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Study Plan for
Study 8.3.1.17.4.2

Study Plan for Evaluating the Location and Recency of Faulting Near Prospective Surface Facilities

Revision 0

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STUDY PLAN FOR EVALUATING THE LOCATION AND RECENCY OF FAULTING NEAR PROSPECTIVE SURFACE FACILITIES

Site Characterization Plan
Study 8.3.1.17.4.2

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ABSTRACT

Midway Valley, located directly east of Yucca Mountain, Nye County, Nevada, has been identified as a potential location for the surface facilities of a high-level nuclear waste repository. This study will acquire surface and near-surface geologic data from Midway Valley with particular emphasis on evaluating the existence of late Quaternary (<100,000 yr) faults. If faults are found, the slip rate and direction of displacement along each observed fault or fault zone will be determined. Two interrelated activities are proposed for the study, slightly modified from those outlined in the Site Characterization Plan (SCP). During Activity 1, a detailed map of the surface geology will be prepared, based on interpretation of new and existing aerial photographs, field mapping, soil pits and exploratory (<30-50 m) trenches, and selected geophysical data. Activity 2 is an extensive trenching program in which long (>100 m) trenches will be excavated and mapped. This second activity will contribute most of the data gathered in the study. The objective of this study is strictly to gather geologic data from Midway Valley and to identify areas where late Quaternary faults are absent. However, information gathered by this and other SCP studies will support the siting and design of the surface facilities for the Yucca Mountain repository.

The procedures used to prepare this document were done in accordance with SNL's requirements for Quality Level I.

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Effective Date: May 16, 1989

1.0 INTRODUCTION

Emplacement of high-level radioactive waste at the Yucca Mountain repository (Figure 1-1) will require surface facilities for waste handling and packaging, numerous outlying support buildings, and access to the underground portion of the repository (SNL, 1987). Neal (1985) has considered several sites in Midway Valley, along the eastern base of Yucca Mountain, as locations for siting the surface facilities of the repository and has defined a "reference conceptual site," pending detailed site characterization, for use in the conceptual design of a repository for high-level radioactive waste (SNL, 1987). As part of site characterization for the Yucca Mountain repository, the potential for fault displacement near the surface facilities must be evaluated. A study involving surface geologic mapping and trenching activities, as described in this report, will be conducted to evaluate the location and recency of faulting near prospective surface facilities in Midway Valley.

Figure 1-2 illustrates the proposed boundary for the Midway Valley study area, including the reference conceptual site. Midway Valley lies between two known, north-south trending, Quaternary fault zones. The Paintbrush Canyon fault borders Midway Valley on its eastern side while the Bow Ridge fault lies to the west of the valley at the western base of Exile Hill. Whether active or inactive faults lie between these two regional faults in Midway Valley is not known.

The general location and layout of the surface facilities within Midway Valley are governed by their functions, topography, and constraints imposed by the underground excavations. The surface facilities (Figure 1-3), which may include facilities important to safety [i.e., portions of the waste-handling buildings, Site Characterization Plan (SCP) Section 6.1.4 (DOE, 1988)], encompass an area of about 0.5 km^2. Significant displacement along a fault or fault zone that underlies or is immediately adjacent to the surface facilities could disrupt operations, potentially damage facilities, and lead to offsite release of radioactive material. If a fault propagates to the surface, various portions of building foundations

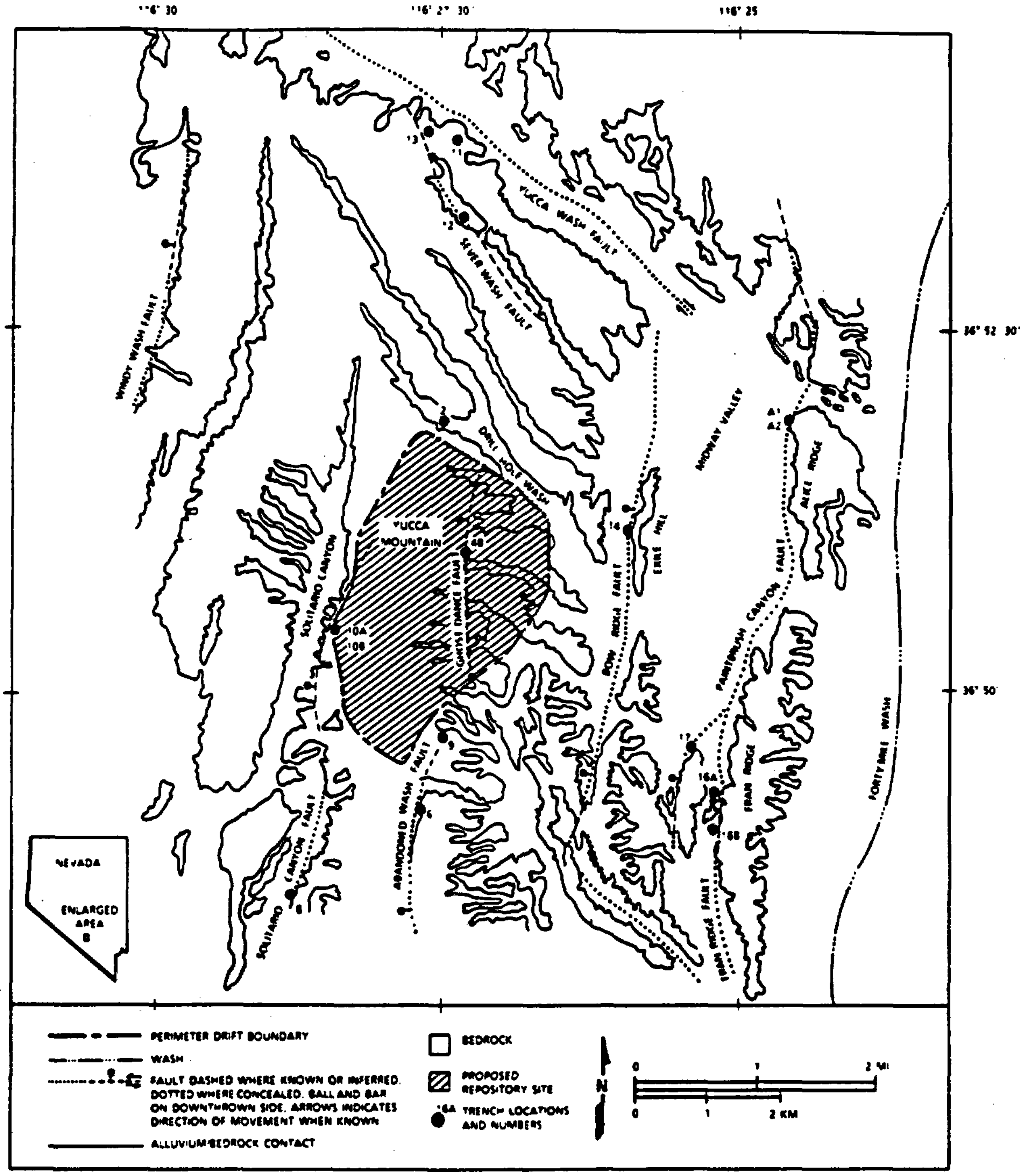

Figure 1-1. Location of Yucca Mountain and the proposed repository site relative to the surrounding region [Modified from the Site Characterization Plan Conceptual Design Report (SCP-CDR) (SNL,1987)].

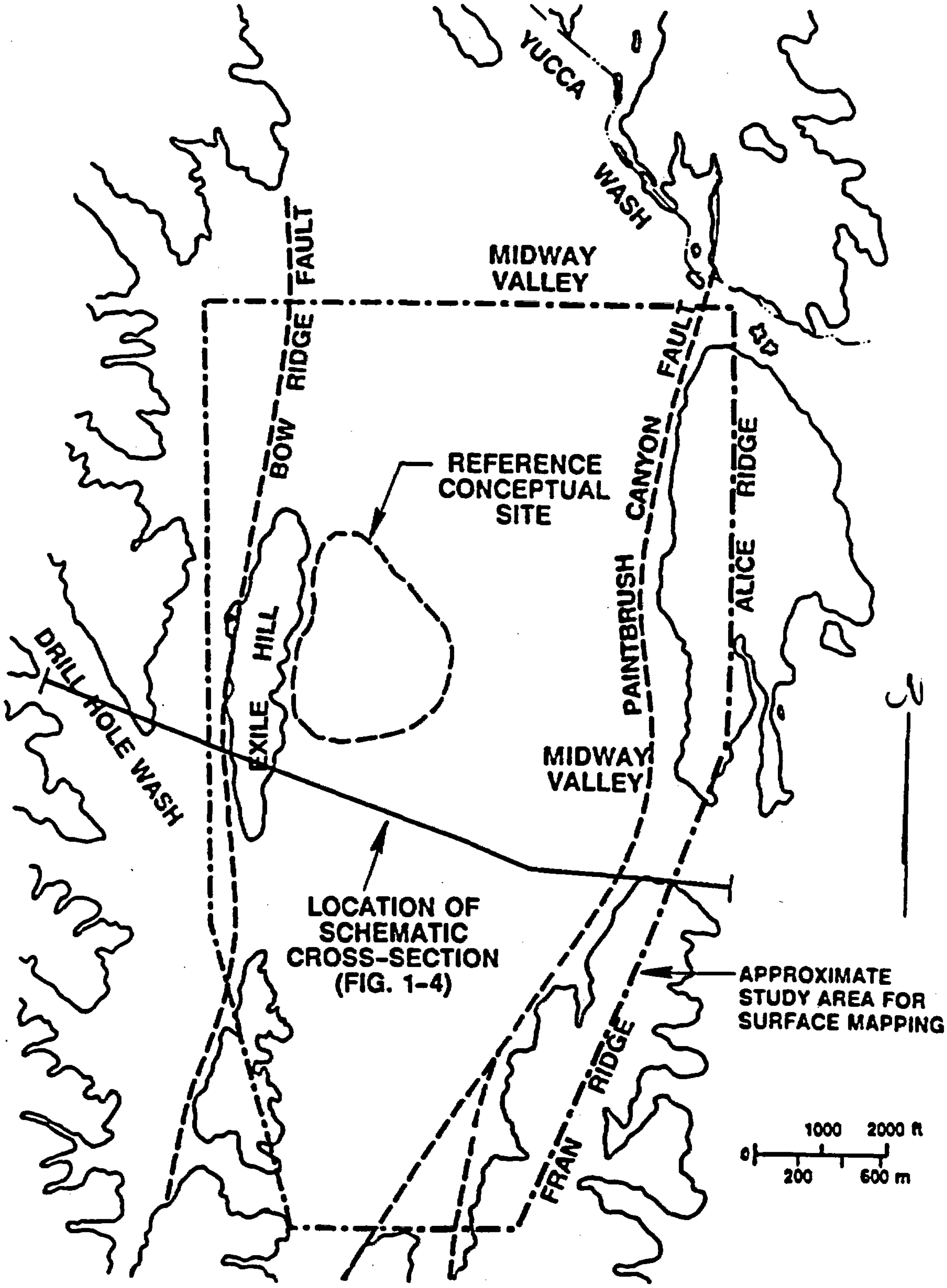

Figure 1-2. Proposed boundary of the Midway Valley Study area. Study area includes the reference conceptual site of Neal (1985).

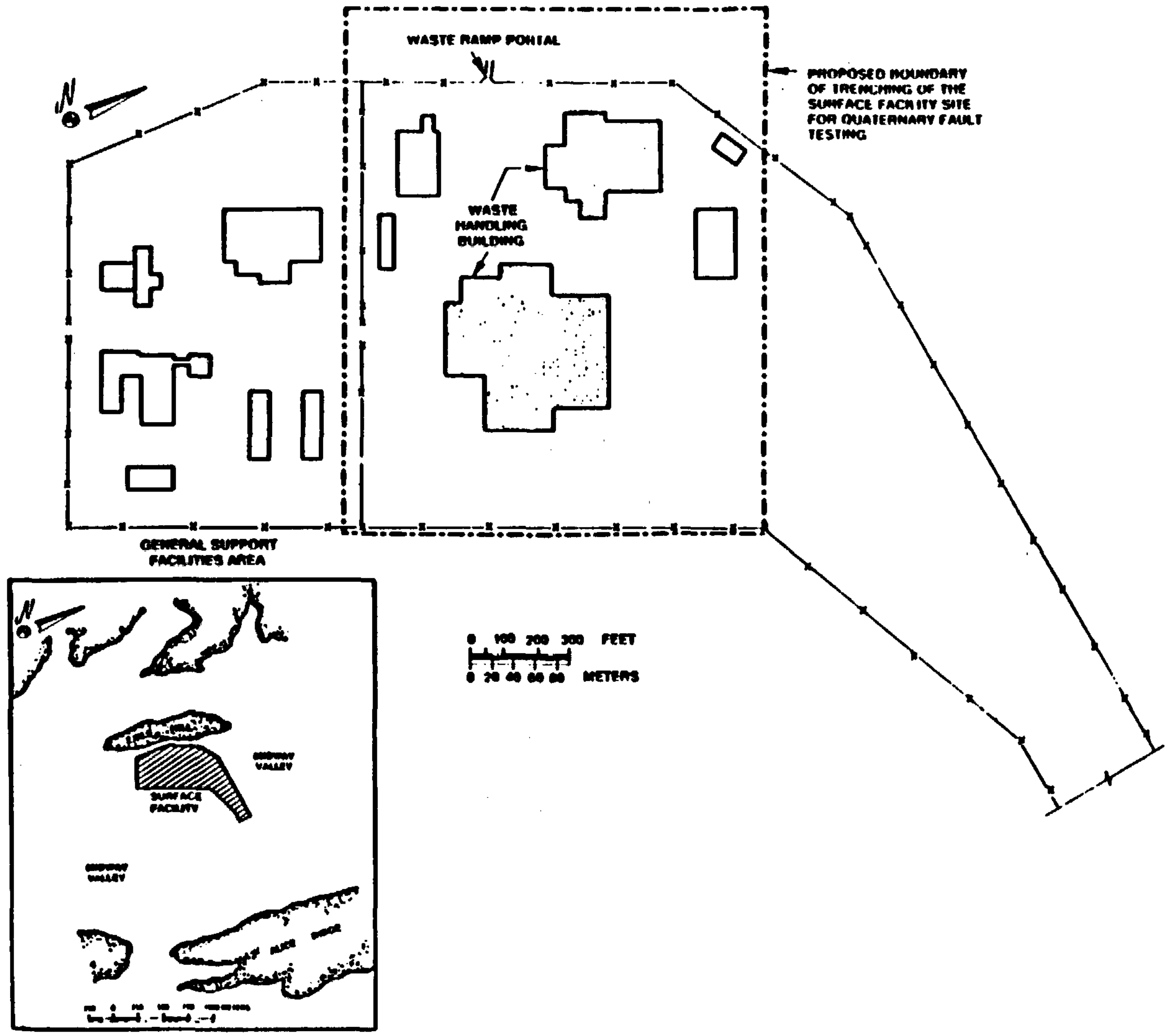

Figure 1-3. Layout of the reference conceptual site for the surface facilities, showing the approximate boundary and the area where trenching may occur relative to the location of the waste-handling buildings.

may be offset relative to each other. The concern is for avoiding relative displacements at the base of the structural foundation in excess of 5 cm (SCP Section 8.3.1.17).

