Equip ES-1	**20 days**
Start MTL Const. from ES-2	0 days
Develop ESF to ES-1	50 days
Mine ES-1 MTL Station	**37 days**
Preassemble V-Mole	30 days
Remove ES-2 Sinking Equipment	5 days
Install V-Mole Equip in ES-2	30 days
Preassemble ES-2 Lining Equip	30 days
Excavate ES-1 to Shaft Bottom	**16 days**
V-Mole ES-2 Foreshaft	10 days
Furnish ES-1 Sump / Pockets	**20 days**
Install ES-2 Lining Equipment	30 days
Changeover ES-1 to Permt Hoist	**12 days**
VMole/Map/Smpl/Line/Eqp to MTL	90 days
Demobilize V-Mole	30 days
MTL Available	0 days
Complete UDBR Tests in ES-1	**0 days**
Excavate DBOR	0 days
Install RBTs in ES-2	0 days
SCT#3 and Lower Exc. Effects	0 days
Complete ES-2 Sump	10 days

Schedule Name: Yucca Mtn ESF Schedule Case No. 4(b)
Project Manager:
As of date: 31-May-89 3:45pm Schedule File: A:ESCS#4B

ES-1 Conventional [Mine UDBR, Delay Thermomech tests, Mucking Shaft]
ES-2 Conventional and V-Mole [Delay RBTs, Scientific Shaft]

TASK	TOTAL
Start ES-1 Shaft Construction	0
Construct ES-1 Collar	300,000
Preassemble ES-1 Sinking Equip	200,000
Construct ES-1 Foreshaft	400,000
ES-1 Hoist and Hoist House	1,300,000
Install ES-1 Sinking Plant	500,000
Sink/Line ES-1 to UDBR	2,725,000
Start ES-2 Construction	0
Construct ES-2 Collar	100,000
Preassemble ES-2 Sinking Equip	100,000
Construct ES-2 Foreshaft	200,000
ES-2 Hoist and Hoisthouse	600,000
Install ES-2 Sinking Plant	250,000
Shaft Conv. Test #1 in ES-1	320,000
Sink / Support ES-2 to MTL	2,510,000
Excavate UDBR in ES-1	875,000
Exc. Effects, Geot. Mon ES-1	880,000
Sink/Line ES-1 to MTL	2,452,000
Excavate ES-2 MTL Station	555,000
Shaft Convergence Test #2 ES-1	320,000
Lower ESF Exc. Equip. in ES-2	45,000
Equip ES-1	720,000
Start MTL Const. from ES-2	0
Develop ESF to ES-1	405,000
Mine ES-1 MTL Station	925,000
Preassemble V-Mole	675,000
Remove ES-2 Sinking Equipment	75,000
Install V-Mole Equip in ES-2	675,000
Preassemble ES-2 Lining Equip	100,000
Excavate ES-1 to Shaft Bottom	400,000
V-Mole ES-2 Foreshaft	225,000
Furnish ES-1 Sump / Pockets	600,000
Install ES-2 Lining Equipment	250,000
Changeover ES-1 to Permt Hoist	300,000
VMole/Map/Smpl/Line/Eqp to MTL	3,645,000
Demobilize V-Mole	675,000
MTL Available	0
Complete UDBR Tests in ES-1	0
Excavate DBOR	0
Install RBTs in ES-2	0
SCT#3 and Lower Exc. Effects	0
Complete ES-2 Sump	150,000
TOTALS	24,452,000



ES-1 (Scientific) Conventional (Drill-and-Blast)/V-Mole Construction
ES-2 (Mucking)Single-Pass Raise Bore
Thermomechanical testing in UDBR and all RBTs (in ES-1) delayed until after MTL is available

Not to Scale

SCHEMATIC DESCRIPTION OF THE SEQUENCE OF SHAFT DEVELOPMENT/TESTING FOR CASE 5(b)

PROJECT NO. 833-1017-116 DWG. NO. 12406 DATE 6/20/89 DRAWN CW APPROVED CB

Golder Associates

Schedule Name: Yucca Mtn ESF Schedule Case No. 5.(b)
Project Manager:
As of date: 29-Aug-89 1:15pm Schedule File: A:ESCS#5B

ES-1 Convntnl Small Diam/V-Mole [UDBR, Delay Therm/RBDTs, Scientific Shaft]
ES-2 Raise Bored [Mucking Shaft]

This is a selective report. All items shown in bold
* Notes (1) contains "ES1"

D Done
C Critical
R Resource conflict
p Partial dependency
Scale: Each character equals 1 week

=== Task
+++ Started task
M Milestone

- Slack time (==---), or
Resource delay (---==)
> Conflict

(months): 6, 12, 18, 24, 28

Task	Status	Schedule
Start ES-1 Shaft Construction	C	M
Construct ES-1 Collar	C	===
Preassemble ES-1 Sinking Equip	C	=====
Construct ES-1 Foreshaft	C	===
ES-1 Hoist and Hoist House	C	======
Install ES-1 Sinking Plant	C	=====
Sink/Support ES-1 to UDBR	C	============
Shaft Conv. Test #1 in ES-1	C	====
Excavate UDBR in ES-1	C	======
ES-1 Exc. Effects, Geotech Mon	C	==========
Sink/Support ES-1 to MTL	C	===========
Shaft Convergence Test #2 ES-1	C	====
Mine ES-1 MTL Station	C	======
Start ES-2 Construction	C	M
Construct ES-2 Collar	C	====
Lower ESF Exc. Equip. in ES-1	C	=
Install Temp Equip in ES-1	C	==
Install Surface Raise Equipmet	C	===
Start ESF Const. from ES-1	C	M
Develop ESF to ES-2	C	========
Drill Pilot Bhole/Instl String	C	=======
Lower raisebore Equip in ES-1	C	=
Assemble Raisehead at ES-2	pC	=
Preassemble ES-2 Lining Equip	C	=====
Raisebore ES-2	pC	=====
Install ES-2 Hoist	C	=======
Demobilize Raise Equipment	C	=
Install ES-2 Lining Plant	pC	======
Map/Smpl/Line/Equp ES-2 to MTL	C	=============
Preassemble V-Mole for ES-1	C	=====
Excavate ES-2 to Shaft Bottom	C	===
Remove Shaft Equip from ES-1	C	=
Furnish Sump / Pockets in ES-2	C	====
Install V-Mole Equip in ES-1	C	=====
Preassemble ES-1 Lining Equip	C	=====
Changeover to Perm Hoist ES-2	C	===
V-Mole ES-1 Foreshaft	C	==
Install ES-1 Lining Equip	C	=====
Vmole/Map/Smpl/Line/Eqp to MTL	C	=============
Demobilize V-Mole	C	======
MTL Available	C	M

Schedule Name: Yucca Mtn ESF Schedule Case No. 5.(b)
Project Manager:
As of date: 29-Aug-89 1:16pm Schedule File: A:ESCS#5B

ES-1 Convntnl Small Diam/V-Mole [UDBR, Delay Therm/RBDTs, Scientific Sha
ES-2 Raise Bored [Mucking Shaft]

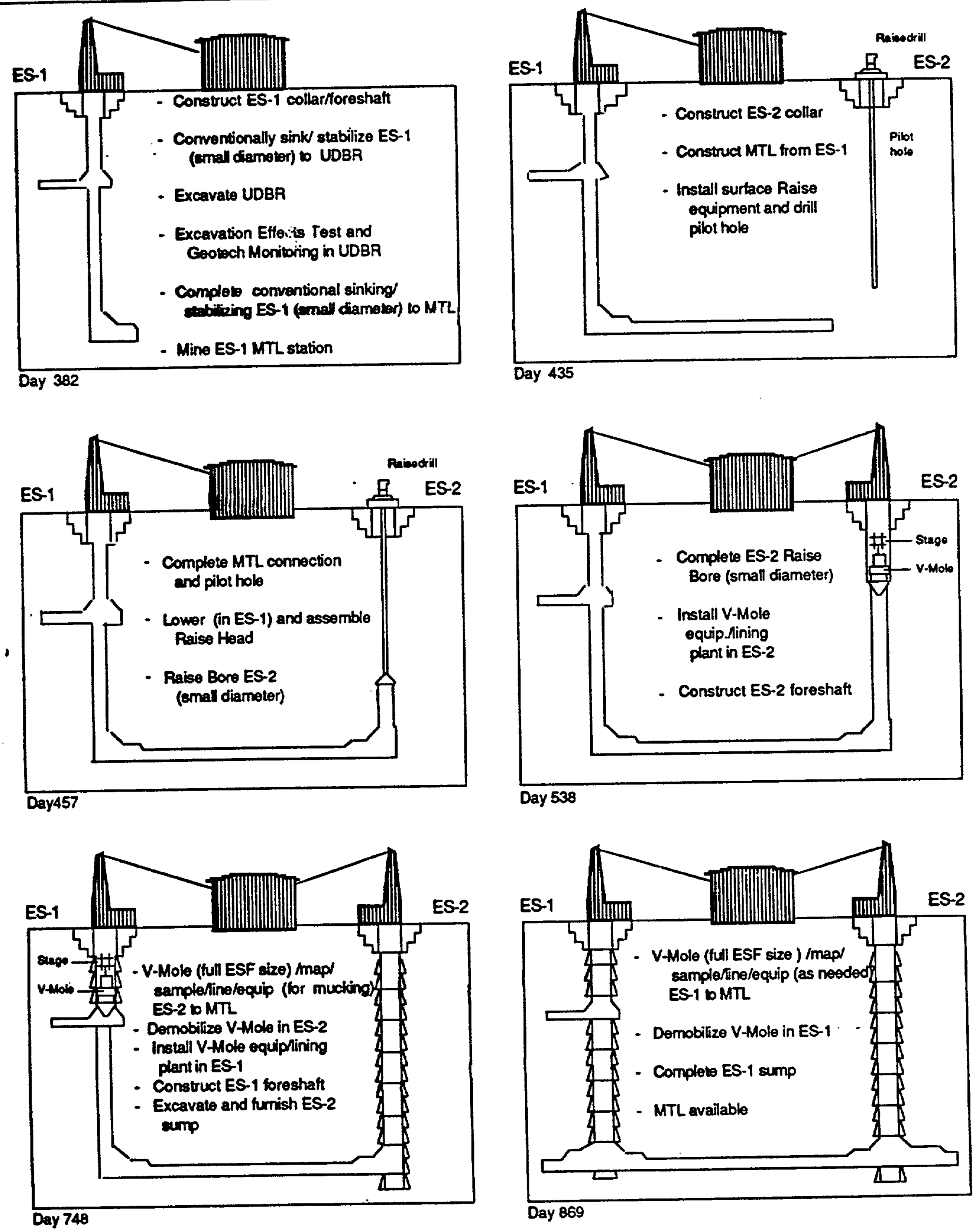
This is a selective report. All items shown in bold
* Notes (1) contains "ES1"

