Department of Energy
Washington, DC 20585

AUG 28 1987

Robert Browning, Director
Division of High-Level Waste Management
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Mr. Browning:

In response to NRC's request, and as discussed by our staffs, we are scheduling a meeting with representatives of your division on the Nevada Nuclear Waste Storage Investigation (NNWSI) seismic-tectonic site characterization plan strategies. This meeting will be held on September 22 and 23, 1987 beginning at 8:30 am.

The meeting will be held in Las Vegas, Nevada at the Science Applications International Corporation offices in the Valley Bank Center at 101 Convention Center Drive, Suite 407. The objective of this interaction is for DOE to provide a briefing to NRC on the technical basis for the NNWSI Project approach to resolving licensing issues that require seismic-tectonic data. By copy of this letter we are inviting interested representatives from States and Indian Tribes to participate.

As background for the briefing we recommend that participants review the attached copy of the overviews and investigation descriptions of the preclosure and postclosure tectonics program sections of the SCP.

A draft agenda for the briefing is also attached. If the participating groups have any specific requests regarding the

1462

agenda, we will do our best to accommodate them provided such requests are received by September 15, 1987. The point of contact for this meeting is Mr. Edward Regnier (202-586-4959/FTS 896-4959).

Sincerely,

James P. Knight, Director
Siting, Licensing and Quality
Assurance Division, Office of
Civilian Radioactive Waste Management

Attachments:
Draft SCP Tectonics Sections
Draft Meeting Agenda

cc: M. Kunich
J. Anttonen
J. Neff
D. Dawson, SAIC
J. Leahy (20 copies)

102.8

PDR-1
LPDR-Wm-11
(2)

WM DOCKET CONTROL
CENTER

'87 SEP -3 P2:44

WM Record File
102.8

WM Project 11
Docket No.
× PDR ✓ (N)
LPDR ✓

Distribution:
×PEB ×MJB ×Still
×Stablein ×Youngblood
(Return to WM, 623-SS)

JCF

1462

MEETING ON NEVADA NUCLEAR WASTE STORAGE INVESTIGATION
SEISMIC-TECTONIC SITE CHARACTERIZATION PLAN STRATEGIES

Las Vegas, Nevada
September 22 and 23, 1987

Agenda

Objective of the meeting

The objective of this activity is for DOE to provide a briefing to NRC on the technical basis for the NNWSI Project approach to resolving licensing issues that require seismic/tectonic data. It is not the purpose of this meeting to engage in substantive technical discussion on issues. Those items are to be the subject of a seismic/tectonic meeting to be held later.

September 22, 1987

I.	Introduction	DOE (20 minutes)
	A. Welcome and introduction of participants	
	B. Objectives of the Briefing	
	C. Status and schedule of site characterization activities	
	D. Introduction of topics and speakers	
	E. Comments from NRC/State on Agenda	NRC/State
II.	Site Characterization Overview	DOE (1 hour)
	A. Requirements imposed by the regulations	
	B. Compliance with the regulations	
	— Open Time (Caucus)--	All (30 minutes)
	-- Discussion and Comments	All (1 hour)
III.	Geologic Setting of Yucca Mountain	DOE (1 hour)
	A. Geologic overview	
	B. Neotectonic deformation	
	C. State of Stress	

D. Tectonic models and their relationship to the site

-- Discussion and Comments-- All (1 hour)

-- Open Time (Caucus)-- All (30 minutes)

IV. Site Characterization Plan for Preclosure Tectonics — DOE (1 hour)

A. Scope and organization of preclosure tectonics site investigations

B. Faulting (surface and underground)

C. Ground motion (surface and underground)

D. Volcanic ash fall

-- Discussion and Comments-- All (1 hour)

September 23, 1987

V. Site Characterization Plan for Postclosure Tectonics — DOE (1 hour)

A. Scope and organization of postclosure tectonics

B. Disruption o' the repository by volcanic eruptions

C. Disruption of waste packages by faulting

D. Changes in ground-water conditions due to tectonic processes and events

— Discussion and Comment-- All (1 hour)

-- Open Time (Caucus) All (30 minutes)

VI. Conclusion — DOE (20 minutes)

A. Synopsis of presentations

B. Restatement of purpose of presentations

C. Future NRC-DOE interactions relating to tectonics

8.3.1.8 Overview of the/tectonics program: Description of future tectonic processes and events required by the performance and design issues

8.3.1.8.1 Investigation: Studies to provide information required on direct releases resulting from volcanic activity

8.3.1.8.1.1 Study: Probability of a volcanic eruption penetrating the repository

8.3.1.8.1.1.1 Activity: Location and timing of volcanic events

8.3.1.8.1.1.2 Activity: Evaluation of the structural controls of basaltic volcanic activity

8.3.1.8.1.1.3 Activity: Presence of magma bodies in the vicinity of the site

8.3.1.8.1.1.4 Activity: Probability calculations and assessment

8.3.1.8.1.2 Study: Effects of a volcanic eruption penetrating the repository

8.3.1.8.1.2.1 Activity: Effects of strombolian eruptions

8.3.1.8.1.2.2 Activity: Effects of hydrovolcanic eruptions

8.3.1 8.1.3 Application of results

8.3.1.8.1.4 Schedule and milestones

8.3.1.8.2 Investigation: Studies to provide information required on rupture of waste packages due to tectonic events

8.3.1.8.2.1 Study: Analysis of waste package rupture due to tectonic processes and events

8.3.1.8.2.1.1 Activity: Assessment of waste package rupture due to igneous intrusion

8.3.1.8.2.1.2 Activity: Calculation of the number of waste packages intersected by a fault

8.3.1.8.2.1.3 Activity: Probability and rate of faulting

8.3.1.8.2.1.4 Activity: Assessment of waste package rupture due to faulting

8.3.1.8.2.1.5 Activity: Assessment of postclosure ground motion in the subsurface

8.3.1.8.2.1.6 Activity: Nature, age, and rate of folding and deformation in the repository horizon

8.3.1.8.2.1.7 Activity: Assessment of waste package rupture due to folding and deformation

8.3.1.8.2.2 Application of results

8.3.1.8.2.3 Schedule and milestones

8.3.1.8.3 Investigation: Studies to provide information required on changes in unsaturated and saturated zone hydrology due to tectonic events

8.3.1.8.3.1 Study: Analysis of the effects of tectonic processes events on average percolation flux rates over the repository