This study plan presents the rationale for and the approach to evaluating the location and recency of faulting near prospective surface facilities (SCP Section 8.3.1.17.4.2). The organization and content of this document are governed by Yucca Mountain Project (YMP) and Sandia National Laboratories (SNL) requirements for SCP study plans. The remainder of Section 1.0 presents the objectives and regulatory requirements for the study and a discussion on the tectonic characteristics of the Yucca Mountain region. Section 2.0 presents the technical rationale for the study, and Section 3.0 presents a detailed description of study plan activities. Section 4.0 discusses the application of study plan results, and Section 5.0 presents the schedule for and milestones related to this study.

This document was upgraded from Sandia Letter Report, SLTR88-3004.

1.1 Study Plan Objective and Information Requirements

The objective of this study is to gather geologic data from Midway Valley to support (1) the siting of the surface facilities and (2) an assessment of the effect of fault displacement on repository design. SCP Section 8.3.1.17.4.2 identifies two activities, with associated information requirements (Table 1-1), to accomplish the objectives of this study. The emphasis of these activities will be on determining the existence of significant late Quaternary faults in Midway Valley. "Significant late Quaternary faults," as defined for this study, are those with a slip rate >0.001 mm/yr over the last 100 Ka; "Ka" = 1,000 yr (SCP Section 8.3.1.17). If late Quaternary faults are found, they will be characterized.

Although the siting of the surface facilities is not within the scope of this study, the goals for the study are defined by the design, performance, and characterization parameters related to surface facilities

TABLE 1-1

GENERAL INFORMATION TO BE OBTAINED FOR EACH ACTIVITY CONDUCTED DURING THE STUDY

Activity	Information Requirements
Activity 1: Identify Appropriate Trench Locations in Midway Valley (SCP Section 8.3.1.17.4.2.1)	Distribution, age, and characteristics of Quaternary/Tertiary surficial units
	Distribution, age, and characteristics of Tertiary bedrock units
	Structural and stratigraphic relationships of surficial and bedrock units
	Characteristics, ages, and distribution of faults
Activity 2: Conduct Exploratory Trenching in Midway Valley (SCP Section 8.3.1.17.4.2.2)	Thickness and continuity of stratigraphic units
	Characteristics, ages, and histories of faults

and preclosure fault displacement (Tables 1-2 and 1-3) and are stated in terms of distances from the waste-handling buildings. Throughout this study plan, reference will be made to candidate sites for the surface facilities that contain a location suitable for the waste-handling buildings (i.e., where significant late Quaternary faults are absent). If faults are found in Midway Valley, the information provided by this study will assist in determining if the surface facilities should be designed to mitigate the effects of these faults or if the facilities should be moved to another location.

1.2 Use of Study Plan Results

The design of the surface facilities, in particular the waste-handling buildings, must take into account tectonic activity expected at the site during the operational lifetime of the repository (i.e., ~100 yr).

TABLE 1-2

DESIGN AND PERFORMANCE PARAMETERS RELATED TO SURFACE FACILITIES AND PRECLOSURE FAULT DISPLACEMENT [MODIFIED FROM SCP TABLE 8.3.1.17-3(A)]

Design or Performance Parameter	Needed Confidence
Identification of any fault within 100 m of the proposed site for the waste-handling buildings with >1 chance in 100 of producing more than 5 cm of surface offset during the preclosure period (approximately 100 yr)	High
If existence is determined, establish	
Classification	High
Location at surface	High
Orientation at surface	High
Total probability of exceeding 5 cm fault displacement at locations proposed for the waste-handling buildings	High

TABLE 1-3

CHARACTERIZATION PARAMETERS RELATED TO SURFACE FACILITIES AND PRECLOSURE FAULT DISPLACEMENT PROVIDED BY ACTIVITIES CONDUCTED AS PART OF THE PRECLOSURE TECTONICS SITE PROGRAM [MODIFIED FROM SCP TABLE 8.3.1.17-3(B)]

Characterization Parameters	SCP Activity
Estimate of total probability for >5 cm displacement beneath the waste-handling building site considering known and possibly concealed faults and tectonic interrelationships among local faults	8.3.1.17.2.1.1: Assess the Potential for Surface Faulting at Prospective Sites of Surface Waste-Handling Buildings
Identification and characterization of faults within 100 m of the waste-handling buildings that have apparent Quaternary slip rates >0.001 mm/yr or that measurably offset materials <100 Ka	8.3.1.17.4.2.2: Conduct Exploratory Trenching in Midway Valley
Identification and characterization of potentially significant Quaternary faults within 5 km of the waste-handling buildings	8.3.1.17.4.6.1: Evaluate Quaternary Geology and Potential Quaternary Faults at Yucca Mountain

Displacements and vibratory ground motion that may occur as a result of faults are perhaps the two most important tectonic effects. This study will document the existence of any faults within and adjacent to a candidate area proposed for the waste-handling buildings as well as identify those areas within the Midway Valley where faults are unlikely. It is anticipated that a candidate site where significant late Quaternary faults are absent can be delineated in Midway Valley. If this is not possible, the geologic structures that do exist in Midway Valley will be evaluated.

Although preliminary work by Neal (1985) has been used to define a reference conceptual site (Figure 1-2) which is currently being used by the YMP for design and performance calculations, the results from this and other SCP investigations (Table 1-4) along with extensive interaction with design engineers will determine the final design and location of the surface facilities. The results from this study will also be used with the results from other investigations to estimate the probability of displacement beneath the location of the waste-handling buildings (SCP Section 8.3.1.17.2.1; Assess the Potential for Surface Faulting at Prospective Site of Surface Waste-Handling Buildings).

1.3 Rationale and Justification for Information to Be Obtained

1.3.1 Resolution of Performance and Design Issues

The performance allocation process has been used by the YMP to establish appropriate issue resolution strategies (issues to be resolved are listed in SCP Section 8.2.1). A general discussion of the performance allocation approach is provided in SCP Section 8.1. Issue resolution strategies and details of performance allocation for each design and performance assessment issue are summarized in SCP Section 8.2 and provided in full detail in SCP Sections 8.3.2 through 8.3.5. The primary Performance and Design Issues and Information Needs to be addressed using the information and data obtained in this study are summarized in Table 1-5. The approach that will be used to site and design the surface

TABLE 1-4

SUMMARY OF RELATED INVESTIGATIONS AND STUDIES THAT WILL PROVIDE INFORMATION FOR SITE CHARACTERIZATION OF MIDWAY VALLEY

Investigation 8.3.1.4.2	Geologic Framework of the Yucca Mountain Site
• Study 8.3.1.4.2.2	Characterization of the Structural Features Within the Site Area
Investigation 8.3.1.5.1.4	Studies to Provide the Information Required on Nature and Rates of Change in Climatic Conditions to Predict Future Climates
• Study 8.3.1.5.1.4	Analysis of the Paleoenvironmental History of the Yucca Mountain Region
Investigation 8.3.1.14.2	Studies to Provide Soil and Rock Properties of Potential Locations of Surface Facilities
• Study 8.3.1.14.2.1	Exploration Program
• Study 8.3.1.14.2.2	Laboratory Tests and Material Property Measurements
• Study 8.3.1.14.2.3	Field Tests and Characterization Measurements
Investigation 8.3.1.17.4	Preclosure Tectonics Data Collection and Analysis
• Study 8.3.1.17.4.3	Quaternary Faulting Within 100 km of Yucca Mountain, Including the Walker Lane
• Study 8.3.1.17.4.6	Quaternary Faulting Within the Site Area
• Study 8.3.1.17.4.7	Subsurface Geometry and Concealed Extensions of Quaternary Faults at Yucca Mountain
• Study 8.3.1.17.4.9	Tectonic Geomorphology of the Yucca Mountain Region

TABLE 1-5

ISSUES AND INFORMATION NEEDS TO BE ADDRESSED USING DATA AND INFORMATION OBTAINED IN THIS STUDY

Issue 2.3 Can the repository be designed, constructed, operated, closed, and decommissioned in such a way that credible accidents do not result in projected radiological exposures of the general public at the nearest boundary of the unrestricted area, or workers in the restricted area, in excess of applicable limiting values?

Information Need 2.3.1 Determination of credible accident sequences and their respective frequencies applicable to the repository.

Information Need 2.3.2 Determination of the predicted releases of radioactive material and projected public and worker exposures and exposure conditions under accident conditions and that these meet applicable requirements.

Issue 2.7 Have the characteristics and configurations of the repository been adequately established to (a) show compliance with the preclosure design criteria of 10 CFR 60.130 through 60.133; and (b) provide information for the resolution of the performance issues?

Information Need. 2.7.1 Determination that the design criteria in 10 CFR 60.131 through 60.133 and any additional appropriate design objectives pertaining to radiological protections have been met.

Information Need 2.7.2 Determination that the design criteria in 10 CFR 60.131 through 60.133 and any additional appropriate design objectives pertaining to the design and protection of structures, systems, and components important to safety have been met.

Issue 4.4 Are the technologies of repository construction, operation, closure, and decommissioning adequately established to support resolution of the performance issues?

Information Need 4.4.1 Site and performance assessment needed for design.

Information Need 4.4.4 Repository design requirements for construction, operation, closure, and decommissioning.

Information Need 4.4.7 Design analyses, including those addressing impacts of surface conditions, rock characteristics, hydrology, and tectonic activity.

Information Need 4.4.8 Identification of technologies for surface facility construction, operation, closure, and decommissioning.

facilities [SCP Section 6.2.4; SCP-CDR Section 4.2.3 (SNL, 1987)] emphasizes preclosure radiological safety, environmental quality, and ease and cost of construction, operation, and decommissioning.

Reliable estimates of the amount of fault displacement and recurrence intervals within 100 m of a candidate location for the waste-handling buildings over the last 100 Ka are fundamental to evaluating credible accident scenarios and potential releases of radioactive materials resulting in worker or public exposure (Issue 2.3). Similarly, natural phenomena, such as faults, must be accounted for in the design of the waste-handling buildings so that the appropriate safety functions for these facilities are not compromised during operation (Issue 2.7).

Fault displacement data for the vicinity of the surface facilities are essential to developing a design for the waste-handling buildings that is safe and cost-efficient. Information related to fault characteristics and displacement history is needed to assess the feasibility of designing and building facilities at a candidate site that can accommodate limited surface displacement (Issue 4.4). A high degree of confidence in predicting the amount and rate of surface displacement should help to minimize costs, increase credibility in the design of the waste-handling buildings, and facilitate construction.

The results from the activities conducted for this study should provide the types of data necessary to address the information needs associated with these issues.

1.3.2 Regulatory Requirements

This study will provide some of the information needed to demonstrate compliance with several key requirements outlined in 10 CFR 60 and 10 CFR 960 (NRC, 1986 and DOE, 1986, respectively). 10 CFR 60.122 (Siting Criteria) presents a list of favorable and potentially adverse conditions relative to isolation; 60.122(b)(1) and 60.122(c)(11), (12), (13), and (14) provide seismic/tectonic criteria that could be related to surface facility siting. The Design Criteria for the Geologic Repository Operations Area (10 CFR 60; Sections 60.131 through 60.134) specify minimum criteria for the design of the facilities where waste handling occurs. Section 60.131(b) states that the structures, systems, and components important to safety shall be designed so that natural phenomena and environmental conditions expected at the geologic repository operations area will not interfere with necessary safety functions. Information obtained in this study will contribute to the data base established for calculating the probability of Quaternary faulting (SCP Section 8.3.1.17.2.1; Assess the Potential for Surface Faulting at Prospective Sites of Surface Waste-Handling Buildings), which may influence the integrity and safe function of the structures, systems and components.

System guidelines proposed in 10 CFR 960.5-1(a)(3) advise that construction and operation be technically feasible on the basis of reasonably available technology and that costs be demonstrated to be reasonable relative to other available and comparable siting options. Qualifying conditions are summarized in 10 CFR 960.5-2-11, which states that the site shall be located in a geologic setting in which any projected effects of expected tectonic phenomena or igneous activity on repository construction, operation, or closure will be such that the requirements specified in 10 CFR 960.5-1(a)(3) can be met. Potentially adverse conditions include evidence of active faulting within the geologic setting [10 CFR 960.5-2-11(c)]. A site shall be disqualified if, based on the expected nature and rates of fault movement or other ground motion, it is likely that engineering measures beyond reasonably available technology will be needed for exploratory shaft construction or for repository construction, operation, or closure [10 CFR 960.5-2-11(d)]. Data obtained as part of this study and studies outlined in SCP Sections 8.3.1.14.2.1, 8.3.1.14.2.3, and 8.3.1.17.4.6 are expected to identify and characterize geologic structures in Midway Valley and in the candidate location for the surface facilities so that the design and construction of the surface facilities can be completed in a timely and cost-effective manner.

1.4 Tectonic Characteristics of the Yucca Mountain Region

Yucca Mountain is located in a tectonically complex region that has been affected by numerous periods of silicic and basaltic volcanism (SCP Chapter 1; Carr, 1984). The bedrock generally consists of Tertiary volcanic rocks, predominantly welded to nonwelded ashflow tuffs of Miocene age. Yucca Mountain is located within a zone of northerly trending, high-angle normal faults (Figure 1-1), most of which have displacement down to the west and repeat and gently tilt the volcanic rock section eastward (Lipman and McKay, 1965; Scott and Bonk, 1984). Scott (1988) suggests that these steep normal faults flatten to join low-angle detachment faults at depth. Some of the faults die out to the north near the southern margin of the Claim Canyon/Timber Mountain Caldera, but others continue into the caldera (Carr, 1984).