Task	How Long
Start ES-1 Shaft Construction	**0 days**
Construct ES-1 Collar	**20 days**
Preassemble ES-1 Sinking Equip	**30 days**
Construct ES-1 Foreshaft	**13 days**
ES-1 Hoist and Hoist House	**40 days**
Install ES-1 Sinking Plant	**30 days**
Sink/Support ES-1 to UDBR	**81 days**
Shaft Conv. Test #1 in ES-1	**20 days**
Excavate UDBR in ES-1	**35 days**
ES-1 Exc. Effects, Geotech Mon	**55 days**
Sink/Support ES-1 to MTL	**74 days**
Shaft Convergence Test #2 ES-1	**20 days**
Mine ES-1 MTL Station	**37 days**
Start ES-2 Construction	0 days
Construct ES-2 Collar	20 days
Lower ESF Exc. Equip. in ES-1	**3 days**
Install Temp Equip in ES-1	**10 days**
Install Surface Raise Equipmet	10 days
Start ESF Const. from ES-1	**0 days**
Develop ESF to ES-2	**50 days**
Drill Pilot Bhole/Instl String	45 days
Lower raisebore Equip in ES-1	**2 days**
Assemble Raisehead at ES-2	3 days
Preassemble ES-2 Lining Equip	30 days
Raisebore ES-2	25 days
Install ES-2 Hoist	40 days
Demobilize Raise Equipment	3 days
Install ES-2 Lining Plant	30 days
Map/Smpl/Line/Equp ES-2 to MTL	90 days
Preassemble V-Mole for ES-1	**30 days**
Excavate ES-2 to Shaft Bottom	16 days
Remove Shaft Equip from ES-1	**5 days**
Furnish Sump / Pockets in ES-2	20 days
Install V-Mole Equip in ES-1	**30 days**
Preassemble ES-1 Lining Equip	**30 days**
Changeover to Perm Hoist ES-2	12 days
V-Mole ES-1 Foreshaft	**10 days**
Install ES-1 Lining Equip	**30 days**
Vmole/Map/Smpl/Line/Eqp to MTL	**90 days**
Demobilize V-Mole	**30 days**
MTL Available	0 days
Complete UDBR Tests in ES-1	**0 days**
Excavate DBOR	0 days
Install RBTs in ES-1	0 days
SCT #3 and Lower Exc. Effects	0 days
Construct ES-1 Sump	**10 days**

Schedule Name: Yucca Mtn ESF Schedule Case No. 5.(b)
Project Manager:
As of date: 29-Aug-89 1:17pm Schedule File: A:ESCS#5B

ES-1 Convntnl Small Diam/V-Mole [UDBR, Delay Therm/RBDTs, Scientific Sha
ES-2 Raise Bored [Mucking Shaft]

TASK	TOTAL
Start ES-1 Shaft Construction	0
Construct ES-1 Collar	300,000
Preassemble ES-1 Sinking Equip	200,000
Construct ES-1 Foreshaft	400,000
ES-1 Hoist and Hoist House	1,300,000
Install ES-1 Sinking Plant	500,000
Sink/Support ES-1 to UDBR	2,125,000
Shaft Conv. Test #1 in ES-1	320,000
Excavate UDBR in ES-1	875,000
ES-1 Exc. Effects, Geotech Mon	880,000
Sink/Support ES-1 to MTL	1,936,000
Shaft Convergence Test #2 ES-1	320,000
Mine ES-1 MTL Station	925,000
Start ES-2 Construction	0
Construct ES-2 Collar	100,000
Lower ESF Exc. Equip. in ES-1	75,000
Install Temp Equip in ES-1	250,000
Install Surface Raise Equipmet	200,000
Start ESF Const. from ES-1	0
Develop ESF to ES-2	405,000
Drill Pilot Bhole/Instl String	300,000
Lower raisebore Equip in ES-1	50,000
Assemble Raisehead at ES-2	10,000
Preassemble ES-2 Lining Equip	100,000
Raisebore ES-2	312,500
Install ES-2 Hoist	600,000
Demobilize Raise Equipment	200,000
Install ES-2 Lining Plant	250,000
Map/Smpl/Line/Equp ES-2 to MTL	2,145,000
Preassemble V-Mole for ES-1	675,000
Excavate ES-2 to Shaft Bottom	400,000
Remove Shaft Equip from ES-1	125,000
Furnish Sump / Pockets in ES-2	400,000
Install V-Mole Equip in ES-1	675,000
Preassemble ES-1 Lining Equip	100,000
Changeover to Perm Hoist ES-2	180,000
V-Mole ES-1 Foreshaft	225,000
Install ES-1 Lining Equip	250,000
Vmole/Map/Smpl/Line/Eqp to MTL	3,645,000
Demobilize V-Mole	675,000
MTL Available	0
Complete UDBR Tests in ES-1	0
Excavate DBOR	0
Install RBTs in ES-1	0
SCT #3 and Lower Exc. Effects	0
Construct ES-1 Sump	250,000
TOTALS	22,678,500



ES-1 (Scientific) Conventional (Drill-and-Blast)/V-Mole Construction
ES-2 (Mucking) Raise Bore/V-Mole
Thermomechanical testing in UDBR and all RBTs (in ES-1) delayed until after MTL is available.

Not to Scale

SCHEMATIC DESCRIPTION OF THE SEQUENCE OF SHAFT DEVELOPMENT/TESTING FOR CASE 6(b)

PROJECT NO. 833-1017-116 DWG. NO. 12407 DATE 6/20/89 DRAWN CW APPROVED CB

Golder Associates

Schedule Name: Yucca Mtn ESF Schedule Case No. 6.(b)
Project Manager:
As of date: 29-Aug-89 1:13pm Schedule File: A:ESCS#6B

D Done
C Critical
R Resource conflict
p Partial dependency
Scale: Each character equals 1 week

=== Task
+++ Started task
M Milestone

- Slack time (==---), or
Resource delay (---==)
> Conflict

ES-1 Small Conventional/V-Mole [UDBR, Delay Thermomech, Mucking Shaft]
ES-2 Raise/V-Mole [Delay RBTs, Scientific Shaft]

This is a selective report. All items shown in bold
* Notes (1) contains "ES1"

(months) 6 12 18 24 28

Task	Status
Start ES-1 Shaft Construction	C M
Construct ES-1 Collar	C
Preassemble ES-1 Sinking Equip	C
Construct ES-1 Foreshaft	C
ES-1 Hoist & Hoist House	C
Install ES-1 Sinking Plant	C
Sink Support ES-1 to UDBR	C
Shaft Conv. Test #1 in ES-1	C
Excavate UDBR in ES-1	C
ES-1 Exc. Effects, Geotech Mon	C
Sink Support ES-1 to MTL	C
Shaft Convergence Test #2 ES-1	C
Mine ES-1 MTL Station	C
Start ES-2 Construction	C
Construct ES-2 Collar	C
Lower ESF Exc. Equip. in ES-1	C
Install Temp Equip in ES-1	C
Install Surface Raise Equipmet	C
Start ESF Const. from ES-1	C
Develop ESF to ES-2	C
Drill Pilot Bhle/Instal String	C
Preassemble V-Mole ES-2	C
Lower raisebore Equip in ES-1	C
Assemble Raisehead at ES-2	pC
Raisebore ES-2 to 8 ft	pC
Demobilize Raise Equipment	C
Install V-Mole Equipment ES-2	C
Preassemble ES-2 Lining Equip	C
Install ES-2 Hoist	C
V-Mole ES-2 Foreshaft	C
Install ES-2 Lining Equip	pC
VMole/Map/Smpl/Line/Eqp to MTL	C
Demobe + Assmbl V-Mole for ES1	C
Excavate ES-2 to Shaft Bottom	C
Remove Shaft Equip from ES-1	C
Furnish ES-2 Sump / Pockets	C
Install V-Mole in ES-1	C
Preassemble ES-1 Lining Equip	C
Changeover to Perm Hoist ES-2	C
V-Mole ES-1 Foreshaft	C
Install ES-1 Lining Equip	C
VMole/Line/Equip to MTL	C
Demobilize V-Mole	C M

Schedule Name: Yucca Mtn ESF Schedule Case No. 6.(b)
Project Manager:
As of date: 29-Aug-89 1:11pm Schedule File: A:ESCS#6B

ES-1 Small Conventional/V-Mole [UDBR, Delay Thermomech, Mucking Shaft]
ES-2 Raise/V-Mole [Delay RBTs, Scientific Shaft]