8.3.1.8.3.1.1 Activity: Annual probability of volcanic or igneous events in the controlled area

8.3.1.8.3.1.2 Activity: Assessment of the effects of igneous intrusions and volcanic events on flux rates

8.3.1.8.3.1.3 Activity: Faulting rates, recurrence intervals, and probable cumulative offset in 10,000 yr

8.3.1.8.3.1.4 Activity: Effects of faulting on average flux rates
8.3.1.8.3.1.5 Activity: Assessment of the effects of faulting on flux rates
8.3.1.8.3.1.6 Activity: Uplift rates in the controlled area
8.3.1.8.3.1.7 Activity: Assessment of the effects of folding, uplift, and subsidence on flux rates
8.3.1.8.3.2 Study: Analysis of the effect of tectonic processes and events on changes in water-table altitude
8.3.1.8.3.2.1 Activity: Thermal and barrier-to-flow effects of igneous intrusions on water-table altitudes
8.3.1.8.3.2.2 Activity: Assessment of the effects of igneous intrusions on water-table levels
8.3.1.8.3.2.3 Activity: Assessment of the effect of strain changes on water-table altitude
8.3.1.8.3.2.4 Activity: Assessment of the effect of folding, uplift, or subsidence on water-table altitude
8.3.1.8.3.2.5 Activity: Effects of faulting on water-table altitudes
8.3.1.8.3.2.6 Activity: Assessment of the effects of faulting on water-table altitude
8.3.1.8.3.3 Study: Analysis of the effects of tectonic processes and events on local fracture permeability and effective porosity
8.3.1.8.3.3.1 Activity: Assessment of the effects of igneous intrusions on local fracture permeability and effective porosities
8.3.1.8.3.3.2 Activity: Assessment of the effects of faulting on local fracture permeability and effective porosities
8.3.1.8.3.3.3 Activity: Assessment of the effects of stress or strain on hydrologic properties of the rock mass
8.3.1.8.3.4 Application of results
8.3.1.8.3.5 Schedule and milestones
8.3.1.8.4 Investigation: Studies to provide information required on changes in rock geochemical properties resulting from tectonic processes
8.3.1.8.4.1 Study: Analysis of the effects of tectonic processes and events on rock geochemical properties
8.3.1.8.4.1.1 Activity: Assessment of the change in rock geochemical properties due to igneous intrusions
8.3.1.8.4.1.2 Activity: Assessment of the degree of mineralogic change along fault zones in 10,000 yr
8.3.1.8.4.1.3 Activity: Assessment of the effects of fault offset on travel pathway
8.3.1.8.4.1.4 Activity: Assessment of the degree of mineralogic change in the controlled area resulting from tectonic change in water-table levels

8.3.1.8.4.2 Application of results
8.3.1.8.4.3 Schedule and milestones
8.3.1.8.5 Investigation: Studies to provide information required by the analysis and assessment investigations of the tectonics program
8.3.1.8.5.1 Study: Characterization of volcanic features
8.3.1.8.5.1.1 Activity: Volcanism drillholes
8.3.1.8.5.1.2 Activity: Geochronology studies
8.3.1.8.5.1.3 Activity: Field geologic studies
8.3.1.8.5.1.4 Activity: Geochemistry of scoria sequences
8.3.1.8.5.1.5 Activity: Geochemical cycles of basaltic volcanic fields
8.3.1.8.5.2 Study: Characterization of igneous intrusive features
8.3.1.8.5.2.1 Activity: Evaluation of depth of curie temperature isotherm
8.3.1.8.5.2.2 Activity: Chemical and physical changes around dikes
8.3.1.8.5.2.3 Activity: Heat flow at Yucca Mountain and evaluation of regional ambient heat flow and local heat flow anomalies
8.3.1.8.5.3 Study: Investigation of folds in Miocene and younger rocks of region
8.3.1.8.5.3.1 Activity: Evaluation of folds in Neogene rocks of the region
8.3.1.8.5.4 Application of results
8.3.1.8.5.5 Schedule and milestones
8.3.1.17 Overview of preclosure tectonics: Description of tectonic and igneous events required by performance and design requirements
8.3.1.17.1 Investigation: Studies to provide information on volcanic activity that could affect repository design or performance
8.3.1.17.1.1 Study: Potential for ash fall at the site
8.3.1.17.1.1.1 Activity: Survey literature regarding Quaternary silicic volcanic centers in the western Great Basin
8.3.1.17.1.1.2 Activity: Assess potential ash-fall thickness at the site
8.3.1.17.1.1.3 Activity: Assess potential particle density and size distribution of ash-fall at the site
8.3.1.17.1.2 Application of results
8.3.1.17.1.3 Schedule and milestones
8.3.1.17.2 Investigation: Studies to provide information on fault displacement that could affect repository design or performance
8.3.1.17.2.1 Study: Faulting potential at the repository
8.3.1.17.2.1.1 Activity: Assess the potential for surface faulting at prospective sites of surface facilities that are important to safety

8.3.1.17.2.1.2 Activity: Assess the potential for displacement on faults that intersect underground facilities
8.3.1.17.2.2 Application of results
8.3.1.17.2.3 Schedule and milestones
8.3.1.17.3 Investigation: Studies to provide required information on vibratory ground motion that could affect repository design or performance
8.3.1.17.3.1 Study: Relevant earthquake sources
8.3.1.17.3.1.1 Activity: Identify relevant earthquake sources
8.3.1.17.3.1.2 Activity: Characterize exceptional earthquakes for relevant seismogenic sources
8.3.1.17.3.2 Study: Underground nuclear explosion (UNE) sources
8.3.1.17.3.2.1 Activity: Determine the range of UNE sources
8.3.1.17.3.2.2 Activity: Determine maximum UNE source(s)
8.3.1.17.3.3 Study: Ground motion from regional earthquakes and UNEs
8.3.1.17.3.3.1 Activity: Select or develop empirical models for earthquake ground motions
8.3.1.17.3.3.2 Activity: Select or develop empirical models for UNEs
8.3.1.17.3.4 Study: Effects of local site geology on surface and subsurface motions
8.3.1.17.3.4.1 Activity: Determine site effects from ground-motion recordings
8.3.1.17.3.4.2 Activity: Model site effects using the wave properties of the local geology
8.3.1.17.3.5 Study: Ground motion at the site from controlling seismic events
8.3.1.17.3.5.1 Activity: Identify controlling seismic events
8.3.1.17.3.5.2 Activity: Characterize ground motion from the controlling seismic events
8.3.1.17.3.6 Study: Probabilistic seismic hazards analyses
8.3.1.17.3.6.1 Activity: Evaluate earthquake sources
8.3.1.17.3.6.2 Activity: Evaluate ground motion probabilities
8.3.1.17.3.7 Application of results
8.3.1.17.3.8 Schedule and milestones
8.3.1.17.4 Investigation: Preclosure tectonics data collection and analysis
8.3.1.17.4.1 Study: Historical and current seismicity
8.3.1.17.4.1.1 Activity: Compile historical earthquake record