The regional distribution of faults at and near Yucca Mountain is shown by Rogers et al. (1983) and Carr (1984). Major faults are spaced about 2 to 3 km apart and have average vertical displacements of about 250 m, most of which are thought to be of Tertiary age (Carr, 1984). Fault blocks are gently tilted east to southeast from about 5 to 15° from horizontal. Several faults exhibit a zone of shearing, generally <100 m wide, in which steep rotation of fault blocks has occurred locally. Zones of minor closely spaced faults are present in a few areas and postulated in others, such as Midway Valley (Scott et al., 1983; Scott and Bonk, 1984; Neal, 1986). Principal movement on the faults of northerly strike has been dip-slip with a component of strike-slip displacement. Focal mechanism solutions for recent microearthquakes in the vicinity of Yucca Mountain (SCP Figure 1-61) indicate strike-slip motion on north-trending faults. Such data imply that fault investigations should consider the possibility of recent lateral offsets, even though the faults may have originated as normal faults.

Scott and Bonk (1984) have named many of the larger faults in the vicinity of Yucca Mountain (Figure 1-1). These include among others, from west to east, (1) Windy Wash Fault; (2) Solitario Canyon Fault, bordering the western margin of Yucca Mountain; (3) Abandoned Wash/Ghost Dance Fault, passing through Yucca Mountain; (4) Bow Ridge Fault along the western margin of Bow Ridge and Exile Hill; and (5) the Paintbrush Canyon/Fran Ridge Fault system near the western margin of Alice Ridge and Fran Ridge. Some, but not all, of these faults have increased displacement southward (C·rr, 1984). In addition, most of these faults appear to bifurcate and intersect with adjacent faults so that correlation of faults beneath surficial deposits is difficult. This is particularly evident with respect to the southern continuation of the Bow Ridge and Paintbrush Canyon Faults and in areas such as Midway Valley and Yucca Wash.

The age of most recent displacement and the recurrence interval of fault activity at Yucca Mountain is not well known but is the subject of previous and proposed (SCP Section 8.3.1.17.4.6; Quaternary Faulting Within the Site Area) trenching and mapping investigations by the U. S. Geological Survey (USGS). Holocene fault scarps or indications of Holocene fault activity are not evident in Midway Valley. Historic records of earthquakes in the vicinity of Yucca Mountain suggest that for at least the last 50 yr seismic activity at Yucca Mountain has been distinctly less than in most of the southern Great Basin region (Carr, 1984). Similar trends for seismicity near Yucca Mountain have also been determined from a local seismic network in service since 1978 (Rogers et al., 1987).

Evidence for Quaternary displacement along faults at Yucca Mountain is based primarily on the mapping of surficial deposits (Hoover et al., 1981) and trench investigations across known or suspected Quaternary fault traces (Swadley and Hoover, 1983; Swadley et al., 1984). Evaluation by the State of Nevada (Ramelli et al., 1988) of aerial photographs taken at low sun angle indicate Quaternary activity on faults in the Yucca Mountain region. At least 23 exploratory trenches have been excavated and mapped in the Yucca Mountain area (Swadley et al., 1984). Quaternary fault activity was evident in several trenches along the Paintbrush Canyon/Fran Ridge Fault system, Bow Ridge Fault, Solitario Canyon Fault, and on two faults in Crater Flat (west of Yucca Mountain). Detailed mapping of several of the trenches that exhibit Quaternary fault displacement has been completed.

Preliminary results are discussed by Whitney et al. (1986) and Fairer et al. (1987).

Hoover et al. (1981) developed a general stratigraphy for Quaternary deposits at the Nevada Test Site (NTS) based on physical and geomorphological features and sparse radiometric age data (Table 1-6). Swadley et al. (1984) used this stratigraphy and additional radiometric ages to determine the time of most recent faulting. In most trenches that expose Quaternary faults, samples of surficial deposits, soil carbonate,

TABLE 1-6

GENERAL STRATIGRAPHY OF PLIOCENE THROUGH HOLOCENE DEPOSITS WITHIN MIDWAY VALLEY [MODIFIED FROM HOOVER ET AL. (1981) AND SWADLEY ET AL. (1984)].

UNIT		ESTIMATED AGE RANGE (yr)
	Holocene Deposits	
Q1a	- Fluvial deposits	present to 150
Q1b	- Fluvial deposits and debris flows	150 to 4000
Q1e	- Eolian dunes and sheets	present to 8000
Q1s	- Fluvial sand sheets	4000 to 7000
Q1c	- Coarse fluvial deposits	7000 to 9000
	Middle and Late Pleistocene Deposits	
Q2a	- Local debris flows	≈40,000
Q2b	- Fluvial deposits	160,000 to 250,000
Q2s	- Fluvial sand sheets	270,000 to 700,000
Qb	- Basalt flows and cinders	230,000 to 300,000
Q2e	- Eolian dunes and sheets	700,000 to 750,000
Q2c	- Coarse fluvial deposits	270,000 to 800,000
	Early Pleistocene - Pliocene (?) Deposits	
QTa	- Debris flows, minor fluvial deposits	1.1×10^6 to 2×10^6
Qb	- Basalt flows and cinders	1.1×10^6 to 1.3×10^6
	Pliocene - Pleistocene Deposits	
QTld	- Lacustrine deposits	$< 2 \times 10^6$ to 4×10^6

and opal have been dated by the uranium-trend (Swadley et al., 1984; Rosholt et al., 1985) and/or conventional uranium-series methods (Szabo and O'Malley, 1985). In other trenches, Swadley et al. (1984) correlated the Quaternary deposits exposed in the trench with the Quaternary stratigraphy described by Hoover et al. (1981). In several trenches, basaltic volcanic ash is present in an exposed fault plane but cannot be correlated confidently with nearby sources. Based on tentative correlation of deposits with the stratigraphy of Hoover et al. (1981), Swadley et al. (1984) bracket the age of last significant movement on the Paintbrush Canyon/Fran Ridge Fault system at 270 to 700 Ka.

The Bow Ridge Fault, located along the western flank of Exile Hill (Scott and Bonk, 1984), trends northward for about 6 km from Bow Ridge on the south to Yucca Wash on the north. Six trenches or pits have been excavated across or near the fault--one at Bow Ridge and five at Exile Hill. Two trenches at Exile Hill expose disrupted Quaternary alluvium against faulted and brecciated Tertiary bedrock. Uranium-trend dates on the displaced sediment suggest a minimum age for movement along the fault between 38 $\pm$10 Ka to 270 $\pm$90 Ka (Swadley et al., 1984). No conclusive evidence for Quaternary displacement along the Bow Ridge Fault was observed on Exile Hill before trenching, although a lineament was observed at the bedrock/alluvium contact.

The geologic structure of Midway Valley and the surrounding area has been mapped by Scott and Bonk (1984) and discussed by Neal (1986). Lipman and McKay (1965) infer a fault through the center of Midway Valley, informally named the "Midway Valley Fault" (Figure 1-4), approximately 1 km east of Exile Hill, although there is no apparent Quaternary offset. On the basis of limited subsurface data from Midway Valley and the style of faults exposed locally at Yucca Mountain, Scott and Bonk (1984) suggest that the structure of the bedrock is characterized by a series of closely spaced Miocene normal faults bounding relatively stable, passive zones as represented by the Exile Hill Block and the major topographic features of Yucca Mountain (Figure 1-4). In several areas at Yucca Mountain, the bedrock contains closely spaced normal faults that have apparently rotated

QTac QUATERNARY/TERTIARY ALLUVIUM AND COLLUVIUM

Tmrn RAINIER MESA MEMBER OF TIMBER MOUNTAIN TUFF, NONWELDED

Tpcw TIVA CANYON MEMBER OF PAINTBRUSH TUFF, WELDED

n NONWELDED TUFF

Tptw TOPOPAH SPRING MEMBER OF PAINTBRUSH TUFF, WELDED

Tcbw BULLFROG MEMBER OF CRATER FLAT TUFF, WELDED

-△- BRECCIA

DRILL HOLE SHOWING TOTAL DEPTH

FAULT WITH DOMINANT DIP-SLIP DISPLACEMENT

FAULT WITH DOMINANT STRIKE-SLIP DISPLACEMENT:

⊙ INDICATES DISPLACEMENT INTO PAGE

⊕ INDICATES DISPLACEMENT OUT OF PAGE

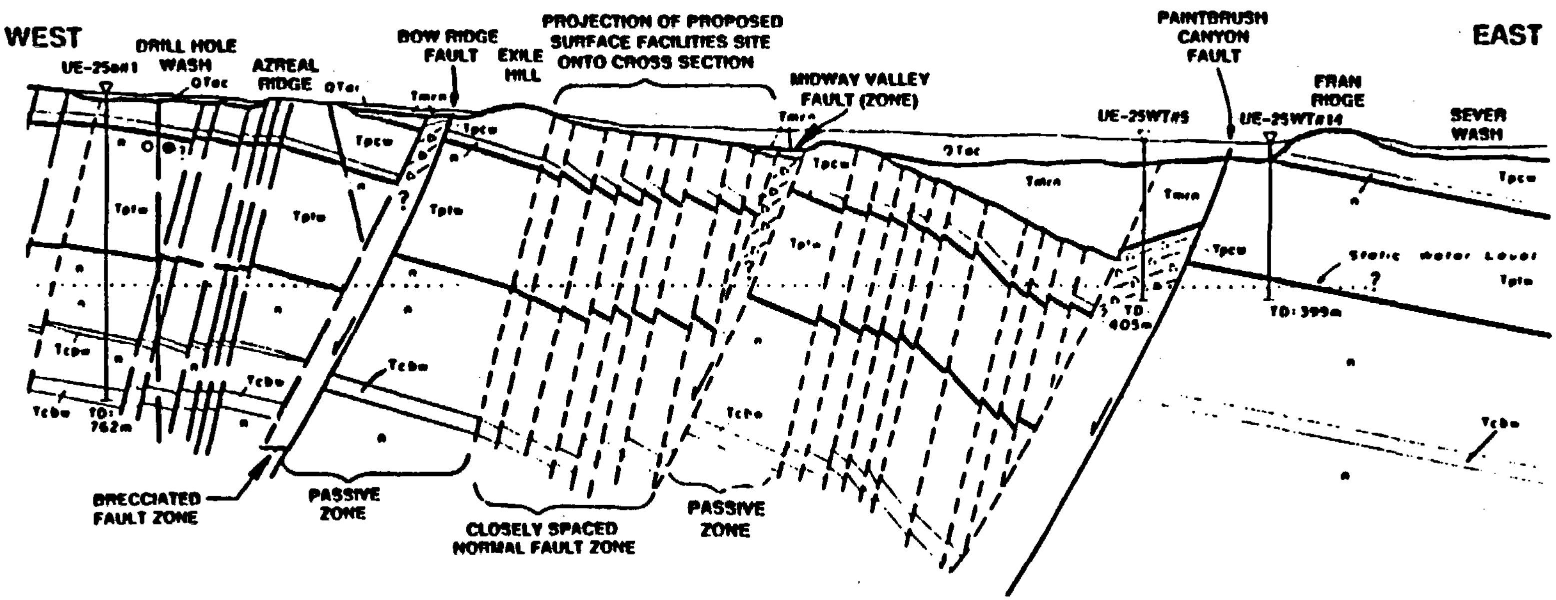

Figure 1-4. Cross section through Midway Valley emphasizing inferred structural features [Modified from Neal (1986) and Scott and Bonk (1984)]. Location of cross section is shown on Figure 1-2.

the strata through 10° to about 50°, whereas, within the passive zones, dips are commonly 5° to 15° to the east, indicating little rotation of strata by movement along faults. Individual offsets in the zone of closely spaced normal faulting may be small and difficult to detect, but zones of this faulting style may be as much as a kilometer in width with a cumulative vertical offset of several hundred meters. The amount of tectonic extension is believed to be greatest in these zones. Borehole data reported by Neal (1986) can be interpreted to indicate that the normal faulting in the Midway Valley area may be as complex as that postulated by Scott (1984) and Scott and Bonk (1984), although it is not known how many, if any, of these faults actually penetrate the alluvium.

2.0 RATIONALE FOR THE STUDY OF THE LOCATION AND RECENCY OF FAULTING NEAR PROSPECTIVE SURFACE FACILITIES LOCATIONS

The data currently available from Midway Valley do not provide adequate assurance that Quaternary fault displacement has not occurred in the sedimentary deposits located in the study area. A highly generalized small-scale map of surficial deposits in Midway Valley (Swadley et al., 1984) is not adequate to define possible geomorphologic features that may indicate the existence of Quaternary faults. There is considerable uncertainty concerning the age of the most recent movement on known Quaternary faults in the vicinity of Yucca Mountain. Relevant information has gradually been refined (Whitney et al., 1986; Fairer et al., 1987; Ramelli et al., 1988) as additional work has been completed on the regional geologic structure. For example, trenching and radiometric age determination studies on the Bow Ridge and Paintbrush Canyon Faults bordering the study area have not conclusively demonstrated movement on these faults more recent than about 400 Ka nor disproven that movement may have been as recent as the last 30-40 Ka.

2.1 Proposed Approach to the Study

The Midway Valley study area (Figure 1-2) encompasses an area of about 15 km^2. The study to evaluate the potential and recency of faulting in this area will be conducted in two interrelated activities. The description of these activities presented in this study plan is similar to, but slightly modified from that outlined in the SCP (Table 1-1). The two activities are intended collectively to provide the data necessary to document the existence of late Quaternary faults and to establish the displacement history of any faults present. This approach is expected to supply some of the geologic data necessary for identifying a candidate site for the surface facilities that contains an location suitable for the waste-handling buildings where late Quaternary faults are not likely to be present.

During Activity 1, a geologic map of the Midway Valley study area will be developed using aerial photographs, surface geologic mapping, soil pits and exploratory trenches, and various geophysical and remote sensing techniques. This map will be used to select locations for long trenches that will cut across an area suitable for the waste-handling buildings. During Activity 2, long trenches, as well as supplemental trenches, will be excavated and mapped.

As defined for this study, "exploratory" trenches are trenches of a few tens of meters length that are excavated during Activity 1. "Long" trenches are excavated during Activity 2, are greater than 100 m in length, and may be several hundreds to even a thousand meters in total length. "Supplemental" trenches are also excavated during Activity 2 but have the same dimensions as exploratory trenches. These supplemental trenches will be used to further understand features and relationships found in the long trenches. The depth and width of all three types of trenches are similar. No prescribed number of exploratory trenches is required before a long trench is excavated, and it is conceivable that an "exploratory" trench excavated in Activity 1 could be extended into a "long" trench as part of Activity 2. This approach makes optimum use of time and resources in reaching the goals of the study.