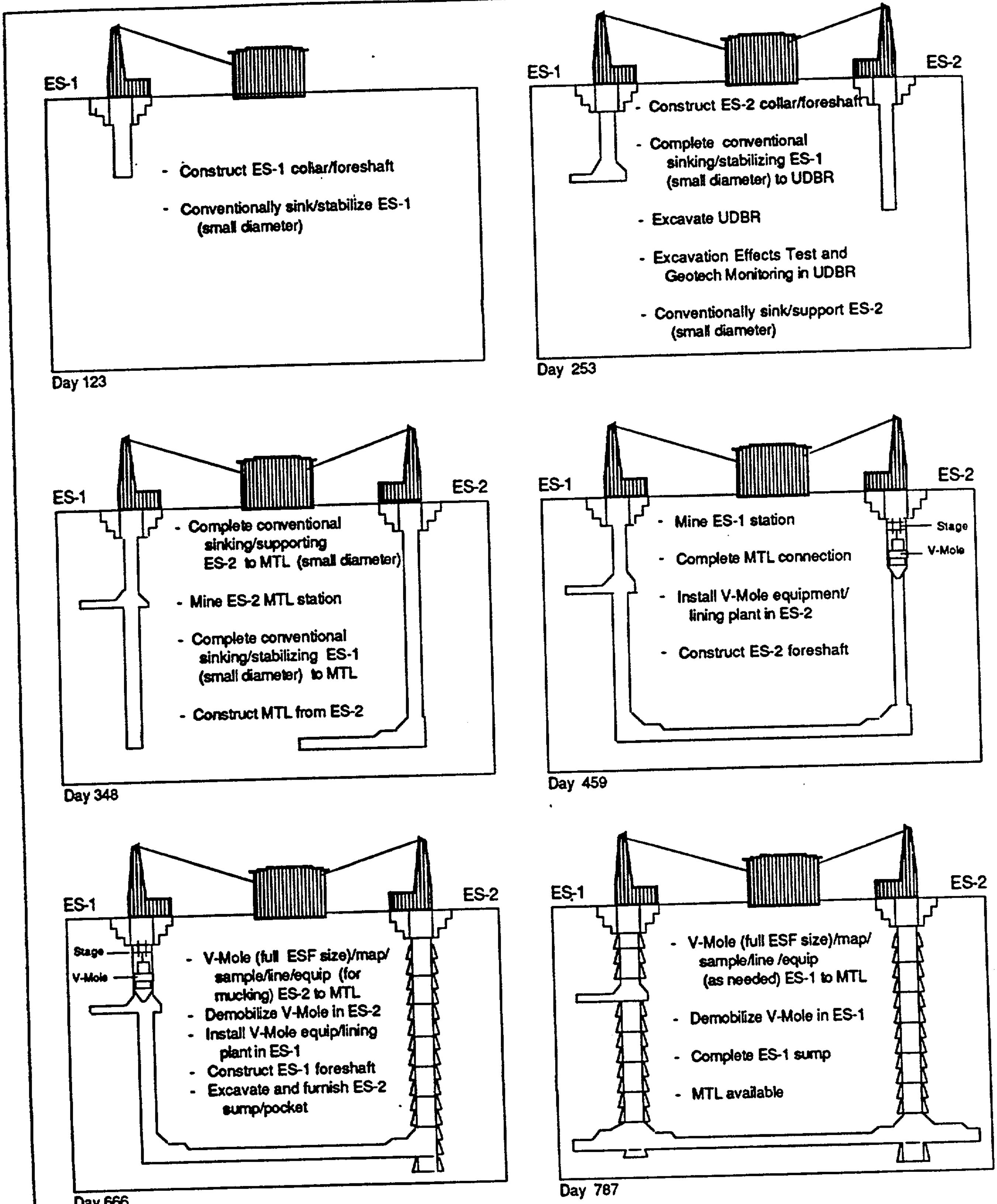
This is a selective report. All items shown in bold
 * Notes (1) contains "ES1"

Task	How Long
Start ES-1 Shaft Construction	**0 days**
Construct ES-1 Collar	**20 days**
Preassemble ES-1 Sinking Equip	**30 days**
Construct ES-1 Foreshaft	**13 days**
ES-1 Hoist & Hoist House	**40 days**
Install ES-1 Sinking Plant	**30 days**
Sink Support ES-1 to UDBR	**81 days**
Shaft Conv. Test #1 in ES-1	**20 days**
Excavate UDBR in ES-1	**35 days**
ES-1 Exc. Effects, Geotech Mon	**55 days**
Sink Support ES-1 to MTL	**74 days**
Shaft Convergence Test #2 ES-1	**20 days**
Mine ES-1 MTL Station	**37 days**
Start ES-2 Construction	0 days
Construct ES-2 Collar	20 days
Lower ESF Exc. Equip. in ES-1	**3 days**
Install Temp Equip in ES-1	**10 days**
Install Surface Raise Equipmet	10 days
Start ESF Const. from ES-1	**0 days**
Develop ESF to ES-2	**50 days**
Drill Pilot Bhle/Instal String	45 days
Preassemble V-Mole ES-2	30 days
Lower raisebore Equip in ES-1	**2 days**
Assemble Raisehead at ES-2	3 days
Raisebore ES-2 to 8 ft	15 days
Demobilize Raise Equipment	2 days
Install V-Mole Equipment ES-2	30 days
Preassemble ES-2 Lining Equip	30 days
Install ES-2 Hoist	40 days
V-Mole ES-2 Foreshaft	10 days
Install ES-2 Lining Equip	30 days
VMole/Map/Smpl/Line/Eqp to MTL	90 days
Demobe + Assmbl V-Mole for ES1	**30 days**
Excavate ES-2 to Shaft Bottom	16 days
Remove Shaft Equip from ES-1	**5 days**
Furnish ES-2 Sump / Pockets	20 days
Install V-Mole in ES-1	**30 days**
Preassemble ES-1 Lining Equip	**30 days**
Changeover to Perm Hoist ES-2	12 days
V-Mole ES-1 Foreshaft	**10 days**
Install ES-1 Lining Equip	**30 days**
VMole/Line/Equip to MTL	**90 days**
Demobilize V-Mole	**30 days**
MTL Available	**0 days**
Complete UDBR Tests	0 days
Excavate DBOR	0 days
SCT #3 and Lower Exc. Effects	0 days
Complete ES-1 Sump	**10 days**
Install RBTs in ES-1	0 days

Schedule Name: Yucca Mtn ESF Schedule Case No. 6.(b)
Project Manager:
As of date: 29-Aug-89 1:12pm Schedule File: A:ESCS#6B

ES-1 Small Conventional/V-Mole [UDBR, Delay Thermomech, Mucking Shaft]
ES-2 Raise/V-Mole [Delay RBTs, Scientific Shaft]

TASK	TOTAL
Start ES-1 Shaft Construction	0
Construct ES-1 Collar	300,000
Preassemble ES-1 Sinking Equip	200,000
Construct ES-1 Foreshaft	400,000
ES-1 Hoist & Hoist House	1,300,000
Install ES-1 Sinking Plant	500,000
Sink Support ES-1 to UDBR	2,125,000
Shaft Conv. Test #1 in ES-1	320,000
Excavate UDBR in ES-1	875,000
ES-1 Exc. Effects, Geotech Mon	880,000
Sink Support ES-1 to MTL	1,936,000
Shaft Convergence Test #2 ES-1	320,000
Mine ES-1 MTL Station	925,000
Start ES-2 Construction	0
Construct ES-2 Collar	100,000
Lower ESF Exc. Equip. in ES-1	75,000
Install Temp Equip in ES-1	250,000
Install Surface Raise Equipmet	200,000
Start ESF Const. from ES-1	0
Develop ESF to ES-2	405,000
Drill Pilot Bhle/Instal String	300,000
Preassemble V-Mole ES-2	675,000
Lower raisebore Equip in ES-1	50,000
Assemble Raisehead at ES-2	10,000
Raisebore ES-2 to 8 ft	187,500
Demobilize Raise Equipment	200,000
Install V-Mole Equipment ES-2	675,000
Preassemble ES-2 Lining Equip	100,000
Install ES-2 Hoist	600,000
V-Mole ES-2 Foreshaft	225,000
Install ES-2 Lining Equip	250,000
VMole/Map/Smpl/Line/Eqp to MTL	3,645,000
Demobe + Assmbl V-Mole for ES1	675,000
Excavate ES-2 to Shaft Bottom	240,000
Remove Shaft Equip from ES-1	125,000
Furnish ES-2 Sump / Pockets	400,000
Install V-Mole in ES-1	675,000
Preassemble ES-1 Lining Equip	100,000
Changeover to Perm Hoist ES-2	0
V-Mole ES-1 Foreshaft	225,000
Install ES-1 Lining Equip	250,000
VMole/Line/Equip to MTL	3,645,000
Demobilize V-Mole	675,000
MTL Available	0
Complete UDBR Tests	0
Excavate DBOR	0
SCT #3 and Lower Exc. Effects	0
Complete ES-1 Sump	250,000
Install RBTs in ES-1	0
TOTALS	25,288,500



ES-1 (Scientific) Conventional (Drill-and-Blast)/V-Mole Construction
ES-2 (Mucking) Conventional/V-Mole Construction
Thermomechancial testing in UDBR and all RBTs (in ES-1) delayed until after MTL is available.