8.3.1.17.4.1.2 Activity: Monitor current seismicity
8.3.1.17.4.1.3 Activity: Evaluate potential for induced seismicity at the site
8.3.1.17.4.2 Study: Location and recency of faulting potential near prospective surface facilities
8.3.1.17.4.2.1 Activity: Identify appropriate trench locations in Midway Valley
8.3.1.17.4.2.2 Activity: Conduct exploratory trenching in Midway Valley
8.3.1.17.4.3 Study: Quaternary faulting within 100 km of Yucca Mountain, including the Walker Zone
8.3.1.17.4.3.1 Activity: Evaluate crustal structure and subsurface expression of Quaternary faults in an east-west transect crossing the Furnace Creek fault zone, Yucca Mountain, and the Walker Lane
8.3.1.17.4.3.2 Activity: Evaluate Quaternary faults within 100 km of Yucca Mountain
8.3.1.17.4.3.3 Activity: Evaluate the Cedar Mountain earthquake of 1933 and its bearing on wrench tectonics of the Walker Lane within 100 km of the site
8.3.1.17.4.3.4 Activity: Evaluate the Bare Mountain fault zone
8.3.1.17.4.3.5 Activity: Evaluate structural domains and characterize the Yucca Mountain region with respect to regional patterns of faults and fractures
8.3.1.17.4.4 Study: Quaternary faulting proximal to the site within northeast-trending fault zones
8.3.1.17.4.4.1 Activity: Evaluate the Rock Valley fault system
8.3.1.17.4.4.2 Activity: Evaluate the Mine Mountain fault system
.3.1.17.4.4.3 Activity: Evaluate the Stagecoach Road fault zone
8.3.1.17.4.4.4 Activity: Evaluate the Cane Spring fault system
8.3.1.17.4.5 Study: Detachment faults at or proximal to Yucca Mountain
8.3.1.17.4.5.1 Activity: Evaluate the significance of the Miocene-Paleozoic contact in the Calico Hills area to detachment faulting within the site area
8.3.1.17.4.5.2 Activity: Evaluate postulated detachment faults in the Beatty-Bare Mountain area
8.3.1.17.4.5.3 Activity: Evaluate the potential relationship of megabreccia within and south of Crater Flat to detachment faulting

8.3.1.17.4.5.4 Activity: Evaluate postulated detachment faults in the Specter Range and Camp Desert Rock areas

8.3.1.17.4.5.5 Activity: Evaluate the age of detachment faults using radiometric ages

8.3.1.17.4.6 Study: Quaternary faulting within the site area

8.3.1.17.4.6.1 Activity: Evaluate Quaternary geology and potential Quaternary faults at Yucca Mountain

8.3.1.17.4.6.2 Activity: Evaluate of age and recurrence of movement on suspected and known Quaternary faults

8.3.1.17.4.7 Study: Subsurface geometry and concealed extensions of Quaternary faults at Yucca Mountain

8.3.1.17.4.7.1 Activity: Evaluate intermediate depth (to 2 to 3 km) reflection and refraction methods and plan potential application of these methods within the site area

8.3.1.17.4.7.2 Activity: Detailed gravity survey of the site area

8.3.1.17.4.7.3 Activity: Detailed aeromagnetic survey of the site area

8.3.1.17.4.7.4 Activity: Detailed ground magnetic survey of specific features within the site area

8.3.1.17.4.7.5 Activity: Evaluate surface geoelectric methods and plan potential applications of these methods within the site area

8.3.1.17.4.7.6 Activity: Evaluate methods to detect buried faults using gamma ray measurements, and plan potential application of these methods within the site area

8.3.1.17.4.7.7 Activity: Evaluate thermal infrared methods and plan potential applications of these methods within the site area

8.3.1.17.4.7.8 Activity: Evaluate shallow seismic reflection (mini-sosie) methods and if appropriate conduct surveys of selected structures at and proximal to the site area

8.3.1.17.4.8 Study: Stress field within and proximal to the site area

8.3.1.17.4.8.1 Activity: Evaluate present stress field within the site area

8.3.1.17.4.8.2 Activity: Evaluate and test shallow borehole hydrofrac and triaxial strain recovery methods for the determination of in situ stress, and if appropriate, plan potential application of these methods within and proximal to the site

8.3.1.17.4.8.3 Activity: Evaluate published and unpublished data on paleostress orientation at and proximal to the site and assess the relevance of these data to Quaternary tectonics

8.3.1.17.4.8.4 Activity: Evaluate theoretical stress distributions associated with potential tectonic settings (wrench fault, normal fault, detachment fault setting, etc.) of the site

8.3.1.17.4.9 Study: Tectonic geomorphology of the Yucca Mountain region

8.3.1.17.4.9.1 Activity: Evaluate age and extent of tectonically stable areas at and near Yucca Mountain

8.3.1.17.4.9.2 Activity: Evaluate extent of areas of Quaternary uplift and subsidence at and near Yucca Mountain

8.3.1.17.4.9.3 Activity: Evaluate variations in the nature and intensity of Quaternary faulting within 100 km of Yucca Mountain through morphometric and morphologic analysis

8.3.1.17.4.10 Study: Geodetic leveling

8.3.1.17.4.10.1 Activity: Relevel base-station network, Yucca Mountain and vicinity

8.3.1.17.4.10.2 Activity: GPS survey selected base stations, Yucca Mountain and vicinity

8.3.1.17.4.10.3 Activity: Analyze existing releveling data, Yucca Mountain and vicinity

8.3.1.17.4.11 Study: Characterization of regional lateral crustal movement

8.3.1.17.4.11.1 Activity: Analyze lateral component of crustal movement based on historic faulting, seismicity, and trilateration surveys

8.3.1.17.4.12 Study: Tectonic models and synthesis

8.3.1.17.4.12.1 Activity: Evaluate tectonic processes and tectonic stability at the site

8.3.1.17.4.12.2 Activity: Evaluate tectonic models

8.3.1.17.4.12.3 Activity: Evaluate tectonic disruption sequences

8.3.1.17.4.13 Application of results

8.3.1.17.4.14 Schedule and milestones

DRAFT

8.3.1.8 Overview of the postclosure tectonics program: Description of future tectonic processes and events required by the performance and design issues

Summary of performance and design requirements for postclosure tectonics information

The flow of data through the postclosure tectonics program is shown in Figure 8.3.1.8-1. The performance and design requirements that the postclosure tectonics program must address are to supply data on the probability and effects of tectonic "initiating events" that may alter existing conditions at Yucca Mountain and adversely affect repository performance. These requirements for tectonic information can be summarized as follows:

1. Data on the probability and effects of potentially significant tectonic release-scenario classes addressing both anticipated and unanticipated conditions that are needed for performance assessment calculations of radionuclide releases to the accessible environment (Issue 1.1, Section 8.3.5.13, total system performance).

2. Data required to perform the analysis to determine the degree to which each of the favorable and potentially adverse conditions listed in 10 CFR 60.122 contributes to or detracts from isolation (Issue 1.8, Section 8.3.5.17, NRC siting criteria).