2.2 Rationale and Justification for Study Plan Activities

2.2.1 Activity 1: Identify Appropriate Locations for Long Trenches in Midway Valley

Hatheway and Leighton (1979) emphasize the need to develop a sound understanding of the stratigraphic and structural framework of a proposed site before selecting trench locations. Bonilla (1973 and 1982) concludes that a realistic evaluation of fault activity requires consideration of data obtained well outside the confines of a particular site. During Activity 1, such an evaluation will be developed using a systematic approach that incorporates results from surficial geologic mapping, photogeologic interpretation of aerial photographs, soil pits and exploratory trenches, and geophysical surveys combined with available information obtained from other studies. The distribution and correlation of mappable surficial units will be based on soil development, geomorphic expression, degree of carbonate cementation, development of desert pavement, and lithology (Hoover et al., 1981). Nomenclature for the surficial units will be consistent with that used by Hoover et al. (1981) in the Nevada Test Site (NTS) region. More detailed differentiation of units may be required for this study.

An integral component of Activity 1 is the development of a chronostratigraphic framework based on numerical-, relative-, calibrated-, and correlated-age methods (Colman et al., 1987). The initial development of this framework will be accomplished by sampling the soil pits and exploratory trenches and by correlating major lithologic units. This framework will be used to help site trenches in locations that are expected to be favorable for determining the minimum age of faulting, if present.

Various geophysical and remote sensing techniques (Table 2-1), useful for evaluating subsurface geology, may be considered for this study. The ability to delineate the presence of shallow subsurface structures will aid in locating trenches for Activity 2. Whether these techniques are applicable and useful for this study will be determined as work progresses for this study and the study of subsurface geometry and concealed extensions of Quaternary faults at Yucca Mountain (SCP Section 8.3.1.17.4.7).

2.2.2 Activity 2: Conduct Trenching in Midway Valley

Taylor and Cluff (1973) advocate the use of trenching to assess fault activity and its significance on engineered structures located nearby to differentiate between active and inactive faults and to establish zones of maximum potential surface displacement. Hatheway and Leighton (1979) state that trenching is the most definitive of all subsurface exploratory methods because it permits direct inspection of a continuous geologic section and preparation of a graphic log that delineates both obvious and subtle geologic features. Bonilla (1982) indicates that trenching provides the

TABLE 2-1

POSSIBLE GEOPHYSICAL AND REMOTE SENSING TECHNIQUES FOR USE IN MIDWAY VALLEY

- Ground Penetrating Radar
- Side Looking Aerial Radar
- Resistivity/Electrical Methods
- Seismic Reflection
- Seismic Refraction
- Helium Traverses
- Gravity
- Magnetics

most complete and accurate information for evaluating potential surface faulting and tectonic deformation.

The trenching work conducted during Activity 2 will provide the detailed structural and stratigraphic data needed to document the existence of late Quaternary faults within the study area. Trench mapping, combined with age estimates for the exposed units and correlation with surficial units identified in the Midway Valley study area, should provide the control needed to determine the rate, minimum age, and significance of any faults observed. Trench mapping is also needed to characterize any faults observed in terms of the sense and amount of displacement, age of displacement, evidence for recurrent displacement, amount of displacement per event, age of most recent displacement, and recurrence interval of surface displacement. Geophysical and remote sensing techniques may be considered for evaluating the subsurface geology along the trench wall and floor.

2.3 Rationale for the Scale, Location, Number, and Type of Data Collection Activities

The Midway Valley study area (Figure 1-2) incorporates the Bow Ridge Fault, Exile Hill, and portions of Alice Ridge and Fran Ridge. This area was selected so that structural trends related to Exile Hill and to the Bow

Ridge Fault that extend into Midway Valley could be identified and a preliminary assessment of the structural and stratigraphic characteristics of the surficial deposits and underlying bedrock in any candidate areas could be completed before selecting a site for the surface facilities. Information from Exile Hill and Midway Valley (Scott and Bonk, 1984; Neal, 1985; 1986) is currently insufficient to assess the heterogeneity present in the Quaternary deposits and Tertiary bedrock and the number of lineaments evident at the surface.

The information obtained as part of Activity 1 will be used to select locations for long trenches that may lie within a suitable location for the waste-buildings where late Quaternary faults are absent or, if present, can be confidently demonstrated to have slip rates of much less than 0.001 mm/yr. Surface geologic mapping will be accomplished using a combination of field mapping and photogeologic interpretation of aerial photographs. The compilation of the mapping results will be approximately 1:5,000, a scale that should allow retention of all important details. All lineaments observed on the aerial photographs of the study area will be examined in the field. Local variations in surficial deposits that are observed during mapping will influence the number and location of soil pits. Soil pits will be excavated in each major surficial unit, near selected exploratory trench locations, and to assist in locating long trenches. Additionally, soil pits will be excavated where needed for correlation with geophysical surveys, including ground penetrating radar (GPR) profiles. Existing data suggest that the GPR technique can penetrate to an approximate depth of 3-4 m. If this technique is used, prototype GPR studies will be performed adjacent to an existing or proposed exploratory trench so that results of the technique can be confirmed. The combined results of these tasks should provide some of the information needed to support siting the surface facilities where it can be demonstrated that late Quaternary faults are absent or where the alluvium has characteristics (i.e., material suitable for age determination) that can be used to document the displacement history of any faults present.

To enhance the ability to discern even small offsets and to better delineate the history of displacement and tectonic activity, trenches should also be located, where possible, in areas characterized by stratified deposits that span a wide range in age and can be dated by more than one reliable method. The level of confidence in the goal of the design and performance parameters will increase as the age of the unfaulted alluvium increases. Ideally, continuous exposures of alluvium that have not been faulted and are significantly older than 100 Ka (preferably QTa), would provide a sufficiently high level of confidence.

The presence or absence of favorable conditions summarized above is yet to be determined in the study area. Preliminary work in the Exile Hill and Midway Valley area (Neal, 1986) has not positively identified any expressions of faults in surficial deposits, except for those associated with the Bow Ridge Fault. However, several lineaments formed by brushlines, tonal contrasts, and aligned drainages are evident on aerial photographs of Midway Valley. Whether these lineaments represent faults cutting the surficial deposits is at present unknown. The surficial deposits in Midway Valley appear to consist largely of Q2 and QTa surficial units (Swadley et al., 1984). These units range in age from ~2.0 to 0.04 Ma ("Ma" = million years) and are often difficult to date using existing numerical-age determination methods. If faults are present, the limitations in establishing reliable numerical ages for these units will lower the confidence in the calculated displacement history. If late Quaternary faults (nominally <100 Ka) are observed within a candidate site and the characteristics of the exposures limit the ability to establish the displacement history, alternate locations for the surface facilities may be considered by design engineers.

Long trenches are needed to expose a complete section across the candidate site to permit identification and characterization of any faults that might pass under or near the surface facilities. These trenches will extend a nominal 100 m beyond the site to meet the requirement to identify and characterize any faults closer than 100 m to the waste-handling buildings. Supplemental trenches will provide additional data to clarify geologic interpretations and to improve confidence that the long trenches are truly representative of the site area.

The proposed trenching for Activity 2 includes a minimum of two long trenches extending across and at least 100 m beyond the boundaries of the candidate area for the waste-handling buildings. The overall length of each trench is expected to reach about 500 m, and at least one of these trenches will be oriented east-west approximately normal to the north-south structural grain observed in Midway Valley. The depth of most trenches is expected to be approximately 4 m. Whenever feasible, trenches will be excavated to a depth such that 100 Ka sediments are exposed. Supplemental trenches (nominal length of 30 m) may be used to enhance or clarify the interpretation of structures observed in the long trenches (e.g., fault type, displacement history, and stratigraphic continuity). In addition, several supplemental trenches of unknown length may be excavated and mapped for the characterization of the candidate site for the surface facilities. Information gathered in this manner should improve the confidence level for the conclusions reached in this study and should contribute significantly to the understanding of the late Quaternary tectonic history of the location for the waste-handling buildings and the surrounding site.

2.4 Study Plan Alternatives

At the present time, no available alternatives are adequate to furnish the information needed for this study. Results from this study are expected to provide information necessary to make timely decisions on siting the surface facilities during the early phase of repository Advanced Conceptual Design (ACD). The plan minimizes the commitment of significant resources until preliminary information on site suitability is obtained and allows consideration of alternate locations, if necessary, that would satisfy the design and performance parameters in time to finish characterization before the completion of ACD. A limited number of alternative locations that comply with the specified design and performance parameters exist for the waste-handling buildings.

Direct observation and sampling of the uppermost surficial deposits are the most reliable methods of investigating Quaternary fault displacements. The techniques recommended for this study (i.e., surface mapping, geophysical techniques, trench wall mapping, and age determination) are used routinely in investigations of Quaternary faults and will be used to characterize any site that is selected for the waste-handling buildings. Additional types of data (i.e., seismic reflection, seismic refraction, and coreholes) may be necessary to support the interpretations based on the techniques used. Some of these data (i.e., mapping and trenching along the Bow Ridge and Paintbrush Canyon Faults, and gravity and magnetics in Midway Valley) may be provided by other studies (e.g., SCP Section 8.3.1.14.2; Studies to Provide Soil and Rock Properties of Potential Locations of Surface Facilities) at a scale that should be adequate for supporting this study. Data obtained from seismic reflection and refraction might be used to delineate the alluvium/bedrock contact, to identify subsurface structures that are not evident at the surface, and to project subsurface structural trends within the study area. Data obtained from coreholes drilled into the Tiva Canyon Member could be used (1) to enhance the interpretation of seismic reflection and refraction data; (2) to better define the three-dimensional characteristics of the study area; (3) to constrain the models proposed for the tectonic structure of Midway Valley; (4) to characterize the postulated Midway Valley Fault; and (5) to better define the nature of the bedrock/alluvium contact in the vicinity of the proposed site of the waste-handling buildings. Seismic reflection, refraction, and corehole information in Midway Valley are required by the Soil and Rock Properties Investigation (SCP Section 8.3.1.14.2) and the Vibratory Ground Motion Investigation (SCP Section 8.3.1.17.3). Recommendations for additional work to gather this type of information in support of this study, if needed, will be presented in the reports completed after either activity of the study.

2.5 Study Plan Constraints

2.5.1 Potential Impacts on Site

Section 8.4 of the SCP discusses potential impacts of site characterization activities on the waste isolation characteristics of the site and presents analyses to demonstrate that such activities do not adversely impact the site. In particular, SCP Section 8.4.3.2.2.1 discusses the assumed dimensions of the trenches; SCP Section 8.4.3.2.1.1 presents the analysis that was used to evaluate whether surface excavations such as trenches could impact hydrologic conditions at the site; and SCP Section 8.4.3.2.5.1 discusses potential impacts and concludes that surface activities such as trenching will not adversely affect the site. As part of this determination, trenching must be less than or equal to the dimensions assumed in the analysis. The maximum depth of trenches will be limited by the maximum depth (20 ft) considered in the SCP analysis (SCP Section 8.4) and by the configuration of trenches as dictated by Operation, Safety, and Health Administration requirements (DOL, 1988). SNL has developed criteria letters which are used to dictate the dimensions of trenches to ensure that the dimensions will not exceed those assumed for the analysis of site impacts. If it is determined that larger trenches are needed, additional analysis may be necessary to demonstrate that no adverse site impacts will occur.

For this study, the expected maximum depth of the trenches is ≈ 4 m, significantly less than the depth considered in the SCP analysis and less than the foundation depth (≈ 8 m) for the waste-handling buildings (SNL, 1987). Trench sites outside of the actual construction area will be restored.

2.5.2 Limitations of Surface and Trench Mapping

The process of developing an interpretation of the geologic history of a particular area usually combines analytical results (e.g., age determination techniques) with observations of the structural and stratigraphic relationships evident in field and trench exposures. Interpretations of these relationships may vary between investigators, possibly resulting in differing conclusions based on the same geologic evidence. The reliability and accuracy of maps of the surface and near-surface (~0- to 5-m depth) alluvium and bedrock depend largely on the experience of those responsible for the field work and their familiarity with the region being mapped, their judgment regarding the age and origin of the lithologic units, and their ability to discern important structural and stratigraphic relationships between lithologic units. The selected mapping scale may also affect the accuracy of the map generated.

Experience is also essential for properly integrating results based on the interpretation of aerial photographs with those obtained from the surface mapping. Accurate locations for specific reference points are necessary to tie the aerial photographic information to the mapping program. The reliability and accuracy of interpretations based on the results of trench mapping are also highly contingent on the experience of the individuals performing the mapping, their familiarity with the stratigraphic and soil horizons exposed in the excavations, and their ability to recognize and delineate the structural and stratigraphic relationships evident along the trench walls.

A technical overview panel (TOP) consisting of recognized experts in Quaternary geology, neotectonics, and engineering seismic design will be formed at the onset of the study. This panel has a purely advisory and/or review role in the study. All members of the panel need not be convened at the same time; those present at a meeting will be dictated by the topic of discussion. For example, a portion of this panel, those members whose expertise is in field activities, may participate as observers during part of the data collection process. Members of the panel will review the data collected in the field, the criteria used to select the locations for the surface facilities, the waste-handling buildings, and the long trenches, and the conclusions of the investigation before publication of the final report. Recommendations from this group or portions of the group may include requests for specific types of additional data to help clarify interpretations or to consider alternate locations for the waste-handling buildings. Requests by this TOP for additional data that are not already being collected will be evaluated at that time and may involve increasing the scope of this study.

2.5.3 Recognition of Quaternary Faults

Results of previous investigations in the Yucca Mountain region (Hoover et al., 1981; Swadley et al., 1984) suggest that identifying evidence for Quaternary faulting on the basis of surface mapping, aerial photographs, and various geophysical techniques can be difficult and uncertain, even over sections of the major faults defined by Scott and Bonk (1984). This difficulty occurs in part because the sometimes subtle surface exposure can be obscured by erosion of the fault scarp and the influx of alluvium and in part because the geophysical techniques may not have the resolution to distinguish the features at depth. Available information documents Quaternary movement on major faults (i.e., Bow Ridge and Paintbrush Canyon) along the western and eastern perimeter, respectively, of Midway Valley but does not show whether fault displacement of Quaternary alluvium has occurred in Midway Valley. Data from soil pits, trenches, and geophysical surveys will supplement the surface mapping to identify areas where Quaternary faults are least likely to be present. To evaluate and improve the quality and resolution of the GPR data, prototype testing may be conducted over areas adjacent to existing trenches that are known to have well-defined Quaternary faults in alluvium similar to that expected in Midway Valley. If GPR surveys are conducted, these data will provide a basis for calibrating features observed on the GPR records with changes in lithology and structure evident in the trench.