Not to Scale

SCHEMATIC DESCRIPTION OF THE SEQUENCE OF SHAFT DEVELOPMENT/TESTING FOR CASE 7(b)

Golder Associates

PROJECT NO. 833-1017-116 DWG. NO. 12408 DATE 6/20/89 DRAWN CW APPROVED CB

Schedule Name: Yucca Mtn ESF Schedule Case No. 7.(b)
Project Manager:
As of date: 29-Aug-89 1:01pm Schedule File: A:ESCS#7B

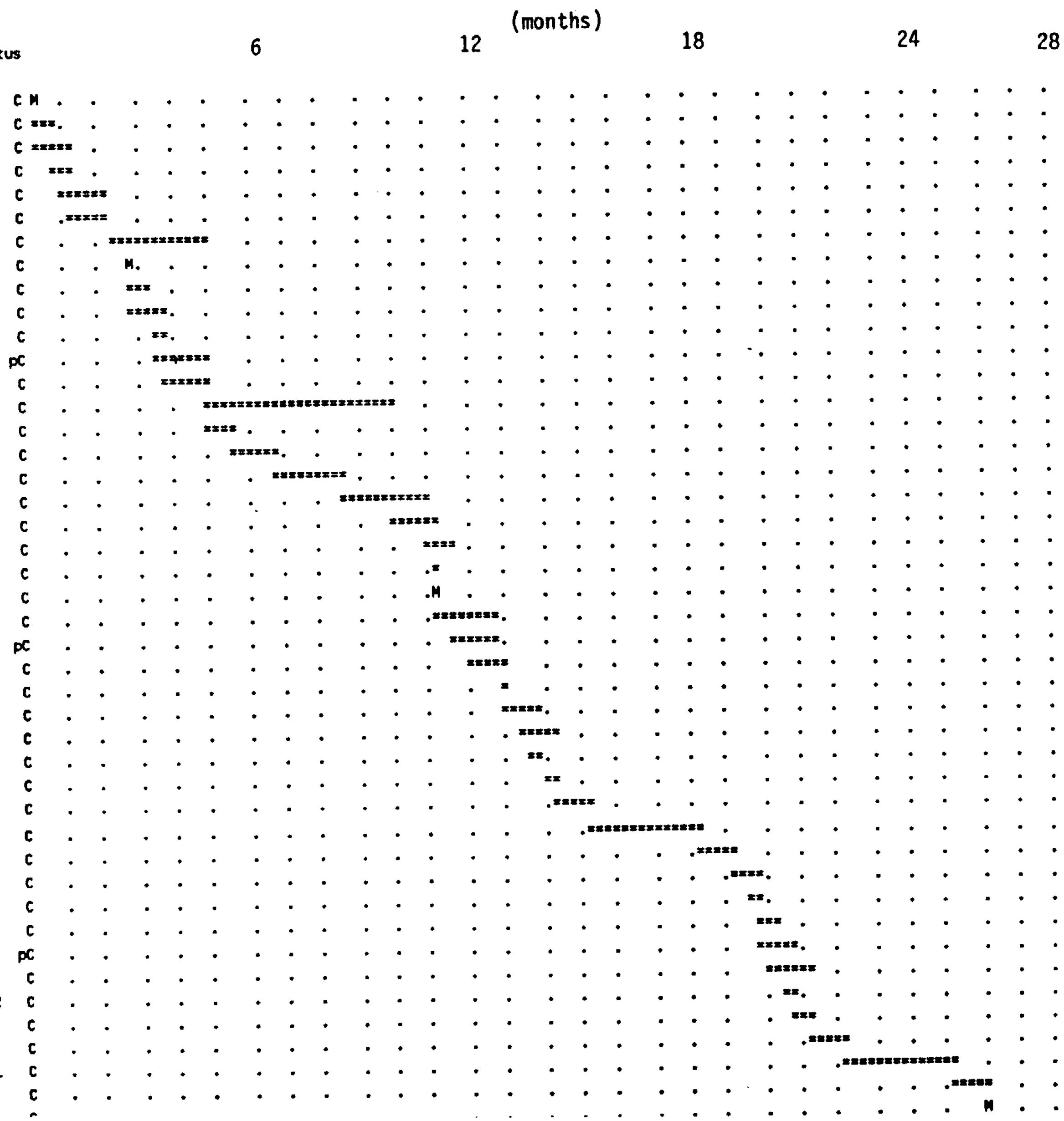
ES-1 Convntnl/V-Mole [Mine UDBR, Delay Thermal and RBDTs, Scientific Shaft]
ES-2 Conventional/V-Mole [Mucking Shaft]

This is a selective report. All items shown in bold
* Notes (1) contains "ES1"

D Done
C Critical
R Resource conflict
p Partial dependency
Scale: Each character equals 1 week

=== Task
+++ Started task
M Milestone

- Slack time (==---), or
Resource delay (---==)
> Conflict



Task	Status
Start ES-1 Shaft Construction	C
Construct ES-1 Collar	C
Preassemble ES-1 Sinking Equip	C
Construct ES-1 Convn Foreshaft	C
ES-1 Hoist and Hoist House	C
Install ES-1 Sinking Plant	C
Sink/Support ES-1 to UDBR	C
Start ES-2 Construction	C
Construct ES-2 Collar	C
Preassemble ES-2 Sinking Equip	C
Construct ES-2 Foreshaft	C
ES-2 Hoist and Hoisthouse	pC
Install ES-2 Sinking Plant	C
Sink/Support ES-2 to MTL	C
Shaft Conv. Test #1 in ES-1	C
Excavate UDBR in ES-1	C
Exc. Effects, Geot. Mon ES-1	C
Sink/Support ES-1 to MTL	C
Excavate ES-2 MTL Station	C
Shaft Convergence Test #2 ES-1	C
Lower ESF Exc. Equip. in ES-2	C
Start MTL Const. from ES-2	C
Develop ESF to ES-1	C
Mine ES-1 MTL Station	pC
Preassemble V-Mole for ES2	C
Remove Shaft Equip from ES-2	C
Install V-Mole Equip in ES-2	C
Preassemble ES2 Lining Equip	C
Install Temp Equip in ES-1	C
V-Mole ES2 Foreshaft	C
Install ES2 Lining Equip	C
VMole/Map/Smpl/Line/Eqp to MTL	C
Demobe + Assmbl V-Mole for ES1	C
Excavate ES-2 to Shaft Bottom	C
Remove Shaft Equip from ES-1	C
Furnish Sump / Pockets	C
Install V-Mole Equip in ES-1	pC
Preassemble ES-1 Lining Equip	C
Change to Permanent Hoist ES-2	C
V-Mole ES-1 Foreshaft	C
Install Lining Equip in ES-1	C
VMole/Map/Line/Equp ES1 to MTL	C
Demobilize V-Mole thru ES-1	C

Schedule Name: Yucca Mtn ESF Schedule Case No. 7.(b)
Project Manager:
As of date: 29-Aug-89 1:02pm Schedule File: A:ESCS#7B

ES-1 Convntnl/V-Mole [Mine UDBR, Delay Thermal and RBDTs, Scientific Sha
ES-2 Conventional/V-Mole [Mucking Shaft]

This is a selective report. All items shown in bold
* Notes (1) contains "ES1"

Task	How Long
Start ES-1 Shaft Construction	**0 days**
Construct ES-1 Collar	**20 days**
Preassemble ES-1 Sinking Equip	**30 days**
Construct ES-1 Convn Foreshaft	**13 days**
ES-1 Hoist and Hoist House	**40 days**
Install ES-1 Sinking Plant	**30 days**
Sink/Support ES-1 to UDBR	**81 days**
Start ES-2 Construction	0 days
Construct ES-2 Collar	20 days
Preassemble ES-2 Sinking Equip	30 days
Construct ES-2 Foreshaft	13 days
ES-2 Hoist and Hoisthouse	40 days
Install ES-2 Sinking Plant	30 days
Sink/Support ES-2 to MTL	154 days
Shaft Conv. Test #1 in ES-1	**20 days**
Excavate UDBR in ES-1	**35 days**
Exc. Effects, Geot. Mon ES-1	**55 days**
Sink/Support ES-1 to MTL	**74 days**
Excavate ES-2 MTL Station	37 days
Shaft Convergence Test #2 ES-1	**20 days**
Lower ESF Exc. Equip. in ES-2	3 days
Start MTL Const. from ES-2	0 days
Develop ESF to ES-1	50 days
Mine ES-1 MTL Station	**37 days**
Preassemble V-Mole for ES2	30 days
Remove Shaft Equip from ES-2	5 days
Install V-Mole Equip in ES-2	30 days
Preassemble ES2 Lining Equip	30 days
Install Temp Equip in ES-1	**10 days**
V-Mole ES2 Foreshaft	10 days
Install ES2 Lining Equip	30 days
VMole/Map/Smpl/Line/Eqp to MTL	90 days
Demobe + Assmbl V-Mole for ES1	**30 days**
Excavate ES-2 to Shaft Bottom	16 days
Remove Shaft Equip from ES-1	**5 days**
Furnish Sump / Pockets	20 days
Install V-Mole Equip in ES-1	**30 days**
Preassemble ES-1 Lining Equip	**30 days**
Change to Permanent Hoist ES-2	12 days
V-Mole ES-1 Foreshaft	**10 days**
Install Lining Equip in ES-1	**30 days**
VMole/Map/Line/Equp ES1 to MTL	**90 days**
Demobilize V-Mole thru ES-1	**30 days**
MTL Available	0 days
Complete UDBR Tests in ES-1	**0 days**
Excavate DBOR	0 days
Install RBTs in ES-1	**0 days**
SCT#3 and Lower Exc. Effects	0 days
Complete ES-1 Sump	**10 days**

Schedule Name: Yucca Mtn ESF Schedule Case No. 7.(b)
Project Manager:
As of date: 29-Aug-89 1:05pm Schedule File: A:ESCS#7B

ES-1 Convntnl/V-Mole [Mine UDBR, Delay Thermal and RBDTs, Scientific Sha
ES-2 Conventional/V-Mole [Mucking Shaft]