3. Data needed to accommodate requirements for knowledge of site-specific tectonic conditions in design concepts for the geometry, layout, and emplacement borehole locations of the underground facility (Issue 1.11, Section 8.3.2.2, configuration of underground facilities (postclosure)).

4. Data required so that the higher level findings of 10 CFR Part 960 can be evaluated (Issue 1.9, Section 8.3.5.18, higher level findings (postclosure)).

Four investigations in the postclosure tectonics program provide the analysis and assessment of data necessary to meet these requirements (Figure 8.3.1.8-1). These four investigations have been designed to parallel the intermediate performance measures and initiating events defined in Sections 8.3.5.13 and 8.3.2.2. Investigation 8.3.1.8.3 (tectonic effects on hydrology) has been further subdivided into three separate intermediate performance measures because of the number of performance parameters that have been identified by Issue 1.1 in this investigation. The final column of Figure 8.3.1.8-1 identifies the investigations that will provide data required by Investigations 8.3.1.8.1 through 8.3.1.8.4 in order to complete their analysis and assessment for the postclosure tectonics program. These data collection investigations include Investigation 8.3.1.8.5 which will house the data collecting studies and activities specific to the postclosure tectonics program and investigations from several other programs that provide important data for the analysis and assessment investigations.

Tables 8.3.1.8-1 through 8.3.1.8-6 list the favorable and potentially adverse conditions on which data is required for the resolution of Issue 1.8 and the performance measures, intermediate performance measures and

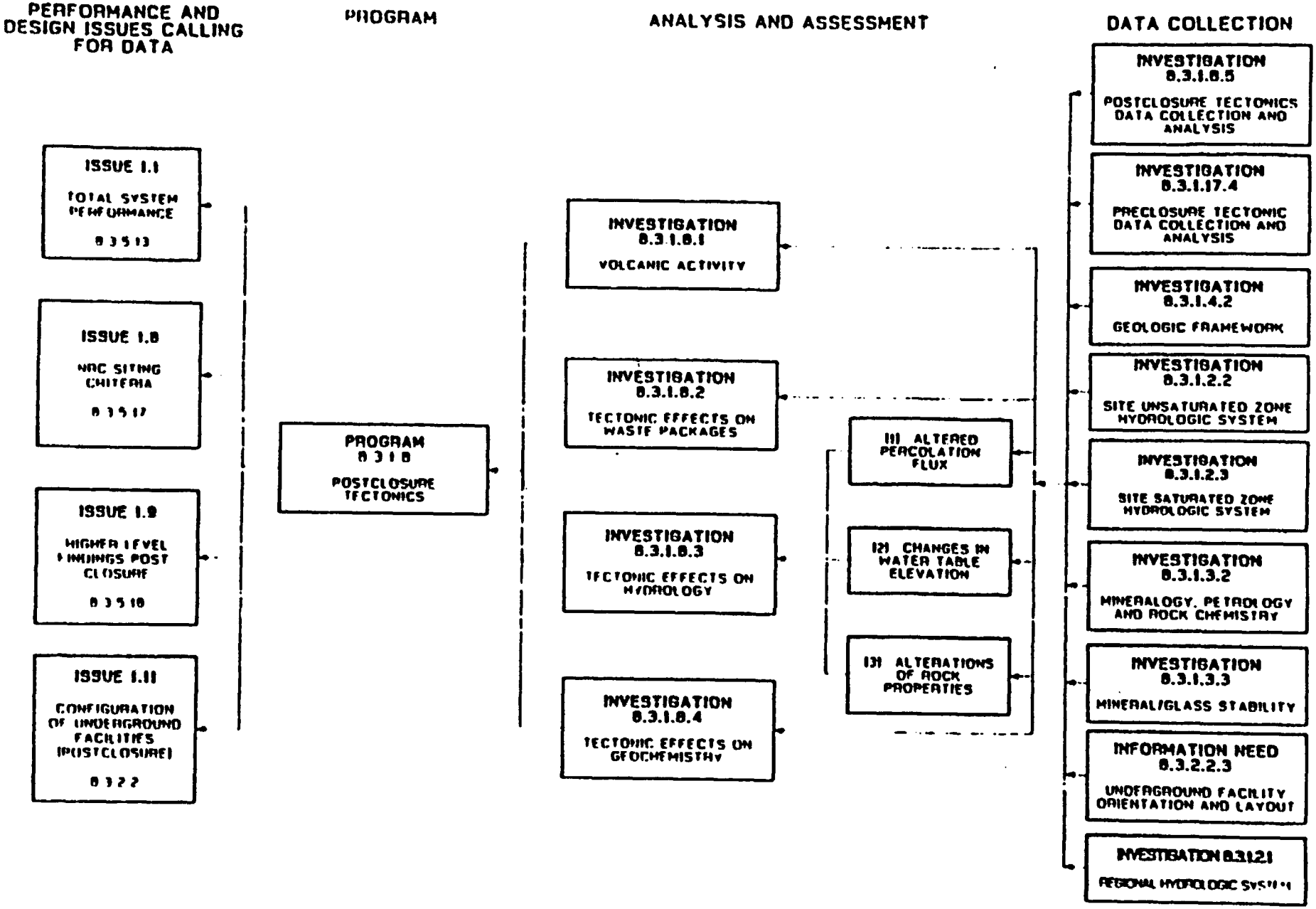


Figure 8.3.1.8-1. Relationships between the postclosure tectonics program, investigations, and performance design issues

Table 8.3.1.8 1(a). Investigation 8.3.1.8 1 Studies to provide information required on direct releases resulting from volcanic activity

SCP section requesting parameter	Potentially adverse condition addressed (10 CFR 60 122(c)) (Section 8 3 5 17)	Favorable condition addressed (10 CFR 60 122(b)) (Section 8 3 5 17)	Initiating event	Performance measure	Tentative goal	Intermediate performance parameter	Goal	Performance parameter
8 3 5 13 (Issue 1 1, total system performance)	15	1	Volcanic eruption penetrates repository and causes direct release to the accessible environment	EPPM[a]	<<1	Not applicable	--	Annual probability of volcanic eruption that penetrates the repository
8 3 5 17 (Issue 1 8, NRC siting criteria)								Effects of volcanic eruption penetrating repository, including area of repository disrupted
8 3 5 18 (Issue 1 9, higher level findings-postclosure)								

[a]EPPM = expected partial performance measure (Section 8 3 5 13)

DRAFT

Table 8.3.1.8-1(b). Investigation 8.3.1.8.1 - Studies to provide information required on direct releases resulting from volcanic activity (page 1 of 2)