2.5.4 Chronostratigraphic Framework for Evaluating Fault Displacement History

The data gathered during this study should determine if faults exist in areas of Midway Valley. Ideally, unfaulted material with an age of more than 100 Ka will be encountered in trenches. If faults are present, however, the geologic assessment of active tectonism depends on clearly discerning the age and the amount of deformation of a given stratigraphic unit. The amount of deformation can normally be measured with greater accuracy than the age; thus, adequate age control is likely to be the limiting factor. Pierce (1986) summarizes the general characteristics of 26 age determination techniques categorized in three groups (numerical, relative, and correlative) that have been used to estimate age and times of deformation of late Cenozoic deposits. Of these, fewer than half may have some application for the Quaternary deposits expected in the Midway Valley study area. To establish reliable age control, more than one numerical-age technique may be needed. Relative age determination and correlation methods are also important because they provide age control in the absence of numerical techniques, or they can be used to evaluate the reliability of the numerical ages, which can be subject to large uncertainties. Additionally, the availability of the appropriate materials present in the trench exposures may limit the number of samples that can be obtained or the type of numerical technique used.

Experience in the NTS area (Szabo et al., 1981; Swadley et al., 1984; Rosholt et al., 1985; Shroba et al., 1988) suggests that uranium-series dates on soil carbonate and opal and uranium-trend dates on select depositional units may be useful methods for establishing numerical ages of Quaternary deposits in Midway Valley. The uranium-series method (Szabo and O'Malley, 1985) is a widely accepted technique with a well-defined theoretical basis. This method measures the age of last precipitation of opal and carbonate and is particularly useful in systems closed with respect to uranium isotopes and ^{230}Th. In open systems the uranium-series technique provides an erroneous age younger than beginning of deposition of secondary minerals such as opal and carbonate. The uranium-trend method (Rosholt, 1980) is based on empirical techniques and has been used most extensively at the NTS but also to a lesser extent in other areas. It is very effective in the types of materials expected to be found in Midway Valley, but considerable time is required for sample processing and performance of analyses (~3 months).

A comparison of the results obtained using these two techniques on samples collected from Trench 14 along the Bow Ridge Fault (Swadley et al., 1984; Szabo and O'Malley, 1985) suggests that the latest movement along the fault may have occurred either less than 270 ±90 Ka (uranium-trend) (Swadley et al., 1984) or greater than 350 Ka (uranium-series) (Szabo and O'Malley, 1985). The apparent difference in the time of last movement between techniques may result in part from a lack of deposits that can more closely constrain the age at this locale. This example, combined with the limitations of other techniques for determining numerical ages, illustrates the difficulties that may be encountered in accurately establishing the displacement history of any faults (Table 1-2).

Three numerical-age techniques previously attempted on Quaternary deposits in the Yucca Mountain area may have limited application in this study if local conditions are favorable. Rock-varnish age determination techniques (Dorn, 1983; Harrington and Whitney, 1987), which use cation ratios in rock varnish to determine the time of varnish initiation on clasts from a variety of erosional and depositional surfaces, may be used to determine the age of these surfaces. Thermoluminescence age determination (Wintle and Huntley, 1982) may be useful under specific conditions, but it is not expected to have wide-scale application in this study because of the lack of appropriate material for age determination (e.g., material with a unique, well-defined time zero and without post-depositional changes such as weathering). Potassium/argon ($^{40}K/^{40}Ar$) age determination may be attempted if uncontaminated volcanic ash is found in any of the trench exposures.

Relative age techniques will include stratigraphic correlation and the comparison of soils in trenches and test pits. Correlations between units will be made using the general classification proposed by Hoover et al. (1981), which subdivides the deposits into three major groups: Q1 (0 to 9 Ka), Q2 (≈40 to 800 Ka), and QTa (1.1 to 2 Ma) (see Table 1-6). This approach should be more useful for correlating lithostratigraphic units within the rather limited area of study in Midway Valley than in those regions where correlation is attempted between alluvium-filled basins (as described by Hoover et al., 1981). The oldest dated Q2 deposits that contain calcretes range in age between 270 ±50 Ka and 440 ±60 Ka, based on uranium-trend dates reported by Rosholt et al. (1985). It is expected that there are even older Q2 deposits that contain calcretes. Calcretes are anticipated to be ubiquitous within the study area and may provide a primary means for establishing a relative age framework (Taylor, 1986).

The Bishop Ash (~740 Ka) occurs in the lowest part of Q2 at several localities in the Yucca Mountain area, and other ashes may provide an additional means of correlation. If found, ashes will be considered for geochemical analyses or radiometric age determination.

The age of the deposits in the study area could also limit the capability to discern the displacement history of any faults observed in the study area. Swadley et al. (1984) indicate that the deposits in the study area are primarily Q2 and QTa and are therefore probably older than 40 Ka. In several areas, Q1 alluvium is present, however, its thickness has not been documented. If faults are evident in older deposits where younger deposits are absent, it would be very difficult to determine a minimum age of last movement. This is also a concern in those areas of faulted bedrock that are not covered by alluvium. Conversely, if continuous exposures of QTa have not been disrupted by faults, then a high level of confidence could be assigned to the design and performance parameters for this study. The uncertainty in establishing an accurate displacement history for Quaternary faults resulting from a lack of reliable age control would probably preclude using an area for the waste-handling buildings where faults have occurred. To minimize this uncertainty, a considerable effort will be placed on identifying an area for the waste-handling buildings where no Quaternary faults have occurred.

2.5.5 Statistical Relevance of Data Obtained for this Study

The quantity of data collected in this study will depend, in part, on the number of trench locations excavated in the study area. Long trenches will transect the candidate area for the waste-handling buildings. Supplemental trenches may be sited at several locations within the study area to augment other data or to help clarify interpretation derived from other data. Because fault zones may have several episodes of activity, analysis of multiple age samples is particularly important. When feasible, multiple age dates on the same horizon will be used to improve confidence in numerical ages. If a fault is exposed in a long trench, supplemental trenches along the strike of the fault will be excavated, and samples for age determination will be collected. The sampling in the supplementary trenches should increase confidence in the findings from the long trenches.

This study is intended only to gather some of the information needed to identify an area suitable for the waste-handling buildings. The data will, however, be combined with data from other studies conducted as part of the Preclosure Tectonics Investigation (SCP Section 8.3.1.17.4) to perform analyses as described in the Faulting Potential at the Repository Study (SCP Section 8.3.1.17.2.1).

2.5.6 Interrelationships with Other Studies

The results of this study should supplement the information collected as part of the Preclosure Tectonics Site Program (SCP Section 8.3.1.17, Figure 8.3.1.17-4). The nature and style of faulting in Midway Valley is expected to be similar to that evident in other parts of the Yucca Mountain area. The Midway Valley study will generally be more detailed than similar studies performed in other areas and may be useful for creating generalized models for Quaternary faults at Yucca Mountain. The confidence required for values of design and performance parameters dictate that the conclusions reached in this study be consistent with the overall conclusions reached in the Preclosure Tectonics Program. Thus, these studies must be well-coordinated, with sufficient overlap and integration to facilitate the correlation of data collected at the various scales and levels of detail proposed.

The results of this study will also be used with the results from the other Quaternary fault studies (SCP Section 8.3.1.17.4) (see Table 2-1) in an assessment of the potential for displacement of faults that intersect the surface and underground facilities (SCP Section 8.3.1.17.2.1; Faulting Potential at the Repository). Data obtained in this study will supplement the information obtained as part of the Quaternary Faulting Within the Site Area Study (SCP Section 8.3.1.17.4.6), which will identify and characterize Quaternary faults within 5 km of the location of the surface facilities that intersect or project toward the location. Data acquired from the mapping and trenching program in Midway Valley may be useful for assessing the potential for similar types of faults occurring in other alluvium-filled basins bounded by major faults.

The mapping and trenching results from this study will provide preliminary information on the age, distribution, and characteristics of the alluvium and bedrock in the study area, which can be used in planning the soil and rock properties studies (SCP Section 8.3.1.14.2). Those studies will collect several different types of data using seismic refraction and seismic reflection profiles, coreholes, and trench mapping that should complement the results obtained in this study and improve the level of confidence in the results.

Gravity and magnetics data (see Table 2-1) may be obtained in the Midway Valley study area as part of the Subsurface Geometry and Concealed Extensions of Quaternary Faults at Yucca Mountain (SCP Section 8.3.1.17.4.7). These data may be useful for correlating surface and subsurface expressions of faults in the alluvium with offsets evident in the bedrock and for determining the characteristics of the bedrock near the postulated Midway Valley fault (Neal, 1986).

In accordance with scoping analyses of SCP Section 8.4.2.2.2.1, no interference between this study and Exploratory Shaft Facility design and construction can be identified at this time.

2.5.7 Time Needed for Evaluating the Location and Recency of Faulting

The presence of faults with a history of recent movement in the immediate vicinity of the reference conceptual site may dictate an alternate area for the waste-handling buildings. This change could have a significant effect on the design and layout of the surface facilities and could seriously impact program schedules for ACD and, possibly, the schedule for license application. This study is intended to provide information during the early stages of ACD that is necessary to identify a area for the waste-handling buildings in Midway Valley where late

Quaternary faults are absent or can be confidently demonstrated to have slip rates of much less than 0.001 mm/yr, if present. If necessary, alternative areas for the waste-handling buildings could be selected in time to minimize the impact on the overall project schedule. If a suitable area is identified, the additional information collected after the start of ACD will support the demonstration, with the prescribed high level of confidence, that Quaternary fault displacement rates have not exceeded 0.001 mm/yr and that materials <100 Ka have not experienced measurable offset. Schedules presented in Section 5.0 of this study plan indicate that adequate time is available to use the results of this study in the design of surface facilities.

3.0 DESCRIPTION OF STUDY PLAN ACTIVITIES

Figure 3-1 presents the general sequence of tasks for Activities 1 and 2. Some of these tasks may be conducted concurrently, and work for Activity 1 may overlap into Activity 2. Sections 3.1 and 3.2 describe the technical tasks for both activities identified in Figure 3-1. Section 1.2 describes how results will be used to resolve information needs.

An SNL Experiment Procedure will direct the field and laboratory work for this study. Experiment procedures are unique to SNL among the various YMP participants; they are distinct from study plans and provide the actual documentation for implementing a study. Experiment procedures include technical procedures and/or reference other separate technical procedures required for the work governed by an experiment procedure. All technical procedures for this study internal to SNL are included in the Experiment Procedure, EP-0001, and are listed in Table 3-1. USGS technical procedures that may be used for age determination of samples are also listed in Table 3-1. The actual USGS technical procedures used in this study will be determined by the types of datable material found in the field. A standard procedure will be completed and approved at least 30 days before it is used for this study. A non-standard procedure will be completed and approved at least 60 days before it is used for this study.

3.1 Description of Activity 1

During Activity 1, surface geologic mapping of the study area will be conducted. The tasks for Activity 1 include geologic mapping (photo-geologic interpretation and field mapping), soil pit description and sampling, exploratory trenching, numerical-age determination, and geophysical surveys. The key parameters for each of these tasks are summarized in Table 3-2.

The geologic mapping will delineate units of Tertiary volcanic rocks, overlying Tertiary and Quaternary surficial units, and structural data as identified in the field and on aerial photographs. The aerial photography

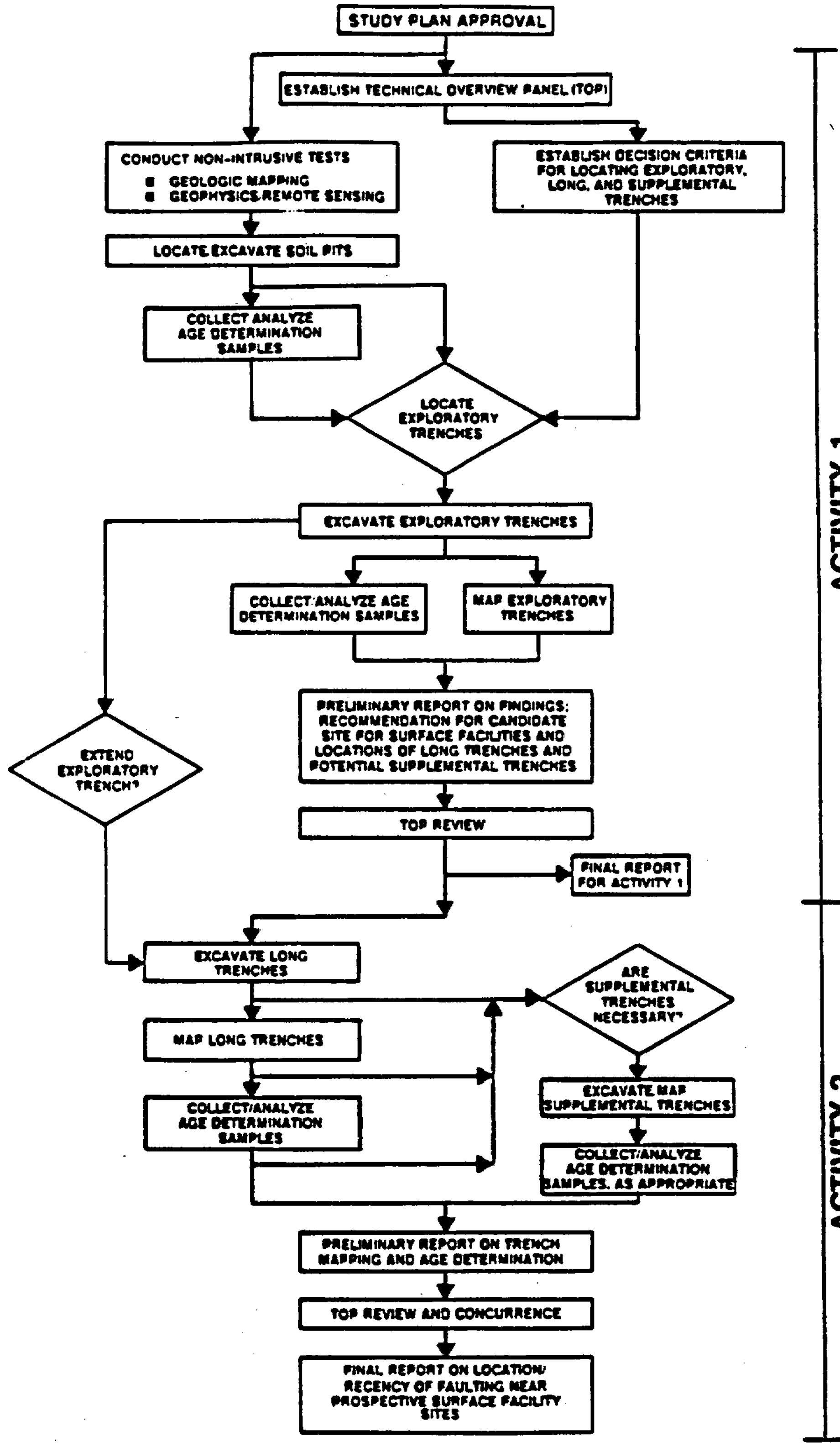

Figure 3-1. Summary of tasks for Activities 1 and 2 in the study to evaluate the location and displacement history of Quaternary faults in Midway Valley.