TASK	TOTAL
Start ES-1 Shaft Construction	0
Construct ES-1 Collar	300,000
Preassemble ES-1 Sinking Equip	200,000
Construct ES-1 Convn Foreshaft	400,000
ES-1 Hoist and Hoist House	1,300,000
Install ES-1 Sinking Plant	500,000
Sink/Support ES-1 to UDBR	2,125,000
Start ES-2 Construction	0
Construct ES-2 Collar	100,000
Preassemble ES-2 Sinking Equip	100,000
Construct ES-2 Foreshaft	200,000
ES-2 Hoist and Hoisthouse	600,000
Install ES-2 Sinking Plant	250,000
Sink/Support ES-2 to MTL	2,496,000
Shaft Conv. Test #1 in ES-1	320,000
Excavate UDBR in ES-1	875,000
Exc. Effects, Geot. Mon ES-1	880,000
Sink/Support ES-1 to MTL	1,936,000
Excavate ES-2 MTL Station	555,000
Shaft Convergence Test #2 ES-1	320,000
Lower ESF Exc. Equip. in ES-2	45,000
Start MTL Const. from ES-2	0
Develop ESF to ES-1	405,000
Mine ES-1 MTL Station	925,000
Preassemble V-Mole for ES2	675,000
Remove Shaft Equip from ES-2	75,000
Install V-Mole Equip in ES-2	675,000
Preassemble ES2 Lining Equip	100,000
Install Temp Equip in ES-1	250,000
V-Mole ES2 Foreshaft	225,000
Install ES2 Lining Equip	250,000
VMole/Map/Smpl/Line/Eqp to MTL	3,645,000
Demobe + Assmbl V-Mole for ES1	675,000
Excavate ES-2 to Shaft Bottom	240,000
Remove Shaft Equip from ES-1	125,000
Furnish Sump / Pockets	400,000
Install V-Mole Equip in ES-1	675,000
Preassemble ES-1 Lining Equip	100,000
Change to Permanent Hoist ES-2	180,000
V-Mole ES-1 Foreshaft	225,000
Install Lining Equip in ES-1	250,000
VMole/Map/Line/Equp ES1 to MTL	3,645,000
Demobilize V-Mole thru ES-1	675,000
MTL Available	0
Complete UDBR Tests in ES-1	0
Excavate DBOR	0
Install RBTs in ES-1	0
SCT#3 and Lower Exc. Effects	0
Complete ES-1 Sump	250,000
TOTALS	28,167,000

APPENDIX C

EVALUATORS' QUALIFICATIONS

The qualifications of each of the personnel involved in the identification and evaluation of the various alternative ESF shaft construction methods/testing sequences are documented in the attached resumes.

Golder Associates

Christopher D. Breeds

EDUCATION	B.Sc., Mining Engineering (Honors), University of Nottingham, U.K., 1973. Ph.D., Mining - Rock Mechanics, University of Nottingham, U.K., 1976.
AFFILIATIONS	Member, American Institute of Mining Engineers. Charter Member, Institute of Shaft Drilling Technology. International Society of Rock Mechanics.

EXPERIENCE

1984 to date	Senior Mining Engineer, Golder Associates Inc.
1979 - 1984	Mining Engineer, International Ground Support Systems, Denver, Colorado.
1976 - 1979	Assistant Professor, Mining Department, Virginia Polytechnic Institute and State University, Blacksburg, Virginia (VPI and SU).
1973 - 1976	Research Engineer, Mining Department, Nottingham University, U.K.

PROFESSIONAL SUMMARY

Dr. Breeds is a Senior Mining Engineer with Golder Associates Inc. His career has exposed him to a unique combination of applied research, education and practical field experience on underground mining and civil engineering projects. His specialties include: mine systems analyses, mine ventilation, subsurface rock mechanics, subsidence engineering, shotcrete and concrete technology and the general field of underground engineering in rock.

EXPERIENCE RELATED TO THE DESIGN AND CONSTRUCTION OF SUBSURFACE STRUCTURES

1984	Design support for the Caney Branch shaft. For Morrison Knudsen/Wolf Creek Collieries Company, Kentucky.
1983	Remote lining of surface shafts using prototype shotcrete equipment developed under DOE/USBM contract. For Reynolds Electric Engineering Company, Nevada Test Site, Nevada.
1983	Design evaluation, inspection and construction supervision of ground support for the Foidel Creek mine entries, Getty Mining Company, Steamboat, Colorado.
1982	Design of support for single and multiple entires for development and production in longwall mining. For Hullera Mexicana, Sabinas, Mexico.
1982	Analysis of rock mechanics data and support design for underground pump chamber, shaft and access tunnels, Strawberry Tunnel project. For Ohbayashi-Gumi and U.S. Bureau of Reclamation, Denver, Colorado.

1982 Assess support requirements, evaluate/analyze lining design, train mining crews and supervise installation of support for undersea coal mine entry, Donkin Morien project. For Beaver Underground Structures, Cape Breton, Nova Scotia.

1982 Assess support requirements, evaluate/analyze lining design, train engineers, inspectors and labor force in support design, support installation and quality control for shotcrete placed as final support in a 2,600 foot coal mine decline. For Long Drain Slope project, Consolidation Coal Company/Frontier Kemper, Fairmont, W.VA.

1982 Evaluation of rock mechanics problems associated with portal development at an oil shale mine. Installation of equipment and personnel training for support of portal and mine entries using shotcrete. For Jasper Construction/Union Oil Shale Company, Parachute, Colorado.

1981 Assess support requirement, analyze/evaluate support design, train engineers and labor force and install shotcrete for temporary and permanent support of shafts and underground laboratories, University of Minnesota, Minneapolis, Minnesota. For Glenn Rehbein Excavating.

1981 Training of engineers, inspectors and labor force with respect to shotcrete technology. Installation of shotcrete in connecting station for production shafts. Installation of support stabilization and control of water in V/E shaft stations. For Occidental Petroleum's C-b Oil Shale Mine, Rifle, Colorado.

1981 Design and installation of shotcrete system for temporary support of eight shafts ranging from 28 to 38 feet in diameter. Training of mining crews, quality control, optimization of pneumatic transport system. For Kiewitt/Shea/Kenny J.V., Chicago Water Treatment Facility, Chicago, Illinois.

1981 Design of shotcrete support for mine entries and draw point stabilization. For CIA Minera Las Cuevas, San Louis Potosi, Mexico.

1980 Design of ground support system involving shotcrete for in situ recovery of heavy crude. For Fenix and Scisson/Getty Mining, Bakersfield, California.

1980 Design of transition point and final lining for the second street tunnel. Design and installation of temporary ground support in tunnel in St. Peter sandstone. For S.J. Groves and Sons, Minneapolis, Minnesota.

EXPERIENCE IN SHOTCRETE AND CONCRETE TECHNOLOGY

Summary During the period of 1979 - 1984, Dr. Breeds was involved in numerous projects involving concrete and shotcrete. Each of the projects referenced below included: (1) preparation of specifications; (2) design and implementation of the quality control program (3) selection of materials; (4) mix design; (5) equipment calibration; (6) training of shotcrete crews; and (7) operation of equipment used to produce and place concrete or shotcrete. He has liaised with numerous other project and owners in an advisory capacity concerning the above topics (e.g., Los Alamos National Lab, U.S. Bureau of Reclamation) and has been involved in the development and testing of concrete/shotcrete additives.

EXPERIENCE IN MINE PLANNING AND SYSTEM DESIGN

1979 - 1984 Design of surface to underground transfer systems for shotcrete materials including pneumatic transportation; design and development of concrete shotcrete batching equipment for use in underground mines.

1982 Evaluation/design of entry support systems for longwall mining. For Hullera Mexicana, Sabinas, Mexico.

1981 Design evaluation of ventilation system using small diameter raises for CIA Minera Las Cuevas, SA, Mexico.

1979 Ventilation survey of underground coal mine and computer simulation to optimize location of new adit and main fan. Terry Glen Coal Company, Kentucky.

1979 Evaluation of alternative underground coal haulage systems by computer simulation. For Department of Energy as part of VPI and SU Minerals research program.

1978 Development of a strata simulator for predicting ground movement over longwall mines. Part of DOE sponsored research performed at VPI and SU.

PUBLICATIONS

1975 Breeds C.D. (1975). "Protection of Surface Structures against Subsidence by Underground Layout and Surface Precautions," paper presented at the North Notts Area, Institute of Mining Engineers (UK).

1976 Breeds C.D. (1976). "A Study of Mining Subsidence Effects on Surface Structures with Special Reference to Geologic Factors," Ph.D. Thesis, University of Nottingham, UK.

1977 Whittaker B.N. and Breeds C.D., (1977). "The Influence of Surface Geology on the Character of Mining Subsidence," Proc. Ground Control in Structurally Complex Formations, Association Geotechnica Italiana, Capri, Italy.

1979 Breeds C.D. and Whittaker B.N. (1979). "A Critical Analysis of Contemporary Methods of Controlling Mine Subsidence Damage," Proc. 6th International School of Rock Mechanics, Kracow, Poland.

1979 Haycocks C.H. and Breeds C.D. (1979). "Strata Control Simulation over Longwall Workings," Annual AIME Conference, New Orleans, published in AIME Proceedings.

1979 Haycocks C.H. and Breeds C.D. (1979). "Ground Control Simulation over Longwall Workings," Annual Conference, Application of Computers in the Minerals Industry (APCOM), Tucson, Arizona, published in AIME Proceedings.

1979 Breeds C.D. and Karmis M. (1979). "Subsidence, Prevention or Control," Proc. 1st Conference on Ground Control Problems in the Illinois Coal Basin, published by Illinois State University, Mining Department, Carbondale, Illinois.

1979 Karmis M., Haycock C.H. and Breeds C.D. (1979). "Design of Coal Pillars from Drill Core Data," Proc. Coal Conference and Exposition V, Louisville, Kentucky.

1981 Valencia F.E., Pye J.H. and Breeds C.D. (1981). "The F.A.S.T. (First Automatic Shotcrete Technique), Proc. Rapid Excavation and Tunnelling Conference, San Francisco.