Performance parameter	Tentative parameter goal	Needed confidence	Characterization parameter	Testing basis: Current estimate (range or bound)	Testing basis: Confidence in current estimate	Testing basis: Needed confidence in final values	Investigations supplying data	Key studies or activities supplying data
Annual probability of volcanic eruption that penetrates the repository	$< 10^{-6}$ per yr	High	Location and timing of volcanic events	See Section 1.3.2.1.2	Moderate	High	8.3.1.8.5	8.3.1.8.5.1.1 - Volcanics drill-holes 8.3.1.8.5.1.2 - Geochronology studies 8.3.1.8.5.1.3 - Field geologic studies 8.3.1.8.5.1.4 - Geochemistry of scoria sequences
			Evaluation of structural controls on volcanism	See Section 1.3.2.1	Low	Moderate	8.3.1.8.1	8.3.1.8.1.1.1 - Location and timing of volcanic events
							8.3.1.8.5	8.3.1.8.5.1.3 - Field geologic studies 8.3.1.8.5.1.5 - Regional geochemical evolution of the BV-PRVZ
							8.3.1.17.4	8.3.1.17.4.12.1 - Evaluate tectonic processes and tectonic stability at the site
			Presence of magma bodies in the vicinity of the site	See Section 1.3.2.1	Low	Moderate	8.3.1.17.4	8.3.1.17.4.7 - Subsurface geometry of Quaternary faults at Yucca Mountain
							8.3.1.8.5	8.3.1.8.5.2.1 - Evaluation of depth of curie temperature isotherm 8.3.1.8.5.2.3 - Heat flow at Yucca Mountain
							8.3.1.17.4	8.3.1.8.4.1.2 - Monitor current seismicity 8.3.1.17.4.3.1 - Evaluate crustal structure and subsurface expression of Quaternary faults

DRAFT

Table 8.3.1.8-1(b). Investigation 8.3.1.8.1 Studies to provide information required on direct releases resulting from volcanic activity (page 2 of 2)

Performance parameter	Tentative parameter goal	Needed confidence	Characterization parameter	Testing basis: Current estimate (range or bound)	Testing basis: Confidence in current estimate	Testing basis: Needed confidence in final values	Investigations supplying data	Key studies or activities supplying data
Effects of volcanic eruption penetrating repository, including area of repository disrupted, and confidence bounds of estimate	Show that < 0.1% of repository area is disrupted with a conditional probability of <0.1 of being exceeded in 10,000 yr, should such an intrusion occur	Moderate	Effects of Strombolian eruptions	< 0.05% of repository area disrupted	Moderate	Moderate	None planned (See Sections 8.3.2.1 and 8.5.1)	
			Effects of hydrovolcanic eruptions	Data not available	Low	Moderate	8.3.1.8.5	8.3.1.8.5.1.3 - Field geologic studies

DRAFT

Table 8.3.1.8-2(a). Investigation 8.3.1.8.2 - Studies to provide information required on rupture of waste packages due to tectonic events

SCP section requesting parameter	Potentially adverse condition addressed (10 CFR 60 122(c)) (Section 8 3 5 17)	...rable condition addressed (10 CFR 60 122(b)) (Section 8 3 5 17)	Initiating event	Performance measure	Testative goal	Intermediate performance parameter	Goal	Performance parameter
8 3 5 17 (Issue 1 8, NRC siting criteria) 8 3 2 2 (Issue 1 11, config uration of underground facilities-postclosure)	15	1	Igneous intrusion penetrating repository resulting in failure of waste packages	Usable area: is usable area adequate for 70,000 MTU of waste?	Probability < 0 1 in 1,000 yr that > 0.5% of waste packages will be ruptured by tectonic processes or events	Not applicable	Not applicable	Probability of igneous intrusion penetrating repository Effects of igneous intrusion penetrating repository
8 3 5 18 (Issue 1 9, higher level findings postclosure)	11	1	Effect of one or more faults intersect waste packages and cause failure	Usable area: is usable area adequate for 70,000 MTU of waste?	Probability < 0 1 in 1,000 yr that > 0.5% of waste packages will be ruptured by tectonic processes or events	Not applicable	Not applicable	Number of waste packages affected by fault penetrating repository Probability of faulting with displacement over 5 cm in repository
	12 13 14	1	Ground motion causes spalling or failure and closes air gap around waste package	Usable area: is usable area adequate for 70,000 MTU of waste?	Placement of waste packages in zones with rock properties that will not lead to failure during expected ground motions	Not applicable	Not applicable	Expected ground motion at emplacement boreholes in 1,000 yr period
	11	1	Folding or distributed shear causes waste emplacement borehole deformation and results in waste package failure	Usable area is usable area adequate for 70,000 MTU of waste?	Probability < 0 1 in 1,000 yr that >0 5% of waste packages will be ruptured by tectonic processes or events	Not applicable	Not applicable	Rate of deformation due to folding or distributed shearing in repository horizon

DRAFT

Table 8.3.1.8 2(b). Investigation 8 3.1.8.2 Studies to provide information required on rupture of waste pa:kages due to tectonic events (page 1 of 2)

Performance parameter	Tentative parameter goal	Needed confidence	Characterization parameter	Testing basis: Current estimate (range or bound)	Testing basis: Confidence in current estimate	Testing basis: Needed confidence in final values	Investigations supplying data	Key studies or activities supplying data
Probability of igneous intrusion penetrating repository	Annual probability less than 10^{-8}	High	Characterization parameters identical to Investigation 8 3.1.8.1	10^{-9} to 10^{-10}	Moderate	High	8.3.1.8.1	8.3.1.8.1.1.4 Probability calculations and assessment
Effects of igneous intrusion penetrating repository	Less than 0.5% of waste packages disrupted	Low	Number of waste packages disrupted by intrusion	1 to 10	Moderate	Moderate	8.3.1.8.1	8.3.1.8.1.2.1 - Effects of Strombolian eruptions
							8.3.2.2.3	8.3.2.2.3 - Design concepts for the underground facility
Number of waste packages affected by fault penetrating repository	Less than 0.5% of waste packages intersected by a single fault with a 95% level of confidence	High	Width of Quaternary fault zones in and near site in which faulting exceeds 5 cm in a single event	< 5 m	Low	Moderate	8.3.1.17.4	8.3.1.17.4.2.2 - Conduct exploratory trenching in Midway Valley 8.3.1.17.4.5.2 - Evaluate age and recurrence of movement on suspected and known Quaternary faults
			Orientation of faults in and near the repository block	N 25.8 W 8.25 E	Moderate	Moderate	8.3.1.4.2	8.3.1.4.2.2.1 - Geologic mapping of zonal features of Paintbrush Tuff
							8.3.1.4	8.3.1.4.2.3.1 - Development of 3-D geologic model of the site area
							8.3.1.17.4	8.3.1.17.4.6.1 - Evaluate Quaternary geology and potential Quaternary faults at Yucca Mountain
			Number of waste packages affected by a fault penetrating the repository	1 to 10	Low	High	8.3.2.2.3	8.3.2.2.3 - Design concepts for the underground facility
							8.3.1.17.4	8.3.1.17.4.2.2 Conduct exploratory trenching in Midway Valley 8.3.1.17.4.6.1 Evaluate Quaternary geology and potential Quaternary faults at Yucca Mountain 8.3.1.17.4.6.2 - Evaluate age and recurrence of movement on suspected and known Quaternary faults