TABLE 3-1

TECHNICAL PROCEDURES FOR THIS STUDY

SNL Technical Procedures
(included in SNL Experiment Procedure)

Procedure ID#	Title	Standard/Non-standard
EP-0001	§ 4.4 Surface Geologic Mapping	Standard
	§ 4.5 Trench Mapping	Standard
	§ 4.6 Collection and Control of Samples	Standard

USGS Technical Procedures
(not all may be used)

Procedure ID#	Title	Standard/Non-standard
GCP-03	Uranium-Series Dating	Standard
GCP-04	Uranium-Trend Dating	Non-standard
GCP-06	Potassium-Argon Dating	Standard
GCP-08	Fission-Track Dating	Standard
GCP-11	Laboratory Preparation of Pedogenic Carbonate Rinds for Radiometric Dating	Standard

interpretation will emphasize the identification of lineaments in the study area. Existing information, including aerial photographs, will be used to generate an accurate base map. Additional aerial photography may be required for this study, the details of which will be included in the Experiment Procedure. Soil pits will be excavated to examine changes in the soil and lithologic characteristics and to supplement the data base for correlation between lithologic units across the study area. Exploratory trenches may be excavated across lineaments determined during the air photo interpretation and surface mapping to better understand the geology of Midway Valley. The exploratory trenches will be mapped and sampled for age determination, using photogrammetry for planimetric control and to provide a photographic record of the trench wall. Geophysical surveys may be performed over portions of the study area where evidence for offset is observed or inferred. These data will be correlated with information from the trench and soil pit exposures to develop a three-dimensional model of

TABLE 3-2

PARAMETERS AND CHARACTERISTICS TO BE OBTAINED IN ACTIVITY 1

Parameters	Characteristics
Distribution and Characteristics of Surficial Deposits	Geomorphic characteristics Soil development and morphology Lithology
Age of Surficial Deposits	Soil properties Rock varnish Weathering features Numerical age determinations Volcanic ashes
Displacement History of Mappable Faults	Slip rate Recurrence interval(s) Recency of movement Amount and style of movement
Fault Expression	Lineaments Length Width Orientation Tectonic features (e.g., brecciation and slickensides) Fault scarps
Underlying Structural Features	Geometry of subsurface reflectors (supplemented with GPR, seismic reflection, seismic refraction, gravity, magnetic data, and drill hole data from other studies)

the near-surface alluvium and to help document the existence of faults in the study area.

Mapping of the exposed Tertiary bedrock units that compose Exile Hill, consisting almost entirely of eastward-dipping ashflow tuffs of the Tiva Canyon Member of the Paintbrush Tuff, will be based on the stratigraphy used by Scott and Bonk (1984) and Neal (1986) for the Yucca Mountain area. Three units of the Tiva Canyon Member, which can be distinguished on the basis of color, texture, topographic expression, and petrology, are exposed on Exile Hill along the upper slopes and in the narrow rills on the lower slopes. The primary objectives of the bedrock mapping are to evaluate the structural integrity of the eastern side of Exile Hill, and to characterize the areal extent, thickness, structure, and nature and degree of weathering of the bedrock units. Mapping in some areas of the bedrock/alluvium contact at Exile Hill may require bulldozing, high-pressure water, or both to clean the bedrock pavement before mapping.

Surficial and near-surface sedimentary Tertiary units will be mapped using the general classification system proposed by Hoover et al. (1981) for the NTS area. This system can be used to divide Holocene and Pleistocene deposits into a number of subunits on the basis of topography, drainage, soils, desert pavement development, depositional environment, and lithology. Surficial units will be characterized by their inferred depositional environment, lithology, soil development, grain size, color, packing, and sorting of desert pavement. Soil pits will be excavated to augment the field mapping where changes in the characteristics of the surficial deposits are evident. Variations in the degree of soil development (i.e., carbonate and silica content, color and clay content of the A and B soil horizons, and the stage and thickness of the K horizon) and the characteristics of the Tertiary deposits will be determined, and samples for age determination may be obtained. Each soil pit will be excavated 1- to 2-m deep and logged at the same scale (nominally 1:10) used for the exploratory trenches. Samples for age determination may be collected in the soil pits to assist in correlating the major lithologic units across the study area and in selecting the location and depth of the trenches. Aerial photographs will be used to identify differences in topography, the depth and shape of drainage patterns, and any geomorphic or vegetative lineaments that will be investigated through field mapping. The photographs will be obtained at a scale comparable to that adopted for the field mapping (nominally 1:5000).

The geophysical surveys are intended primarily to provide information on the alluvium and bedrock down to and below the trench excavation depth. These data will be used to assist in mapping the major lithologic units within the study area, to delineate features in the subsurface that may be indicative of Quaternary fault displacement and, combined with the soil pit information, to estimate the maximum age of the alluvium that will be exposed by trenching. Various geophysical techniques may provide a means of correlating major lithologic and structural trends evident in the trenches over distances of several tens to hundreds of meters surrounding the location of the surface facilities. The feasibility of achieving any or all of these objectives with various geophysical techniques may be assessed with prototype testing conducted adjacent to existing trenches in the Exile Hill area.

The data collected in Activity 1 will provide the basis for determining the locations of long trenches in sites where Quaternary faults are likely to be absent. These data will also provide a basis for correlating the areal stratigraphic and structural relationships with those observed in the long trenches.

The data obtained from the geologic mapping, soil pits and exploratory trenches, and geophysical surveys completed during Activity 1 will be available to the YMP before completion of any written reports and will form the basis for a preliminary report on candidate sites for the surface facilities and waste-handling buildings in Midway Valley. This report should be completed early in ACD and will summarize the results obtained from the tasks completed and discuss their significance relative to siting the surface facilities and waste-handling buildings.

3.2 Description of Activity 2

During Activity 2, excavation and mapping of the long trenches will be conducted. The tasks for Activity 2 include trench-wall mapping, photogrammetry, collection of samples from the trench wall, numerical age determination, and geophysical surveys. The key parameters for this activity are summarized in Table 3-3.

TABLE 3-3

PARAMETERS AND CHARACTERISTICS TO BE OBTAINED IN ACTIVITY 2

Parameter	Characteristics
Stratigraphic Continuity	Bedding contact characteristics Continuity of stratigraphic units
Fault Displacement History	Slip rate Recurrence intervals Amount and orientation of displacement (Dip-slip and Strike-slip) Cracking and fracturing Soil profile development Distribution, thickness, and continuity of stratigraphic units Stratigraphic correlation Age estimates Recency of movement

The specific approach used during the Activity 2 will depend on the results obtained during the Activity 1. At a minimum, two long trenches will be excavated across a candidate site. The orientations of these trenches will be determined using all available information from the study area and the most recent information on the design of the buildings. The first trench will probably be oriented east-west approximately normal to the expected strike of the structural grain in the study area. The orientation of the second trench will be determined using the results from the first trench in addition to other supporting information. The depth of the trenches will be determined, in part, by the thickness of the various stratigraphic units encountered in the trench. Each of the trenches initially will be excavated to a nominal depth of 4 m. If only very young alluvium is found, the trench may need to be deepened to establish the local geologic history over a minimum of the last 100 Ka. Deeper excavations may also be needed if complex stratigraphic and structural relationships are encountered.

Additional supporting data (i.e., supplemental trenches, soil pits, and geophysical surveys) may be obtained before, or possibly after, the long trenches are excavated to facilitate locating the long trenches or to enhance the interpretation or understanding of data. Supplemental trenches may be needed to better define the stratigraphic relationships or structural trends observed in the long trenches and to provide additional data to support the conclusions on the location and recency of faulting near the candidate site. The nominal dimensions of the supplemental trenches are expected to comply with the recommendations of Bonilla (1982) who suggests minimum lengths of 30 m and a minimum depth of about 4 m. These supplemental trenches may be oriented approximately parallel to the inferred strike of an observed fault to help delineate any strike-slip component associated with faulting. These trenches may intercept an offset feature from which the strike-slip component of displacement can be determined. Whether a supplemental trench is necessary to determine strike-slip displacement depends, in part, on the orientation of the long trench and the fault itself. Exposure in a long trench may be sufficient to determine strike-slip offset.

Each trench will be mapped following the objective mapping approach discussed by Hatheway and Leighton (1979), which attempts to portray geologic features on a trench wall with minimal or no geologic interpretations. Because the emphasis of Activity 2 is to determine the absence of faults, the logging will be focused on showing the continuity and absence of displacement of geologic and pedologic units within the trench wall. The objective mapping approach is expected to provide a sufficiently detailed map of the geologic components exposed in the trench so that all concerned parties in the licensing process will be provided with data for analysis and comparison with the interpretation of the principal investigators. At least one wall of each trench will be mapped at a nominal scale of 1:10 to delineate the relationships between the various Quaternary and Tertiary surficial units and Tertiary bedrock units, if present. Additionally, the opposite wall and floor of the trench may be mapped to determine the relationship of structures on one wall to those observed on the opposite wall or floor of the trench. The units will be identified, classified, and correlated with the units in the surrounding area using classifications consistent with Hoover et al. (1981) for the surficial units and Scott and Bonk (1984) for the bedrock. All surficial and bedrock units will be described in detail to include color, texture, cementation, lithology, soil development, weathering features, thickness, lateral extent, and nature of bedding contacts. Samples for numerical-age determination and characterization (e.g., grain size, carbonate and silica content) will be collected from each major unit and in minor units of interest.

The nature of any faults that are present will be described and any other fractures will be characterized to differentiate between displacements of tectonic origin and those possibly resulting from cooling, compaction, dessication, or trenching. The chief characteristics to be noted for any observed faults include the relative sense and amount of displacement, nature and age of multiple displacements and crosscutting relationships, orientation, width, nature of gouge material, presence and orientation of slickensides, type and degree of cementation in the fault zone, and the style and nature of deformation away from the discontinuities.

Photogrammetry will provide the necessary planimetric control for trench-mapping activities. This technique has been used by Fairer et al. (1987) to provide accurate, reliable control of sample station locations, structural relationships, and stratigraphic contacts evident in the trench while minimizing the error induced by multiple measurements using a tape and rope grid. Fairer et al. (1987) also found that the use of photogrammetry for providing survey control greatly reduced the time needed for mapping. Close-range photogrammetric mapping of trench walls requires a series of controlled, overlapping photographs of the trench wall. Photographs are taken at stations along the trench wall with a minimum 60% horizontal overlap to achieve optimum stereoscopic vision and to ensure complete stereoscopic coverage when three or more photographs are used in succession. Each stereo pair of photographs contains at least three control points to help correlate the photographs and the trench face. A third-order survey of each end of the trench, tied to the nearest USGS benchmark, will be used as the basis for the photogrammetry.

Each trench wall will be photographed twice from end to end of the trench. The first photographic survey is an archival survey and will be done as soon as possible after the trench wall is cleaned. No markings, flags, or nails, other than the surveyed control points, should appear in these photographs. This survey will provide an archival set of prints of the trench wall.

The second survey is a geologic survey for which geologic contacts, fractures, soil horizons, sample points, and any other features that are to be included on the map are marked on the walls with nails and various colors of plastic flagging before photographing. The photographic stations and camera settings for the geologic survey should mimic those of the archival survey as closely as possible. Prints obtained as part of the geologic survey may be enlarged to a workable field scale (e.g., 1:10 or 1:20). These prints can serve as an orthographic photomosaic base map that can be used to map geologic features directly in the field, either directly on the base map or on mylar overlays. Use of photos in this manner may reduce the amount of time required by taping and grid techniques that are conventionally used to show relative position when generating a graphic log. Geologic notes, individual Polaroid and 35mm prints, and sketches will be made and their general relationships with the surveyed control points are noted. These notes, sketches, and photographs along with the photogrammetric prints are used to develop a geologic record of the trench with a reasonable amount of detail. The prints from the second survey, along with the record of geologic relationships established in the field, may also be used to develop an oriented photogrammetric model that displays the interrelationships between units evident along the trench walls. This model can be generated when the lines and patterns of each stereo pair are digitized and plotted to generate a cartographically-correct map.

3.3 Quality Assurance Requirements and the Experiment Procedure

The quality assurance (QA) level assignment for the activities in this study is QA Level I in accordance with SNL QAP 2-3 (see Appendix A). All work will be performed in accordance with the SNL Quality Assurance Program Plan. The SNL Experiment Procedure will describe the operational and technical procedures required to fulfill the objectives of the study plan. Included in the Experiment Procedure are technical procedures for surface geologic mapping, trench mapping, and collection and control of samples. These procedures are all considered standard. This Experiment Procedure will be completed at least 60 days before the start of field work in the study area.

3.4 Accuracy and Precision of Results

Interpretation of information obtained as this study is largely contingent on the experience of the principal investigators. The reliability of the data and the accuracy and precision of the results will depend on the specifications outlined in the Experiment Procedure and Technical Procedures used to implement this study.

Numerical-age control on measurably offset deposits will be necessary to determine if the deposits are <100 Ka and have slip rates >0.001 mm/yr (>10 cm/100 Ka). However, the numerical age determination techniques that are expected to be applicable in the study area will likely provide dates with errors in accuracy of thousands of years for deposits of approximately 100 Ka age. This is consistent with the information summarized by Pierce (1986) that indicates an accuracy of 2 to 8% may be achievable over the last million years for some of the 26 techniques he describes, but that most techniques have an accuracy of no better than 8%. Techniques that are likely to be used for establishing numerical ages for the Quaternary (< 2 Ma) deposits may have errors of several tens of thousands of years, based on evidence available from the Yucca Mountain region (Rosholt et al., 1985; Swadley et al., 1984). Only minimum ages can be determined in some instances. These and other limitations may have an effect on determining slip rates within the last 100 Ka.

Age determination techniques need only to supply information of sufficient precision and accuracy to satisfy the characterization parameters: 1) faults within 100 m of the surface facility with apparent Quaternary slip rates of >0.001 mm/yr or that measurably offset materials less than 100 Ka old be identified and characterized and 2) the total probability of >5 cm displacement beneath the surface facility, considering known and possibly concealed faults and tectonic interrelationships among local faults, be estimated. Difficulties in constraining the timing of fault activity may arise if suitable material for age determination is not found. If possible, the trench should expose material that is at least 100 Ka old and that is well stratified so that 10-cm displacements can be detected.