6/88

Golder Associates

R. John Byrne

EDUCATION	B.E., Civil Engineering, James Cook University of North Queensland, Australia, 1970. M.S., James Cook University of North Queensland, Australia, 1972. Ph.D., James Cook University of North Queensland, Australia, 1974.
AFFILIATIONS	Registered Professional Engineer, Washington

POSITIONS

1978 to date	Senior Geotechnical Engineer, Associate and Principal, Golder Associates Inc.
1977 - 1978	Senior Geotechnical Engineer, Golder Associates Inc.
1974 - 1977	Intermediate and Senior Geotechnical Engineer, Golder Associates Inc.
1970 - 1971	Research Geotechnical Engineer, Mount Isa Mines Ltd., Australia.

PROFESSIONAL SUMMARY

Dr. Byrne is a geotechnical engineer with experience in rock and soil mechanics applied to both mining and civil projects in Australia, South Africa, Europe and North America. Dr. Byrne's 15 years of consulting engineering experience has included technical and managerial responsibility for projects involving rock engineering (pumped storage and compressed air storage caverns, nuclear waste disposal facilities, tunnels, mine openings, rock slopes), soils engineering (foundations, tailings dams, tunnels, soils slopes, leach heaps, hazardous and municipal landfills, water supply dams), and off-shore engineering (oil platform foundations).

EXPERIENCE IN GEOTECHNICAL ENGINEERING FOR UNDERGROUND FACILITIES

1984 - 1988	Project Manager for development of an In Situ Test Plan for radioactive high-level waste repository in salt, for DOE through the Office of Nuclear Waste Isolation.
1986	Pillar design and roof support recommendations for an underground limestone quarry, Illinois.
1984	Advice on geotechnical performance of large soft ground highway tunnel, Seattle, Washington.
1984	Geotechnical advice on failure of a high pressure rock tunnel of a remote power station, Alaska.

Golder Associates

R. John Byrne
(Continued)

1983	Technical supervision of development of a Performance Assessment Methodology for selection of a nuclear waste repository in granite, for DOE through Office of Crystalline Repository Development.
1983	Geotechnical studies for recommending mining sequences and instrumentation for a tungsten mine, California.
1982	Technical supervision of stability evaluation of highway tunnel with recommendations for remedial treatment, Idaho.
1981 - 1982	Project Manager for geotechnical/hydrological site investigations and design of a planned hydraulically compensated hard rock compressed air energy storage facility, Illinois.
1980	Geotechnical advice on preparation of bid documents for long transmountain ore transport tunnels, Chile.
1979	Roof stability evaluations and support recommendations for underground coal mining operations, Tennessee.
1978	Geotechnical studies for multiple level mine development in a salt mine, Michigan.
1977	Numerical analysis of thermomechanical response of a conceptual nuclear waste repository in salt, for Nuclear Regulatory Commission.
1975 - 1977	Instrumentation, monitoring and interpretation of data from an underground test facility for a large pumped storage project in sedimentary rock. Design of power station complex, South Africa.
1970	In situ stress measurement and stability analysis of underground mine openings, Mount Isa Australia.

EXPERIENCE IN GEOTECHNICAL ENGINEERING FOR SURFACE FACILITIES

1988	Geotechnical site investigations and design recommendations for a permanent leach heap, Idaho.
1988	Static and seismic stability evaluations for a variety of structures associated with municipal and hazardous waste disposal sites, California and Oregon.
1988	Evaluation of failure of a leach heap, Idaho.
1988	Static and dynamic safety evaluation for existing dam, South Dakota.

1985	Seismic stability evaluation for water supply dam, Idaho.
1983	Seismic stability evaluation for a coal mine slurry retention embankment and foundation, Washington.
1983	Review of tailings embankment construction sequence and design for molybdenum mine, Idaho.
1980 - 1981	Project Manager for foundation investigation and analysis (PSAR preparation) for a multi-unit nuclear power plant, Washington.
1980	Review of tailings dam stability in highly seismic area, Chile.
1978 - 1979	Slope stability studies for open pit copper mine, Arizona.
1977	Evaluation of vibrations induced by rail traffic in rock cuts, bridge abutments and tunnel portals, British Columbia.
1974 - 1975	Static and dynamic design of the foundation for a large-scale off-shore gravity oil drilling platform, North Sea.
1974	Field supervision of construction of a tailings pond earth embankment, Ireland.

LIST OF PUBLICATIONS

Sharp, J.C., L. Richards, and R.J. Byrne, Instrumentation Considerations for Large Underground Trial Openings in Civil Engineering. Proc. of the International Symposium on Field Measurements in Rock Mechanics, Zurich, 1977.

Sharp, J.C., R.J. Pine, D. Moy, and R.J. Byrne. The Use of a Trial Enlargement for the Underground Cavern Design of the Drakensberg Pumped Storage Scheme. Proc. of International Society for Rock Mechanics, Montreaux, 1979.

Byrne, R.J., J.W. Rowe, F. Marinelli, and E.G. Wildanger. Site Investigations for a Hydraulically Compensated CAES Reservoir in Hard Rock. Proc. of AIAA/EPRI International Conference on Underground Pumped Hydro and Compressed Air Energy Storage, San Francisco, 1982.

Salter, de G., M., Macfarlane, I.M., Willett, D.C., and Byrne, R.J. Design Aspects for an Underground Compressed Air Energy Storage System in Hard Rock.

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Golder Associates

William J. Roberds

EDUCATION

B.Sc. (with distinction), Civil Engineering, Stanford University, 1973.
S.M., Civil (Geotechnical) Engineering, Massachusetts Institute of Technology, 1975.
Sc.D., Civil (Geotechnical) Engineering, Massachusetts Institute of Technology, 1979.

AFFILIATIONS

American Society of Civil Engineers (Member of National Committee on Geotechnical Safety and Reliability).
International Society of Rock Mechanics.
International Association for Civil Engineering Reliability and Risk Analysis (Charter Member).

POSITIONS

1985 to date	Associate, Golder Associates Inc.
1983 - 1985	Senior Geotechnical Engineer, Golder Associates Inc.
1979 - 1980	Instructor in Geotechnical Engineering, University of Texas at Austin.
1976 - 1979	Research Assistant in Rock Mechanics, Massachusetts Institute of Technology.
1975 - 1976	Senior Geotechnical Engineer, Geotechnical Engineers, Inc., Winchester, Massachusetts.
1975	Instructor in Geotechnical Engineering, Duke University.
1973 - 1975	Teaching Assistant in Geotechnical Engineering, Massachusetts Institute of Technology.
1972 - 1974	Geotechnical Engineer, Dames & Moore, San Francisco, California.

PROFESSIONAL SUMMARY

Dr. Roberds, an Associate with Golder Associates Inc., is a geotechnical engineer and a recognized expert in the area of probabilistic analyses (including uncertainty and error analysis, risk assessment, and sensitivity studies) and its application in decision-making. He has been involved in a wide range of local, national, and international geotechnical projects related to: nuclear and other hazardous waste disposal (i.e., investigation, analysis, and design of HLW repositories, mixed-waste disposal facilities, hazardous waste disposal facilities/remediation, and defense nuclear facilities); civil engineering (i.e., investigation, analysis, and design of rock slopes, tunnels, dams, embankments, and foundations); and mining engineering (i.e., investigation, analysis, and design of underground openings, pit slopes, waste dumps, tailing dams and backfill schemes). In addition to using traditional and state-of-the-art methods in this work. Dr. Roberds has developed and applied new methods through research and development, including: probabilistic risk assessment methodologies, systems and decision analysis methodologies, test methods, and performance and material behavior models (e.g., related to thermomechanics, fluid flow, solute transport). Much of this work has been conducted in a regulatory environment, under a strict Quality Assurance program. Dr. Roberds has managed, as well as participated technically, in much of this work.

EXPERIENCE

1988 to date — Development of a System Performance Assessment Plan, incorporating probabilistic and decision analysis techniques, for evaluating alternatives and optimizing the mixed-waste disposal system at Hanford for Westinghouse Hanford Co., Richland, Washington.

1988 to date — Evaluation of mine waste control alternatives, on the basis of probabilistic risk assessments and decision analysis, and presentation of a workshop on risk assessment/management for Ok Tedi Mining Ltd., Papua New Guinea.

1987 to date — Development and application of decision, uncertainty, and sensitivity analyses for Hanford Environmental Dose Reconstruction Project to assess probable radiation doses related to past defense activities at Hanford Reservation for Battelle/PNL, Richland, Washington.

1986 to 1988 — Development of probabilistic model to assess reliability of lined hazardous waste facilities for EPA, Cincinnati, Ohio.

1984 to 1988 — Participation in various aspects (especially underground testing) of HLW repository development in salt for Battelle/ONWI, Columbus, Ohio, and then DOE-SRPO, Amarillo, Texas, including: development of "Underground Test Plan for Site Characterization and Testing in an Exploratory Shaft Facility in Salt", including issues analysis, test methods evaluations, and research needs (test development and off-site testing); development of portions of Site Characterization Plan (especially large-scale thermomechanics and underground testing) for Deaf Smith Co., Texas; development of portions and technical review of Shaft Study Plan and At-Depth Study Plan (especially information needs analysis); technical support for performance assessment (including development of probabilistic analysis techniques); technical support for testing/analysis (especially brine migration and effects of heat/radiation on mechanical properties) at Asse, Germany; development support of licensing strategy; development/review of selected aspects of Requirements Document (especially exploratory shaft facility and off-site testing); participation in formal Readiness Review to determine status/plans for repository development; technical review of Laboratory Test Plan and of underground test procedures (especially extensometers, borehole jacking, temperature measurement, and thermal conductivity probe).