DRAFT

Table 8.3.1.8 2(b). Investigation 8.3.1.8.2 Studies to provide information required on rupture of waste packages due to tectonic events (page 2 of 2)

Performance parameter	Tentative parameter goal	Needed confidence	Characterization parameter	Testing basis: Current estimate (range or bound)	Testing basis: Confidence in current estimate	Testing basis: Needed confidence in final values	Investigations supplying data	Key studies or activities supplying data
Probability of faulting with displacement over 5 cm in repository	Annual probability less than 10^{-8} of faulting with displacement over 5 cm	Moderate	Characteristics of faults that penetrate the repository with total offset > 10 m				8.3.1.17.4	8.3.1.4.2 2.1 - Geologic mapping of zonal features of Paintbrush Tuff 8.3.1.2.3.1 - Development of 3-D geologic model of the site area
			Density	See Section 1.3.2.2.2	Low	Moderate	8.3.1.4.2	8.3.1.17.4.6.1 - Evaluate Quaternary geology and potential Quaternary faults at Yucca Mountain 8.3.1.17.4.6.2 - Age and recurrence of movement on suspected and known Quaternary faults
			Length	< 3000 m	Moderate	High		
			Total Offset	10-50 m	Moderate	High		
			Characteristics of Quaternary faults in and near site with slip rates > 0.001 mm/yr				8.3.1.17.4	8.3.1.17.4.6.1 - Evaluate Quaternary geology and potential Quaternary faults at Yucca Mountain 8.3.1.17.4.6.2 - Age and recurrence of movement on suspected and known Quaternary faults
			Location	See Figure 1.3.6	Moderate	High		8.3.1.17.4.12.1 - Evaluate tectonic processes and tectonic stability at the site
			Slip rate	< 0.01 mm/yr	Moderate	High		
			Length	< 35 km	Low	Moderate		
			Total offset	200-500 m	Low	High		
Expected ground motion at emplacement boreholes in 1,000 yr period	Probability of exceeding ground motion values < 0.1 in 1,000-yr	High	Characterization parameters identical to Investigation 8.3.1.17.3	Expected PGA[a] (10,000 yr return period) 0.5-0.7g	Low-moderate	Moderate	8.3.1.17.3	8.3.1.17.3.5.2 - Characterize ground motion from the controlling seismic events 8.3.1.17.3.6.2 - Evaluate ground motion probabilities
Rate of deformation due to folding or distributed shearing in repository horizon	Waste emplacement boreholes will be subject to < 0.005 shear strain in 1,000 yrs as a result of folding or deformation	Low	Nature and age of folding in the repository horizon	No detectable folding in 10 million yr	Moderate	High	8.3.1.4.2	8.3.1.4.2.2.1 - Geologic mapping of zonal features of Paintbrush Tuff
							8.3.1.4.3	8.3.1.4.2.3.1 - Development of 3-D geologic model of the site area
							8.3.1.17.4	8.3.1.17.4.12.1 - Evaluate tectonic processes and tectonic stability at the site
							8.3.1.8.2	8.3.1.8.2.1.2 - Calculation of the number of waste packages intersected by a fault

[a] PGA - Peak Ground Acceleration

Table 8.3.1.8.3(a). Investigation 8.3.1.8.3 Studies to provide information required on changes in unsaturated and saturated zone hydrology due to tectonic events (Study 1; alteration of average percolation flux) (page 1 of 2)

SCP section requesting parameter	Potentially adverse condition addressed (10 CFR 60.122(c)) (Section 8.3.5.17)	Favorable condition addressed (10 CFR 60.122(b)) (Section 8.3.5.17)	Initiating event	Performance measure	Goal	Intermediate performance measure	Goal	Performance parameter
8.3.5.13 (Issue 1.1, total system performance) 8.3.5.17 (Issue 1.6, NRC siting criteria) 8.3.5.18 (Issue 1.9, higher level findings-postclosure)	3, 15	1, 8(i)	Volcanic eruption causes flows or other changes in topography that result in impoundment or diversion of drainage	E^{PTH}[a]	<< 1	Radionuclide transport time through UZ, given fixed UZ thickness, rock hydrologic properties and geochemical properties	Tectonic processes and events will not adversely alter the average percolation flux at the top of the Topopah Spring welded unit by more than a factor of 2. The probability of exceeding the goal will be <0.1 in 10,000 yr	Annual probability of volcanic events within the controlled area Effects of a volcanic event on topography and flux rates
			Igneous intrusion, such as a sill, that could result in a significant change in average flux	Same as above	Same as above	Same as above	Same as above	Annual probability of significant igneous intrusion in the controlled area Effects of an igneous intrusion on flux rates
	3, 4, 11	1, 8(i)	Offset on fault creates surface impoundments, alters drainage, creates perched aquifers, or changes dip of tuff beds, thereby significantly changing average flux	Same as above	Same as above	Same as above	Same as above	Probability of offset > 2 m on a fault in the controlled area in 10,000 yr Probability of changing dip by by > 2° in 10,000 yr by faulting Effect of faulting on flux rates

DRAFT

Table 8.3.1.8-3(a). Investigation 8.3.1.8.3 Studies to provide information required on changes in unsaturated and saturated zone hydrology due to tectonic events (Study 1; alteration of average percolation flux) (page 2 of 2)

SCP section requesting parameter	Potentially adverse condition addressed (10 CFR 60 122(c)) (Section 8 3 5 17)	Favorable condition addressed (10 CFR 60 122(b)) (Section 8 3 5 17)	Initiating event	Performance measure	Goal	Intermediate performance measure	Goal	Performance parameter
	3, 4, 11	1, 8(1)	Folding changes dip of tuff beds controlled area thereby significantly changing average flux	EPPM[a]	<< 1	Same as above	Same as above	Probability of changing dip by > 2° in 10,000 yr by folding
	3, 4, 11, 16	1, 8(1)	Uplift or subsidence changes or drainage thereby significantly changing average flux	Same as above	Same as above	Same as above	Same as above	Probability of exceeding 30 m elevation change in 10,000 yr

[a]EPPM = expected partial performance measure (see Section 8 3 5 13)

DRAFT

Table 8.3.1.8 3(b). Investigation 8.3.1.8.3 - Studies to provide information required on changes in unsaturated and saturated zone hydrology due to tectonic events (Study 1; alteration of average percolation flux) (page 1 of 2)