Planimetric control for mapping and sampling may be provided by photogrammetry that is tied to a USGS benchmark with a third-order survey. The accuracy of a third-order survey is one part in ten thousand.

3.5 Range of Expected Results

Quaternary displacement has been documented (Swadley et al., 1984) along the Bow Ridge and Paintbrush Canyon Faults that border the study area, but no other faults exhibiting Quaternary displacement have been identified within Midway Valley (Neal, 1986). Late Quaternary faults may be present within the study area, but their location or characteristics have not been well-defined in previous work. Interpretations of aerial photographs from the study area suggest that several vegetation and drainage lineaments exist, although their relation to possible Quaternary faults is unknown. Available information (Scott and Bonk, 1984; Neal, 1986) suggests that Tertiary faults associated with bedrock in the study area are pervasive, possibly spaced at horizontal distances of <100 m. The age of the deposits in the study area is expected to range from late Tertiary through Holocene (Swadley et al., 1984). It is anticipated that a site in Midway Valley, with an area for waste handling buildings where no Quaternary faults are present, can be identified as a prospective location for the repository surface facilities. No information is presently available that would preclude Midway Valley as the location for siting the surface facilities.

3.6 Equipment Requirements

The equipment and support (i.e., excavation equipment, survey control, and personnel) needed for this study are readily available and commonly used at the NTS and elsewhere for routine geoscience characterization studies. A list of standard equipment used for this type of geologic study is presented in Table 3-4. The specific equipment required for each activity will be described in the related Experiment and Technical Procedures used to implement this study.

Photogrammetry equipment (camera, sliding camera mount, and tripod rail) is available but will also be used to map the exploratory shafts. Thus, the work that requires photogrammetry must be scheduled to minimize potential conflicts and to limit duplication of purchased equipment. The analytical plotter required for photogrammetric data reduction and analysis is presently available at the USGS in Denver, CO. A second unit is available at a private contractor in Boulder, CO.

3.7 Data Reduction Techniques

The synthesis and interpretation of data collected as part of the geologic mapping task is based largely on the experience of the principal investigators and support staff. Data will be placed on maps at scales (nominally 1:5000) that are considered reasonable for the level of detail needed. Additional details of data reduction techniques can be found in the Experiment Procedure for this study and the USGS technical procedures listed in Table 3-1.

TABLE 3-4

EQUIPMENT LIST

Typical Geologic Field Equipment
hand lens, pick, rock hammer, field notebook, camera, film, camera supplies, shovel, sampling bags, brushes, whisk broom, labeling materials, measuring tapes and rulers, aerial photographs, stereoscope, scale-stable topographic base maps, mapboards, color charts, marking devices (such as nails, flagging, paint, string, pencils, protractors, and straight edges), pocket altimeter, Abney level, Jacob's staff, pocket transit (Brunton compass or equivalent), portable mapping grid, safety supplies (hard hats, safety glasses, etc.).

Excavation Equipment
bulldozer, backhoe, field notebook, camera, film, camera supplies, safety supplies (hard hats, safety glasses, etc.).

Surveying Equipment
theodolite, survey rod, measuring tapes and rulers, field notebook, camera, film, camera supplies, calculator, marking devices (such as nails, flagging, paint, string, pencils, protractors, and straight edges), safety supplies (hard hats, safety glasses, etc.).

Photogrammetric Equipment
metric camera, sliding camera mount, tripod rail, measuring tapes and rulers, field notebook, camera, film, camera supplies, marking devices (such as nails, flagging, paint, string, pencils, protractors, and straight edges), safety supplies (hard hats, safety glasses, etc.).

Data reduction techniques required for the numerical-age estimates will vary with the age determination technique used. However, for those age determination techniques being considered, the data reduction techniques appear to be well-defined (Pierce, 1986). Description of the actual data reduction techniques will be included in the Experiment Procedure and associated Technical Procedures.

3.8 Representativeness of Results

This activity will acquire data from the entire study area within Midway Valley. These results will be used to support the identification of a candidate site for the surface facilities and the waste-handling buildings. This site is expected to be representative of the areas within the entire study area that have not been influenced by late Quaternary faults.

Data obtained from the exploratory, long, and supplemental trenches should provide an adequate determination of surface and near-surface geology in Midway Valley. The degree to which these data are consistent will determine the level of confidence in the representativeness of the data and the results. Trenches excavated during the detailed characterization program (planned as part of SCP Investigation 8.3.1.14.2) and foundation excavations produced during construction of the waste-handling buildings will provide additional data that can be used to evaluate the representativeness of the data collected during this study. The extensive amount of trenching planned for this study contributes to the representativeness of these data.

A technical overview panel (TOP) consisting of recognized experts in Quaternary geology, neotectonics, and engineering seismic design will be formed at the onset of the study. The TOP will be convened before the start of the field program to review the approach adopted and to participate as active observers during portions of the mapping and trenching program. Although the panel or a portion of the panel may be convened at any time, its primary role is to review the results from Activities 1 and 2 as they are completed and before publication of any reports related to the study. Review of Activity 1 will include evaluation of the data collected during surface mapping and trench mapping of the exploratory trenches. The locations for the long trenches that have been proposed by the investigators will be evaluated. Recommendations from this panel may include requests for specific types of additional data to help clarify interpretations or to consider alternate locations for the long trenches. Requests by the TOP for additional data that are not already being collected will be evaluated at the completion of Activity 1 and may involve increasing the scope of this study during Activity 2.

The synthesis of data collected during both the surface mapping and trench mapping activities is largely interpretative in nature and based on the experience of the principal investigator and support staff. The TOP will review the results of these activities and possibly recommend that additional types of analyses or data reduction techniques be performed. These recommendations for additional work will be considered by the investigators.

3.9 Performance Goals and Confidence Levels

The performance allocation process has identified the performance goals and confidence levels required to resolve the key issues addressed by this study plan (SCP Table 8.3.1.17-3). The data that will be obtained as part of this study are expected to be adequate to address concerns related to the potential for Quaternary fault displacement near prospective surface facilities. The older the unfaulted alluvium, the higher the confidence level for the prescribed performance goal. If faults are found, they should be located within ± 5 m and their orientation determined to ± 10° (SCP Table 8.3.1.17-3a).

Additional trenching will also be performed as part of SCP Study 8.3.1.14.1 and during the construction of the waste-handling buildings, which should also be used to evaluate the level of confidence that can be assigned to the performance goals for this study. If suitable locations for the waste-handling buildings cannot be identified in the Midway Valley study area, then other areas may need to be characterized before selecting another site for the surface facilities.

4.0 APPLICATION OF RESULTS

Section 1.2 of this study plan includes a description of how results from the trenching program will be used to resolve the Information Needs identified by the performance allocation process and to satisfy the regulatory requirements. The data from this study will be used to address or help resolve a number of the Information Needs identified in Table 1-5 and the design and performance parameters summarized in Table 1-2.

The primary application of the data obtained as part of this study will be to support the identification of a candidate site for the surface facilities that contains an area suitable for the waste-handling buildings where late Quaternary faults are absent. If faults are present, the characteristics of the alluvium in the candidate site must be adequate to delineate the displacement history with a high level of confidence. Additionally, information from this study will be one source of data for the probabilistic modeling to evaluate the potential for faulting during the operational phase of the repository (SCP Section 8.3.1.17.2). These data will also provide supplementary data for the Quaternary tectonic model being developed for the Yucca Mountain area (SCP Section 8.3.1.17.4.2).

5.0 SCHEDULE AND MILESTONES

5.1 Duration and Relationships of Study Plan Activities

The work planned as part of this study will be performed in two activities. The level of detail and time required to complete the tasks in Activity 2 is largely dependent on the results of the preliminary work conducted as part of Activity 1 (Figure 5-1). Both activities should be completed in time to provide input to the ACD.

5.2 Scheduling Relative to Other Studies

Several tasks conducted as part of this study may supplement activities conducted in other studies or, depending on scheduling, benefit from data collected in those studies. It is expected that during Activity 2 of this study, gravity and magnetics data will be available as a result of work performed in the Subsurface Geometry and Concealed Extensions of Quaternary Faults at Yucca Mountain Study (SCP Section 8.3.1.17.4.7). Studies conducted as part of the Soil and Rock Properties Investigation (SCP Section 8.3.1.14.2) are expected to provide physical properties and seismic refraction data from the reference conceptual site. The completion of this study is not dependent, however, on input from other studies. Additional equipment and manpower may be required if photogrammetry within trenches and the exploratory shaft is required simultaneously. These interactions with other studies will depend on the actual schedules for start of work and on approval of the study plan and associated documents.

A delay in the schedule for this study may have a significant effect on the schedule for the ACD and possibly the submittal of the license application. Milestone Z810 for this study is also an ACD milestone (Table 5-3). Delays in this milestone for this study could affect ACD.

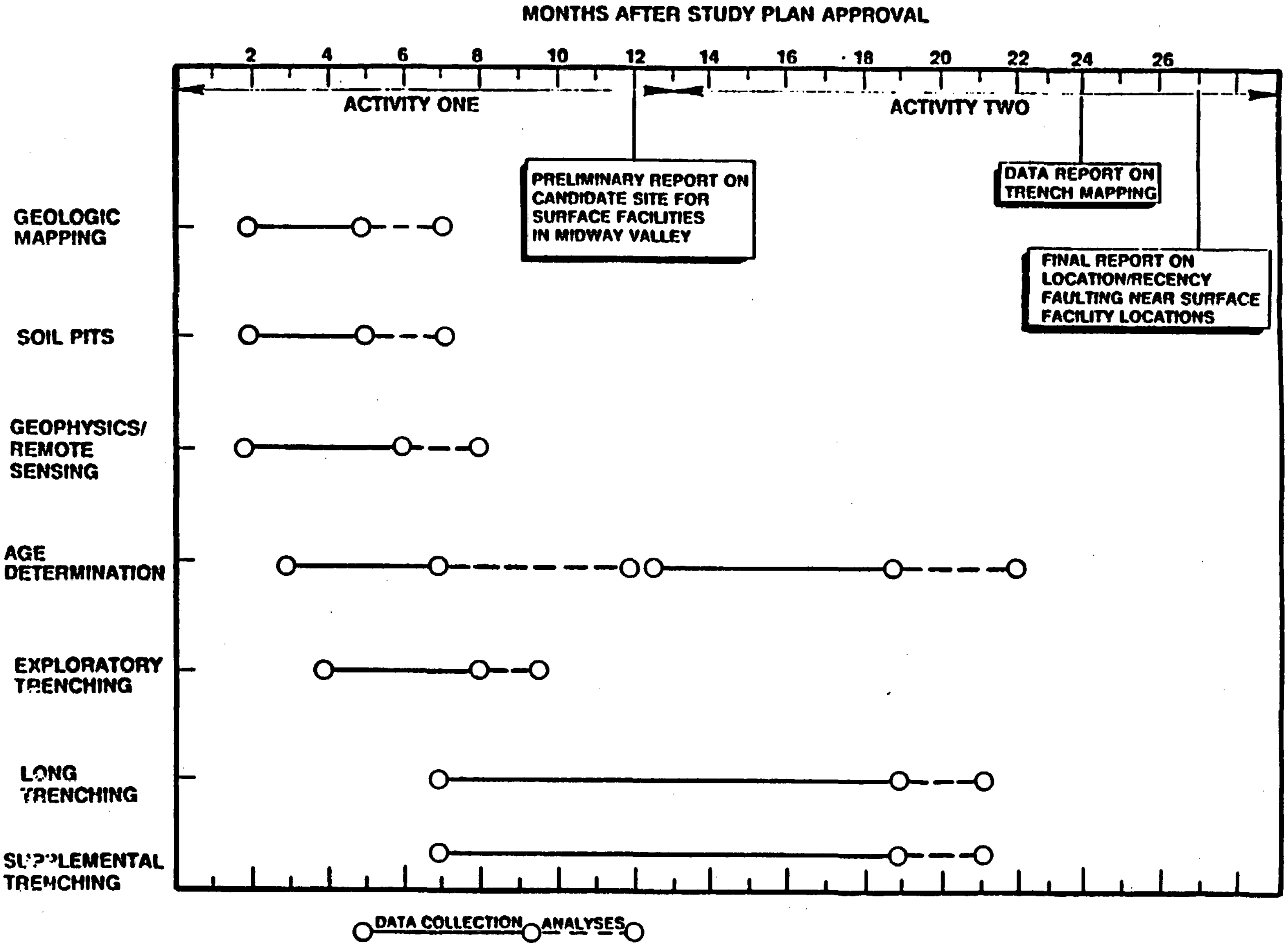

Figure 5-1. Schedule of major tasks and activities for the study to evaluate the location and recency of faulting near prospective surface facilities.

5.3 Schedule

The schedule for the tasks of this study (Tables 5-1 and 5-2 and Figure 5-1) is based on approval of the study plan and completion of relevant procedures at least 60 days before the start of work. Delays related to the approval of the study plan will have a commensurate effect on the tasks planned. The major milestones for this study plan are summarized in Table 5-3. These schedules do not directly correspond with the SCP schedule (SCP Table 8.3.1.17-11). The major events for this study listed in this SCP table do not correspond with the activities and tasks as now defined for this study.

TABLE 5-1

SCHEDULE FOR ACTIVITY 1

Task	Time Before Tasks Begins After Study Plan Approval (months)	Estimated Duration of Task (months)
Geologic Mapping	+2	+5
Soil Pits	+2	+5
Geophysics/Remote Sensing	+2	+5
Age Determination	+3	+9
Exploratory Trenching	+4	+5.5

TABLE 5-2

SCHEDULE FOR ACTIVITY 2

	Time After Study Plan Approval (months)	Estimated Duration (months)
Long Trenching	+7	+14
Supplemental Trenching	+7	+14
Age Determination	+12.5	+9.5

TABLE 5-3

SUMMARY OF STUDY PLAN MILESTONES

Milestone Number	Description
Z814	Complete Plans for Trenching and Initiate Trenching in Midway Valley
Z815	Preliminary Report on Results of Trenching in Midway Valley
Z810	Preliminary Report on the Assessment of the Potential for Faulting Near the Location of Surface Facilities for ACD
Q147	Final Report on the Assessment of the Potential for Faulting at the Site of Prospective Surface Facilities

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APPENDIX A
QUALITY ASSURANCE REQUIREMENTS

This appendix is composed of three parts. First, Table A-1 presents the applicable criteria from NQA-1 together with the procedures and other documents that implement these criteria. Second, SNL's procedures for this study are summarized in Table A-2. Third, a set of pages documenting Quality Assurance Level Assignments for the work in this study is presented.