1984 to 1988	Participation in various aspects (especially performance assessment) of development of second HLW repository for Battelle/OCRD and then of repository technology development for Battelle/OWTD, Chicago, Illinois, including: development and implementation of probabilistic performance assessment based methodology for HLW repository development, including probabilistic performance modeling (preference modeling, subjective assessments, and response surface development), evaluation/ranking/selection of sites, evaluation/optimization of strategies (number of sites and investigation programs), and licensing strategy; development of methodology for identifying and evaluating alternative HLW repository concepts; development of Systems Requirement and Description Document and development support/review of Systems Engineering Management Plan; development of portions of Safety Analysis Report and Performance Assessment Strategic Plan; technical review of Nevada SCP.
1984 to 1988	Participation in various aspects (especially performance assessment) of HLW repository development in basalt for Rockwell/BWIP and then Westinghouse/BWIP, Hanford, Washington, including: development/technical review of performance assessment methodology (scenario/probabilistic/decision analysis) and associated Performance Assessment Plan; probabilistic analysis of groundwater/methane inflow into exploratory shaft facility as input to design; development support/technical review of selected aspects of Site Characterization Report/Plan (especially issues analysis and resolution strategy); analysis of uncertainty in proposed hydrologic cluster field test; technical review of probability encoding study of hydrologic site parameters.
1983 to 1988	Investigation, analysis, design, and specifications for large tied back rock slopes for I-90 in Wallace, Idaho, for Idaho Transportation Department, Boise, Idaho.
1988	Reliability assessment support for proposed regional fiber optics transmission system for BC Telephone, Canada.
1987	Development/presentation of short course on probability, risk, and decision analysis for ASCE and the University of Washington, Seattle, Washington.
1986	Decision analysis support for remedial action in flooded potash mine for International Mines, Saskatchewan, Canada.
1985	Risk assessment support for refinery decontamination study in Toronto for Texaco/Shell, Toronto, Canada.

1984	Review of Bingham open pit mine slope design, based on probabilistic risk assessment, for Kennecott, Salt Lake City, Utah.
1984	Development support/review of siting study/cost model for monitored retrievable storage (MRS) project for Ralph M. Parsons, Pasadena, California.
1983 - 1984	Design/analysis of rock support for dam on Ram Creek in Alaska for OTT, Anchorage, Alaska.
1983 - 1984	Review of selected aspects of HLW repository at Hanford, Washington, especially the impacts on groundwater use, for Washington Department of Ecology, Olympia, Washington.
1981 - 1984	Participation in various aspects of HLW repository program (especially regulatory development) for U.S. Nuclear Regulatory Commission, Washington, D.C., including: development of recommendations for in situ testing; evaluation of engineering backfill properties and design; development support for assessment of properties at domal salt and at tuff sites, of shaft sinking methods, and engineered barrier performance assessments; technical review of proposed hydrogeology investigation, exploratory shaft design/specifications, repository design and Site Characterization Report for a repository at Hanford, Washington; technical review of test methods.
1983	Summary and review of Site Characterization Report (SCR) with presentation to State Council, for State of Washington, Olympia, Washington.
1983	Analysis of large spoil dumps for stability under revised drainage conditions at Thompson Creek for Cypress Mines, Idaho.
1981 - 1983	Review of geohydrologic/solute transport models and of characterization reports for HLW repository sites in basalt and tuff, as well as analysis of 10 CFR 60, for Sandia National Laboratories, Albuquerque, New Mexico.
1981	Review of in situ testing plans for HLW repository for Lawrence Berkeley Laboratory, Berkeley, California.
1981	Probabilistic analysis support of Twin Butte's open pit slope stability for Anamax, Tucson, Arizona.
1981	Investigation, analysis, and design support for pilot tunnel at Cumberland Gap, Tennessee for Federal Highway Administration, Washington, D.C.
1980	Evaluation of innovative mine backfill schemes (including culvert tunnel design) for the U.S. Bureau of Mines, Spokane, Washington.

1979 - 1980	Teaching of soil mechanics, foundation analysis/design, and rock mechanics at the University of Texas, Austin, Texas.
1976 - 1979	Development of displacement discontinuity model for describing the behavior of jointed rock masses (especially brittle fracture of intact rock, strain softening/coupled dilatant behavior of joints, and elastic-plastic behavior for analysis of stress and strain) at Massachusetts Institute of Technology.
1977	Analysis of thermomechanics of HLW disposal in salt (as part of development of 40 CFR 191) for A.D. Little, Cambridge, Massachusetts.
1976	Field investigation of existing flyash retention dam in Louisa, Kentucky for American Electric Power, New York, New York.
1975 - 1976	Field investigations (including offshore) for nuclear power plant sites in New Hampshire and New York, for United Engineers, Philadelphia, Pennsylvania.
1975	Field investigation, laboratory testing, and analysis of proposed flood retention dam stability (especially dynamic) for U.S. Soil Conservation Service, Framingham, Massachusetts.
1975	Off-shore field investigation for oil drilling platform in Alaska for BBN, Cambridge, Massachusetts.
1975	Analysis of oil drilling platform foundations off-shore of California for Union Oil, California.
1975	Analysis and design of building excavation support system for Harvard University, Cambridge, Massachusetts.
1975	Teaching soil mechanics at Duke University, Durham, North Carolina.
1973 - 1975	Teaching assistance in soil mechanics/behavior and foundation analysis at Massachusetts Institute of Technology.
1974	Analysis of refinery foundations for Shell Oil, Indonesia.
1974	Investigation, analysis, and design of oil storage tank foundations for Chevron Oil, Richmond, California.
1973	Analysis of test embankment in Massachusetts as part of International Prediction Symposium on Foundation Behavior at Massachusetts Institute of Technology.

1972 Field investigation for oil refinery foundations for British Petroleum, Marcus Hook, Pennsylvania.

1972 Field investigation for oil refinery foundations for Amerada-Hess, St. Croix, Virgin Islands.

SELECTED PUBLICATIONS

Roberds, W. and I. Miller, The LF Landfill Reliability Computer Model, Part II: Theory, draft report submitted by Golder Associates to U.S. Environmental Protection Agency, Cincinnati, OH, December 1988.

Miller, I. and W. Roberds, The LF Landfill Reliability Computer Model, Part I: General Description, draft report by Golder Associates to U.S. Environmental Protection Agency, Cincinnati, OH, November 1988.

Roberds, W., "Reliability-Based Design of Mine Dewatering and Ventilation System," in Proceedings of Symposium on Reliability-Based Design in Civil Engineering, Lausanne, Switzerland, July 7-9, 1988.

Roberds, W., Manual for Conducting Subjective Probability Assessments, draft internal report by Golder Associates Inc., Redmond, WA, April 1988.

Roberds, W. et. al., "Probabilistic Analysis and Decision Making in the Applied Earth Sciences," short course presented by Geotechnical Group of Seattle Section of ASCE and the University of Washington, Seattle, WA, April 1987.

Kalia, H., W.J. Roberds, and R.J. Byrne, "Coupled Processes Addressed by Underground Testing for the Salt Repository Project," in Coupled Processes Associated with Nuclear Waste Repositories, Tsang (ed.), Academic Press, 1987.

Roberds, W.J., and D.L. Pentz, "Applications of Decision Theory to Hazardous Waste Disposal," paper presented at ASCE specialty conference GEOTECH IV in Boston, MA, October 1986.

Roberds, W.J., "Risk-Based Decision Making in Geotechnical Engineering: Overview and Case Studies," paper presented at Engineering Foundation Conference on Risk-Based Decision Making in Water Resources, Santa Barbara, California, November 3-8, 1985.

Roberds, W.J., R.L. Plum, and P.J. Visca, Proposed Methodology for Completion of Scenario Analysis for the Basalt Waste Isolation Project, Report No. RHO-BW-CR-147P, by Golder Associates Inc. to Rockwell Hanford Operations, November 1984.

Pentz, D.L., J.W. Voss, R. Talbot, and W.J. Roberds, Performance of Engineered Barriers in Deep Geologic Repositories for High Level Nuclear Waste (HLW) - Vol. 1: Summary and Recommendations - Final Report (Task 5), NUREG/CR-4026, final report by Golder Associates Inc. to U.S. Nuclear Regulatory Commission, September 1984.

Roberds, W.J., "In Situ Testing Requirements for High Level Nuclear Waste Deep Geologic Repositories," in Field Measurements in Geomechanics, Kovari (ed.), A.A. Balkema, Rotterdam, 1984.

Roberds, W.J., J. Voss, and D. Pentz, Technical Review on the Site Characterization Report (SCR) for the Basalt Waste Isolation Project (BWIP), final report by Golder Associates Inc. to State of Washington, April 1983.

Roberds, W.J., J. Kleppe, and L. Gonano, Evaluation of Engineering Aspects of Backfill Placement for High Level Nuclear Waste (HLW) Deep Geologic Repositories, NUREG/CR-3218, final report by Golder Associates Inc. to U.S. Nuclear Regulatory Commission, February 1983.

Roberds, W.J., et al., In Situ Test Programs Related to Design and Construction of High-Level Nuclear Waste (HLW) Deep Geologic Repositories, 2 vols., NUREG/CR-3065, final report by Golder Associates Inc. to U.S. Nuclear Regulatory Commission, November 1982.

Rawlings, G., G. Antonnen, M. Chamness, R. Hoffmann, W. Roberds, et al., Identification of Characteristics Which Influence Repository Design - Domal Salt, NUREG/CR-2613, final report by Golder Associates Inc. to U.S. Nuclear Regulatory Commission, March 1982.

Rawlings, G., G. Antonnen, D. Findley, R. Hoffmann, C. Soto, J. Rowe, F. Marinelli, W. Roberds, D. Pentz, and K. Jones, Identification of Characteristics Which Influence Repository Design-Tuff, NUREG/CR-2614, final report by Golder Associates Inc. to U.S. Nuclear Regulatory Commission, March 1982.