Performance parameter	Tentative parameter goal	Needed confidence	Characterization parameter	Testing basis: Current estimate (range or bound)	Testing basis: Confidence in current estimate	Testing basis: Needed confidence in final values	Investigations supplying data	Key studies or activities supplying data
Annual probability of volcanic events within the controlled area	$< 10^{-5}$ per yr	High	Probability calculation for volcanic events	10^{-7} to 10^{-6} per yr	Moderate	High	8.3.1.8.1	8.3.1.8.1.1.4 - Probability calculations and assessment
Effects of a volcanic event on topography and flux rates	Show topographic changes are not great enough to significantly affect flux	Low	Data on topographic changes caused by an eruption	See Section 1.5.1.2.2	Moderate	Moderate	8.3.1.8.1	8.3.1.8.1.2.1 - Effects of Strombolian eruptions 8.3.1.8.1.2.2 - Effects of hydrovolcanic eruptions
			Hydrologic model of flow in the unsaturated zone	See Section 3.9.3.2.1	Moderate	High	8.3.1.2.2	8.3.1.2.2.9 - Unsaturated zone flow and transport modeling
Annual probability of significant igneous intrusion in the controlled area	$< 10^{-8}$ per yr	High	Probability calculation for igneous events	10^{-7} to 10^{-9} per yr	Moderate	High	8.3.1.8.1	8.3.1.8.1.1.4 - Probability calculations and assessment
Effects of an igneous intrusion on flux rates	Show igneous intrusion will not significantly affect flux because of depth, location, and extent of intrusion	Low	Orientation and dimensions of possible intrusions at the site	$\approx$ 8.30.8 $<$ 4 km $\times$ 0.3-4 m	Moderate	Moderate	No new activities planned	--
			Hydrologic model of flow in the unsaturated zone	See Section 3.9.3.2.1	Moderate	High	8.3.1.2.2	8.3.1.2.2.9 - Unsaturated zone flow and transport modeling
Probability of offset $>$ 2 m on a fault in the controlled area in 10,000 yr	$< 10^{-1}$ per 10,000 yr	Moderate	Vertical slip rate and recurrence interval on Quaternary faults in and near the site	Slip rate $<$ 0.01 m per yr	Moderate	High	8.3.1.17.4	8.3.1.17.4.4.3 - Evaluate Stage coach Road fault zone
							8.3.1.17.4	8.3.1.17.4.6.2 - Evaluate age and recurrence of movement on suspended and known Quaternary faults

Table 8.3.1.8 3(b). Investigation 8.3.1.8.3 Studies to provide information required on changes in unsaturated and saturated zone hydrology due to tectonic events (Study 1; alteration of average percolation flux) (page 2 of 2)

Performance parameter	Tentative parameter goal	Testing basis: Confidence in current estimate	Characterization parameter	Current estimate (range or bound)	Testing basis: Needed confidence in final values	Investigations supplying data	Key studies or activities supplying data
Probability of changing dip by > 2° in 10,000 yr by faulting	< 10^{-6} per 10,000 yr	Low	Vertical slip rate on Quaternary faults in and near the site and rate of tilting	< 0.01 m per yr	Moderate	High	8.3.1.17.4	8.3.1.17.4.8.1 Evaluate Quaternary geology and potential Quaternary faults at Yucca Mountain 8.3.1.17.4.8.2 Evaluate age and recurrence of movement on suspected and known Quaternary faults
							8.3.1.4.2	8.3.1.4.2.2.1 - Geologic mapping of zonal features of Paintbrush Tuff
							8.3.1.4.3	8.3.1.4.2.3.1 - Development of a 3-D geologic model of the site area
Effect of faulting on flow rates	Show faulting will not significantly affect flow because of low slip rate	Moderate	Hydrologic model of flow in the unsaturated zone	See Section 3.9.3.2.1	Moderate	High	8.3.1.2.2	8.3.1.2.2.8 - Unsaturated zone flow and transport modeling
Probability of changing dip by > 2° in 10,000 yr by folding	< 10^{-6} per 10,000 yr	Low	Rate of folding in the unsaturated zone section	No detectable folding in 10 million yr	Moderate	High	8.3.1.4.2	8.3.1.4.2.2.1 - Geologic mapping of zonal features of Paintbrush Tuff
							8.3.1.4.3	8.3.1.4.2.2.4 - Geologic mapping of the exploratory shaft and drifts
Probability of exceeding 30 m elevation change in 10,000 yr	< 10^{-6} per 10,000 yr	Low	Rate of uplift or subsidence at site	< 3×10^{-3} m per yr	Moderate	Moderate	8.3.1.17.4	8.3.1.4.2.3.1 Development of a 3-D geologic model of the site area 8.3.1.17.4.8.2 Evaluate extent of Quaternary uplift and subsidence at and near Yucca Mountain 8.3.1.17.4.10 Geodetic leveling

DRAFT

Table 8.3.1.8-4(a). Investigation 8.3.1.8.3 Studies to provide information required on changes in unsaturated and saturated zone hydrology due to tectonic events (Study 2; changes in water table altitude) (page 1 of 2)

SCP section requesting parameter	Potentially adverse condition addressed (10 CFR 60.122(c)) (Section 8.3.5.17)	Favorable condition addressed (10 CFR 60.122(b)) (Section 8.3.5.17)	Initiating event	Performance measure	Goal	Intermediate performance measure	Goal	Performance parameter
8.3.5.13 (Issue 1.1, total system performance) 8.3.5.17 (Issue 1.8, NRC siting criteria) 8.3.5.18 (Issue 1.9, higher level findings postclosure)	5, 15, 22, 23	1, 8(ii)	Igneous intrusion causes barrier to flow or thermal effects that alter water table level	EPRI[a]	<< 1	Radionuclide transport time through UZ, given fixed UZ rock hydrologic and geochemical properties	Water table will not rise to within 100 m of emplaced waste in 10,000 yr No discharge points created in the controlled area Perched aquifers will not be created within 100 m of emplaced waste The probability of exceeding the goals will be < 0.1 in 10,000 yr	Annual probability of a significant igneous intrusion within 0.5 km of controlled area boundary Barrier-to-flow effects of igneous intrusions on water table levels Thermal effects of igneous intrusions on water-table levels
	4, 5, 11, 22, 23	1, 8(ii)	Episodic changes in strain in the rock mass due to faulting causes changes in water table level	Same as above	Same as above	Same as above	Same as above	Probability that strain induced changes increased to potentiometric level to > 850 m mean sea level

DRAFT

Table 8.3.1.8 1(a). Investigation 8.3.1.8.3 Studies to provide information required on changes in unsaturated and saturated zone hydrology due to tectonic events (Study 2; changes in water table altitude) (page 2 of 2)

SCP section requesting parameter	Potentially adverse condition addressed (10 CFR 60 122(c)) (Section 8 3 5 17)	Favorable condition addressed (10 CFR 60 122(b)) (Section 8 3 5 17)	Initiating event	Performance measure	Goal	Intermediate performance measure	Goal	Performance parameter
	4, 5, 11, 22, 23	1, 8(ii)	Folding, uplift, or subsidence lowers repository with respect to water table	Same as above	Same as above	Same as above	Same as above	Probability that repository will be lowered by 100 m through action of folding, uplift, or subsidence in 10,000 yr
	4, 5, 11, 22, 23	1, 8(ii)	Offset on fault juxtaposes transmissive and nontransmissive units resulting in either the creation of a perched aquifer or a rise in the water table	Same as above	Same as above	Same as above	Same as above	Probability of total offsets > 1.0 m in 10,000 yr on a fault within controlled area boundary Effects of fault offset on water-table levels