The QALAs included in this appendix were approved in 1986 and are not completely consistent with Table A-1. At that time, the work for this study fell under WBS #123211 and included SCP Study 8.3.1.14.2.1, Soil and Rock Properties Investigations. Since that time, the work for the two studies has been divided between two WBS numbers, 1232121 for Soil and Rock Properties and 1232122 for Surface Faulting Near Prospective Surface Facilities. Revised QALAs for this Study Plan under WBS #1232122 are currently being developed using new procedures that implement NUREG-1318. When the revised QALAs are approved, they will supersede the 1986 QALAs and will be provided through controlled distribution as a revision to the Study Plan.

TABLE A-1

NQA-1 CRITERIA FOR STUDY 8.3.1.17.4.2
AND IMPLEMENTING DOCUMENTS AND PROCEDURES

NQA-1 Criteria #	Documents Addressing These Requirements
1. "Organization"	The organization of the OCRWM program is described in the Mission Plan (DOE/RW-005, June 1985) and further described in section 8.6 of the Site Characterization Plan (SCP) (DOE, 1988).
2. "QA Program"	The Quality Assurance Programs for the OCRWM are described in NNWSI/88-9, and OCR/B3, for the Project Office and Headquarters, respectively. The SNL QA Program is outlined in the Sandia National Laboratories Quality Assurance

TABLE A-1

NQA-1 CRITERIA FOR STUDY 8.3.1.17.4.2
AND IMPLEMENTING DOCUMENTS AND PROCEDURES
(continued)

NQA-1 Criteria #	Documents Addressing These Requirements
	Program Plan (SLTR 86-0001) and includes a program description addressing each of the NQA-1 criteria. Each of these QA programs contains Quality Assurance Procedures and Department Operating Procedures that further define the program requirements. An overall description of the QA Program for site characterization activities is found in section 8.6 of the SCP. SNL documents related to the QA program include: - QAP 1-3 Quality-Related Work Stoppage - QAP 2-3 Quality Assurance Level Assignment and Work Plans - QAP 2-5 Training and Familiarization Procedures - DOP 2-6 Qualification and Certification of Project Personnel
3. "Design and Scientific Investigation Control"	Since this study is a scientific investigation, the following QA implementing procedures apply: - DOP 2-2 Study Plan Requirements - QAP 2-3 Quality Assurance Level Assignment and Work Plans - QAP 2-5 Training and Familiarization Procedures - DOP 3-7 Technical Data Base - DOP 3-8 Reference Information Base Change Control - DOP 3-11 Requirements for Submitting Data to the NNWSI Project Site and Engineering Properties Data Base (SEPDB)

TABLE A-1

NQA-1 CRITERIA FOR STUDY 8.3.1.17.4.2
AND IMPLEMENTING DOCUMENTS AND PROCEDURES
(continued)

NQA-1 Criteria #	Documents Addressing These Requirements
	- DOP 11-1 Experiment and Equipment-Test Procedure Requirements
	- DOP 11-2 Requirements for Experiment and Equipment-Test Logbooks
4. "Procurement Document Control"	- DOP 4-1 Procurement Document Requirements
	- DOP 7-1 Procurement Planning (supersedes EPI IV-2)
5. "Instructions, Procedures, and Drawings"	The activities in this study are performed according to the Experiment Technical Procedures described in this Study Plan and the QA administrative procedures referenced in this table for criterion #3.
	- DOP 5-1 Procedure Format and Content Requirements
	- DOP 5-2 Technical Procedure Requirements
6. "Document Control"	- DOP 6-1 Document Control System Procedures
	- DOP 6-2 Reviewing, Approving, and Issuing Technical Information Documents
7. "Control of Purchased Material, Equipment, and Services"	- DOP 7-2 Evaluation for Acceptance of Purchased Items or Services
8. "Identification and Control of Materials, Parts, and Samples"	- DOP 8-1 Sample Identification and Handling Requirements
	- DOP 8-2 Operation of the SNL NNWSI Project Samples Library

TABLE A-1

NQA-1 CRITERIA FOR STUDY 8.3.1.17.4.2
AND IMPLEMENTING DOCUMENTS AND PROCEDURES
(concluded)

NQA-1 Criteria #	Documents Addressing These Requirements
	- DOP 13-1 Identification, Handling, Shipping, and Storage Procedures for Items and Materials
9. "Control of Special" Processes	Not applicable to this study since no special processes in the sense intended by NQA-1 are involved in this study.
10. "Inspection"	- QAP 10-1 Surveillance Requirements
11. "Test Control"	Not applicable to this study.
12. "Control of Measuring and Test Equipment"	- DOP 12-1 Measuring and Test Equipment Control
13. "Handling, Storage, and Shipping"	- DOP 8-1 Sample Identification and Handling Requirements
	- DOP 13-1 Identification, Handling, Shipping, and Storage Procedures for Items and Materials
14. "Inspection, Text and Operating Status"	Not applicable to this activity since no hardware is generated by this activity
15. "Nonconforming Materials, Parts or Components"	- DOP 7-2 Evaluation for Acceptance of Purchased Items or Services
16. "Corrective Action"	- QAP 16-1 Corrective Action Reporting
17. "Quality Assurance Records"	- DOP 11-3 Requirements for Interaction with the Data Records Management System
	- DOP 17-1 Records Management System
	- DOP 17-2 Operation of the SNL NNWSI Project Data Records Management System (DRMS)
18. "Audits"	- QAP 10-1 Surveillance Requirements
	- QAP [illegible]-1 Quality Assurance Auditing Procedures

TABLE A-2

SNL DOCUMENTS RELATED TO QUALITY ASSURANCE
FOR THIS STUDY PLAN

Abbreviation	Title
DOP 2-2	Study Plan Requirements
DOP 2-6	Qualification and Certification of Project Personnel
DOP 3-7	Technical Data Base
DOP 3-8	Reference Information Base Change Control
DOP 3-11	Requirements for Submitting Data to the NNWSI Project Site and Engineering Properties Data Base (SEPDB)
DOP 4-1	Procurement Document Requirements
DOP 5-1	Procedure Format and Content Requirements
DOP 5-2	Technical Procedure Requirements
DOP 6-1	Document Control System Procedures
DOP 6-2	Reviewing, Approving, and Issuing Technical Information Documents
DOP 7-1	Procurement Planning (supersedes EPI IV-2)
DOP 7-2	Evaluation for Acceptance of Purchased Items or Services
DOP 8-1	Sample Identification and Handling Requirements
DOP 8-2	Operation of the SNL NNWSI Project Samples Library
DOP 11-1	Experiment and Equipment-Test Procedure Requirements
DOP 11-2	Requirements for Experiment and Equipment-Test Logbooks
DOP 11-3	Requirements for Interaction with the Data Records Management System
DOP 12-1	Measuring and Test Equipment Control
DOP 13-1	Identification, Handling, Shipping, and Storage Procedures for Items and Materials
DOP 17-1	Records Management System
DOP 17-2	Operation of the SNL NNWSI Project Data Records Management System (DRMS)
QAP 1-3	Quality-Related Work Stoppages
QAP 2-3	Quality Assurance Level Assignment and Work Plans
QAP 2-5	Training and Familiarization Procedures
QAP 10-1	Surveillance Requirements
QAP 16-1	Corrective Action Reporting
QAP 18-1	Quality Assurance Auditing Procedures

NNWSI QUALITY ASSURANCE LEVEL ASSIGNMENT

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Rev. B
Page 1 of 1

APPROVALS (Signature and Date)

PI James G. Neal 10 Sept 86
PQA Connie Chavez 9/12/86
Supervisor Leo W Scully 12 Sept 1986
TPO Thomas O. Hunter 9/12/86
WMPO (PQM) James Blaylock 9/12/86
WMPO (Tech) Maxwell Blanchard 9-14-86

Activity: A. Site Data for Surface Facilities

Task Description	QA Level	QA Criteria	Level Justification
A.1. Surface geologic mapping	I	1-8, 10-18	QA Level I applies becaus the activity is in dire support of selecting the trench locations for Task A.2 and subsequently for use in LAD (Step 4).
A.2. Trenching for waste handling facilities (surface rupture)	I	1-8, 10-18	QA Level I applies because the activity generates data which will be used for LAD and subsequently may support the license application (Step 4).
A.3. Trench Wall Mapping Across Faults (ground motion)	I	1-8, 10-18	QA Level I applies because the activity generates data which will be used for LAD and subsequently may support the license application (Step 4).
A.4. Soil properties, hydrographic data	I	1-8 10-18	QA Level I applies because this activity generates data which will be used for LAD and subsequently may support the license application (Step 4).

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Activity: A. Site Data for Surface Facilities

Task: A.1. Surface Geologic Mapping PI J. T. Neal

QA Criterion	Applies	Does Not Apply	Comments
1. QA Organization	X		
2. QA Program	X		
3. Design & Scientific Investigation Control	X		Scientific investigation requirements apply.
4. Procurement Document Control	X		
5. Instructions Procedures & Drawings	X		
6. Document Control	X		
7. Control of Purchased Material, Equipment, and Services	X		
8. ID and Control of Materials, Parts, Components and Samples	X		
9. Control of Processes		X	No special processes
10. Inspection	X		Applies to surveillance only.
11. Test and Experiment/ Research Control	X		
12. Control of Measuring and Test Equipment	X		
13. Handling, Shipping, and Storage	X		
14. Inspection, Test, and Operating Status	X		
15. Control of Nonconformances	X		
16. Corrective Action	X		
17. QA Records	X		
18. QA Audits	X		

QUALITY LEVEL ASSIGNMENT CRITERIA SHEET

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Activity: A. Site Data for Surface Facilities

Task: A.2. Trenching for Waste-Handling Facilities (surface rupture) PI J. T. Neal

QA Criterion	Applies	Does Not Apply	Comments
1. QA Organization	X		
2. QA Program	X		
3. Design & Scientific Investigation Control	X		Scientific investigation requirements apply.
4. Procurement Document Control	X		
5. Instructions Procedures & Drawings	X		
6. Document Control	X		
7. Control of Purchased Material, Equipment, and Services	X		
8. ID and Control of Materials, Parts, Components and Samples	X		
9. Control of Processes		X	No special processes.
10. Inspection	X		Applies to surveillance only.
11. Test and Experiment/ Research Control	X		
12. Control of Measuring and Test Equipment	X		
13. Handling, Shipping, and Storage	X		
14. Inspection, Test, and Operating Status	X		
15. Control of Nonconformances	X		
16. Corrective Action	X		
17. QA Records	X		
18. QA Audits	X		

QUALITY LEVEL ASSIGNMENT CRITERIA SHEET

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Activity: A. Site Data for Surface Facilities

Task: A.3. Trenching Wall Mapping Across Faults (ground motion) PI J. T. Neal

QA Criterion	Applies	Does Not Apply	Comments
1. QA Organization	X		
2. QA Program	X		
3. Design & Scientific Investigation Control	X		Scientific investigation requirements apply.
4. Procurement Document Control	X		
5. Instructions Procedures & Drawings	X		
6. Document Control	X		
7. Control of Purchased Material, Equipment, and Services	X		
8. ID and Control of Materials, Parts, Components and Samples	X		
9. Control of Processes		X	No special processes.
10. Inspection	X		Applies to surveillance only.
11. Test and Experiment/ Research Control	X		
12. Control of Measuring and Test Equipment	X		
13. Handling, Shipping, and Storage	X		
14. Inspection, Test, and Operating Status	X		
15. Control of Nonconformances	X		
16. Corrective Action	X		
17. QA Records	X		
18. QA Audits	X		

QUALITY LEVEL ASSIGNMENT CRITERIA SHEET

No. 123211-86 QALAS No. 062
Rev. B Rev. B

Activity: A. Site Data for Surface Facilities

Task: A.4. Soil Properties, Hydrographic Data PI J. T. Neal

QA Criterion	Applies	Does Not Apply	Comments
1. QA Organization	X		
2. QA Program	X		
3. Design & Scientific Investigation Control	X		Scientific investigation requirements apply.
4. Procurement Document Control	X		
5. Instructions Procedures & Drawings	X		
6. Document Control	X		
7. Control of Purchased Material, Equipment, and Services	X		
8. ID and Control of Materials, Parts, Components and Samples	X		
9. Control of Processes		X	No special processes
10. Inspection	X		Applies to surveillance only.
11. Test and Experiment/ Research Control	X		
12. Control of Measuring and Test Equipment	X		
13. Handling, Shipping, and Storage	X		
14. Inspection, Test, and Operating Status	X		
15. Control of Nonconformances	X		
16. Corrective Action	X		
17. QA Records	X		
18. QA Audits	X		

NNWSI QUALITY ASSURANCE LEVEL ASSIGNMENT SNL-QA-00

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Rev. B
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APPROVALS (Signature and Date)

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Supervisor [signature] 8/19/86
WMPO (PQM) [signature] 9/12/86

PQA [signature] 8/19/86
TPO [signature] 8/19/86
WMPO (Tech) [signature] 9-14-86

Activity: B. Field Support

Task Description	QA Level	QA Criteria	Level Justification
B. Same as Activity	III	* 1-7, 10, 11, 15-18	QA Level III is assigned because field support activities do not affect the quality of the site data for surface facilities (Steps 1-11 do not apply).

* QA LEVEL III CRITERIA FOR SNL USE ONLY

QUALITY LEVEL ASSIGNMENT CRITERIA SHEET
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Activity: B. Field Support

Task: B. Same as Activity PI J. T. Neal

QA Criterion	Applies	Does Not Apply	Comments
1. QA Organization	X		
2. QA Program	X		
3. Design & Scientific Investigation Control	X		Adherence to test plan and procedures required.
4. Procurement Document Control	X		
5. Instructions Procedures & Drawings	X		
6. Document Control	X		
7. Control of Purchased Material, Equipment, and Services	X		
8. ID and Control of Materials, Parts, Components and Samples		X	No hardware or samples
9. Control of Processes		X	No special processes
10. Inspection	X		Applies to surveillance only.
11. Test and Experiment/ Research Control	X		Applies only to meeting prerequisites prior to mapping
12. Control of Measuring and Test Equipment		X	Measuring and test equipment not requ[illegible]
13. Handling, Shipping, and Storage		X	Test equipment and samples not involved
14. Inspection, Test, and Operating Status		X	Inspection and testing no involved
15. Control of Nonconformances	X		
16. Corrective Action	X		
17. QA Records	X		
18. QA Audits	X		

Study Plan for
Study 8.3.1.5.2.1

Characterization of the Yucca Mountain Quaternary Regional Hydrology

Revision 0

June 1989

U.S. Department of Energy
Office of Civilian Radioactive Waste Management
Washington, DC 20585

Prepared by
U.S. Geological Survey

YUCCA MOUNTAIN PROJECT
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