Roberds, W.J., "Risk Assessment Methodology for Geologic Repository of High Level Nuclear Waste," in Proceedings of Symposium on Uncertainties Associated with the Regulation of Geologic Disposal of High Level Radioactive Waste, NUREG/CP-0022, Oak Ridge National Laboratory, Tennessee, March 1982.

White, L., D.L. Pentz, W.S. Dershowitz, and W.J. Roberds, "Decision Analysis for Geologic Repository Development and Licensing," in Proceedings, International Conference on Radioactive Waste Management, Winnipeg, American Nuclear Society, 1982.

Roberds, W.J., Numerical Modeling of Jointed Rock, Sc.D. thesis submitted to Massachusetts Institute of Technology, August 1979.

Roberds, W.J., "Numerical Modeling of Rock Joints," in Proceedings of the 20th U.S. Symposium on Rock Mechanics, Austin, Texas, June 1979.

Roberds, W.J. and H.H. Einstein, "A Comprehensive Model for Rock Discontinuities," Journal of the Geotechnical Engineering Division, American Society of Civil Engineers, Vol. 104, No. GT5, May 1978.

Roberds, W.J. and H.H. Einstein, A General Purpose Elasto Visco-Plastic Critical State Behavioral Model, M.I.T. Research Report R77-8 to the National Science Foundation, Massachusetts Institute of Technology, Cambridge, Massachusetts, March 1977.

Roberds, W.J., A Conceptual, General Purpose, Elastic-Plastic-Critical State Behavioral Model, S.M. thesis submitted to Massachusetts Institute of Technology, September 1975.

Plus numerous presentations and corporate reports on high level nuclear waste projects, system/risk analysis (for nuclear and hazardous waste projects and for civil/mining slope projects), and geotechnical (civil and mining) projects.

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R E S U M E

KLAUS-PETER MICHAEL HANKE

Birth Date:	November 20, 1953
Qualifications:	Bachelor of Science (First Class Honors) in Mining Engineering from the University of Newcastle-upon-Tyne, Great Britain, October 1974 to June 1977.
Languages:	Fluent in English and German
Marital Status:	Married
Citizenship:	West German, Resident Alien Status since 1983 U.S. Citizenship applied for
Present Residence:	2 S 010 Deerfield Lane Warrenville, Illinois 60555 (312) 393-3871

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PRESENT POSITION

Dates:	January 1988 to Present
Employer:	Battelle Memorial Institute Nuclear Systems Group Office of Waste Technology Development (OWTD) Willowbrook, Illinois 60521
Position/Title:	Principal Mining Engineer

Duties:

Assigned to the Engineering Development Section of the OWTD/Chicago office which is developing and evaluating technology for a high-level nuclear waste repository in the USA. Specific duties include:

a) evaluation of repository concepts used by other countries in their nuclear waste storage programs and preparation of a summary report;
b) derivation of possible concepts specific to the US program and conditions;
c) direct involvement as site representative in the shaft sinking and characterization activities at the Underground Research Laboratory Shaft Sinking and Geotechnical Investigation Program of the Atomic Energy of Canada Ltd., in Pinawa, Canada;
d) preparation of data report describing installation and results from an instrument array in the shaft at the AECL Underground Research Laboratory;
e) review of mechanical mining methods and possible application to the Yucca Mountain repository excavation program;
f) review of the NNWSI Site Characterization Plan;
g) preparation of cost estimates for underground construction for the experiments at the Underground Research Laboratory Shaft Sinking and Geotechnical Investigation Program of the Atomic Energy of Canada Ltd., in Pinawa, Canada.

PREVIOUS PROJECTS AND POSITIONS

Dates: January 1987 to December 1987

Employer: Battelle Memorial Institute
Office of Waste Technology Development
Willowbrook, Illinois

Position/Title: Senior Mining Engineer

Duties: Assigned to the Engineering Development Section of the OWTD/Chicago office which is developing and evaluating technology for a high-level nuclear waste repository in the USA. Specific duties include the preparation of an evaluation report of repository concepts used by other countries in their nuclear waste storage programs, derivation of possible concepts specific to the US program and conditions, and direct involvement in the Underground Research Laboratory Program of the Atomic Energy of Canada Ltd., in Pinawa, Canada.

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Dates: March 1985 to December 1986

Employer: J. S. Redpath Corp.
Mesa, Arizona

Position/Title: Chief Engineer

Duties: Assigned to the Parsons-Redpath Joint Venture in Columbus, Ohio, since April 1984, (first held position of Senior Mining Engineer). The joint venture was under prime contract to the Department of Energy as Construction Manager for the construction and operation of an Exploratory Shaft Facility (ESF) (consisting of two shafts plus an underground development and testing program) in salt formations in the Amarillo, Texas, area. This facility was to serve to determine the suitability of the salt formations as a storage medium for commercial high-level nuclear waste. Responsibilities included:

a) Preparation of several detailed construction and operation cost estimates for the ESF (Salt) at the Deaf Smith County, Texas, site;
b) Preparation of construction manuals and procedures for the construction and operation of the Exploratory Shaft Facility;
c) Reviews of the ESF design prepared by the A/E and liaise with the A/E to ensure the constructability, operability, and maintainability of the ESF design;
d) Assisting procurement department in preparation of technical specifications for the various ESF construction subcontracts ;
e) Conducting technical review of vendor proposals for procurement of equipment and subcontractor services;

f) Assisting project controls department in preparation of construction schedules and cost estimating;
g) Interfacing with the quality assurance department to ensure proper implementation of NQA-1 requirements;
h) Participating in meetings with the client and other project participants to coordinate and interface during various phases of the project;
i) Operation, maintenance, preparing specifications, and updating hardware and software requirements for the Parsons-Redpath Personal Computer Systems. Preparation of programs for cost estimating, Monte Carlo simulation for cost estimate analysis, ESF shaft hoisting requirements, ESF shaft freezing requirements, and others.

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Dates:	April 1984 to March 1985
Employer:	J. S. Redpath Corp. Mesa, Arizona
Position/Title:	Senior Mining Engineer
Duties:	Assigned to the Parsons-Redpath Joint Venture in Columbus, Ohio. Duties included:

a) Preparation of drilling, mining and surface construction manuals and procedures;
b) Technical reviews of Architect Engineer's design documents, vendor proposals, specifications, schedules, etc.;
c) Preparation of cost estimates, development of manpower and construction plans, site visits and interface with related projects around the world;
d) Providing technical support to the client and other project participants as required;

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Dates: October 1983 to April 1984

Employer: TMCI Construction, Inc.
Lakewood, Colorado

Position/Title: Project Engineer

Duties: Preparation of detailed construction cost estimating and bid preparation for subsurface structures including drilled and conventionally excavated shafts and underground excavations together with the associated surface facilities. Also, assigned as mining engineer to Architect Engineer Joint Venture in Houston, Texas. This joint venture was the Architect Engineer for the above named Exploratory Shaft Facility (ESF). Duties included study of ventilation requirements for different sizes of ESF shafts, underground configurations and excavation equipment.

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Dates: November 1980 to October 1983

Position/Title: Project Engineer

Employer: Thyssen Schachtbau GmbH
Brookwood, Alabama and Saarbruecken, West Germany

Duties: Planning and engineering design for the construction of four drilled shaft construction projects. Short-and long term analysis and planning of shaft sinking operations using a Wirth SB VII 650/850 shaft-boring machine (V-Mole). Employed as site project engineer on shaft construction project in Alabama where four shafts were sunk for Jim Walter Resources using the V-Mole. Simultaneous shaft boring and concrete lining was employed on two of the shafts. Diameter of the shafts was 23 feet and depths ranged from 1,600 to 2,050 feet. During October 1982, a world record for shaft construction was established with the completion of 1,622 feet of shaft in a 24 day period. Also prepared detailed construction cost estimates and bid preparation for conventional and drilled shafts and underground excavations.

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Dates: July 1977 to November 1980

Employer: University of Newcastle-upon-Tyne
Newcastle-upon-Tyne, Great Britain

Position/Title: Research Associate

Duties: Design and conduct research program for the cutting/excavation of very hard rock with full-scale and small-scale disc cutters using an experimental rock cutting rig.

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Dates: August 1976 to September 1976

Employer: Thyssen Schachtbau GmbH
Muelheim, West Germany

Position/Title: Miner/Driller

Duties: Part of the sinking crew on a conventional shaft sinking project in a salt mine at the Asse II research mine. This mine was used by the German government for nuclear waste storage and is located in Wolfenbuettel, West Germany.

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Dates: July 1976 to August 1976

Employer: Thyssen Schachtbau GmbH
Muelheim, West Germany

Position/Title: Miner/Driller

Duties: Employed as a shaft miner on a shaft-boring machine (V-mole) crew with simultaneous boring and lining installation taking place during blind shaft construction for the Eschweiler Bergwerksverein at the Emil Mayrisch coal mine near Aachen, West Germany.

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Dates: June 1975 to September 1975

Employer: Thyssen Schachtbau GmbH
Muelheim, West Germany

Position/Title: Miner/Driller

Duties: Employed as tunnel miner on a underground development crew at the Nordstern coal mine in Oberhausen, West Germany. The project consisted of construction of a development heading using conventional drill-and-blast techniques.

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Dates: September 1972 to August 1973

Employer: Thyssen Schachtbau GmbH
Kaprun, Austria

Position/Title: Laborer, Miner/Driller, Machine Operator on a machine bored tunnel site

Duties: Crane operator, carpenter, miner/driller, LHD operator, hoist operator, and tunnel miner on a project using both conventional and machine tunnelling techniques.

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PUBLICATIONS:

1. 1982 Proceedings of the 1st Mine Ventilation Symposium (AIME), Tuscaloosa, Alabama, Chapter 1, Page 9. "Shaft sinking using the V-Mole - A description of the TMCI operation in Alabama."

2. American Mining Congress, September 1985, San Francisco, "Exploratory Shaft Facility Construction in Salt."