[a] EPPM = expected partial performance measure (see Section 8 3 5 13)

DRAFT

Table 8.3.1.8 4(b). Investigation 8.3.1.8.3 Studies to provide information required on changes in unsaturated and saturated zone hydrology due to tectonic events (Study 2; changes in water table elevation) (page 1 of 2)

Performance parameter	Tentative parameter goal	Needed confidence	Characterization parameter	Testing basis: Current estimate (range or bound)	Testing basis: Confidence in current estimate	Testing basis: Needed confidence in final values	Investigations supplying data	Key studies or activities supplying data
Annual probability of a significant igneous intrusion within 0.5 km of controlled area boundary	$< 10^{-6}$ per yr	Moderate	Probability calculations for volcanic events	10^{-8} to 10^{-9} per yr	Moderate	High	8.3.1.8.1	8.3.1.8.1.1.4 Probability calculations and assessment
Barrier to flow effects of igneous intrusions on water table levels	Show water table will not rise to within 100 m of repository horizon in 10,000 yr	Low	Orientation and dimensions of possible intrusions at the site	Orientation N 20° 40°E Length 400 6000 m	Moderate	Moderate	8.3.1.17.4	8.3.1.17.4.12.1 - Evaluate volcanic processes and tectonic stability at the site
			Hydrologic model of saturated zone flow system	See Section 3.9.3.2.2	Moderate	High	8.3.1.2.3	8.3.1.2.3.3.1 - Conceptualization of saturated zone flow models
Thermal effects of igneous intrusions on water table levels	Show water table will not rise to within 100 m of repository horizon in 10,0000 yr	Low	Model thermal effects around a dike	600°C at 2 m distance after 60 days	Moderate	Moderate	8.3.1.8.1	8.3.1.8.1.2.1 - Effects of Stream Ledge eruptions 8.3.1.8.1.1.3 Presence of magma bodies in vicinity of site
			Hydrologic model of saturated zone flow system	See Section 3.9.3.2.2	Moderate	High	8.3.1.2.3	8.3.1.2.3.3.1 - Conceptualization of saturated zone flow models
Probability that strain induced changes increase potentiometric level to + 850 m MSL	$< 10^{-6}$ per yr	Low	Strain rates and strain changes due to faulting	See Section 1.3.2.3	Low	Moderate	8.3.1.17.4	8.3.1.17.4.12.1 - Evaluate tectonic processes and tectonic stability at the site
			Hydrologic model of saturated zone flow system	See Section 3.9.3.2.2	Moderate	High	8.3.1.2.3	8.3.1.2.3.3.1 Conceptualization of saturated zone flow models
Probability that repository will be lowered by 100 m through action of folding, uplift, or subsidence in 10,000 yr	$< 10^{-4}$ per 10,000 yr	Low	Folding, uplift, and subsidence rates in site area	$< 3 \times 10^{-3}$ m per yr	Moderate	Moderate	8.3.1.17.4	8.3.1.17.4.9.2 Evaluate extent of Quaternary uplift and subsidence at and near Yucca Mountain 8.3.1.17.4.10 Geodetic leveling
							8.3.1.4.2	8.3.1.4.2.2.1 - Geologic mapping of areal features of Paintbrush Tuff 8.3.1.4.2.2.4 Geologic mapping of exploratory shaft and drifts
							8.3.1.4.3	8.3.1.4.2.3.1 Development of a 3-D geologic model of the site area

DRAFT

Table 8.3.1.8.4(b) Investigation 8.3.1.8.3 Studies to provide information required on changes in unsaturated and saturated zone hydrology due to tectonic events (Study 2; changes in water table elevation) (page 2 of 2)

Performance parameter	Testative parameter goal	Needed confidence	Characterization parameter	Current estimate (range or bound)	Testing basis: Confidence in current estimate	Needed confidence in final value	Investigations supplying data	Key studies or activities supplying data
Probability of total offsets > 2.0 m in 10,000 yr on a fault within controlled area boundary	< 10^{-4} per 10,000 yr	Low	Slip rates on Quaternary faults in and near site	< 0.06 mm/yr	Moderate	High	8.3.1.17.4	8.3.1.17.4.4.3 Evaluate Stage coarse Bead fault zone 8.3.1.17.4.6.1 Evaluate Quaternary geology and potential Quaternary faults at Yucca Mountain 8.3.1.17.4.6.2 Evaluate age and recurrence of movement on suspected and known Quaternary faults
Effects of fault offset on water table levels	Show water table will not rise to within 100 m of repository horizon in 10,000 yr	High	Orientation and length of fault seg	N 25°E N 35°W 10-20 km	Moderate	Moderate	8.3.1.17.3	8.3.1.17.3.1 Relevant earthquake sources
			Hydrologic model of saturated zone flow system	See Section 3.0.3.2.1	Moderate	High	8.3.1.2.3	8.3.1.2.3.3.1 Conceptualization of saturated zone flow models
			Hydrologic model of unsaturated flow system	See Section 3.0.3.2.1	Moderate	High	8.3.1.2.2	8.3.1.2.2.0 Unsaturated zone flow and transport modeling
			Evidence of higher water levels in Quaternary due to faulting	See Section 1.2.2.2.10	Low	Moderate	8.3.1.5.2	8.3.1.5.2.1.5 Studies of calcite and opaline silica vein deposits

DRAFT

Table 8.3.1.8 5(a) Investigation 8 3 1 8 3 Studies to provide information required on changes in unsaturated and saturated zone hydrology due to tectonic events (Study 3; alteration of rock properties along significant travel paths).

SCP section requesting parameter	Potentially adverse condition addressed (10 CFR 60 122(c)) (Section 8 3 5 17)	Favorable condition addressed (10 CFR 60 122(b)) (Section 8 3 5 17)	Initiating event	Performance measure	Goal	Intermediate performance measure	Goal	Performance parameter
8 3 5 13 (Issue 1 1, total system performance) 8 3 5 17 (Issue 1 6, NRC siting criteria) 8 3 5 19 (Issue 1 8, higher level findings postclosure)	5, 15, 24	1, 8(1)	Igneous intrusion causes changes in hydrologic properties	EPPM[a]	.. 1	Radionuclide transport time through RR, given fixed thickness of RR	The localized flow along travel paths from the repository to the accessible environment will not be significantly increased for distances that are a significant part of the travel path over 10,000 yr	Annual probability of significant igneous intrusions within 8 5 km of controlled area boundary Effects of igneous intrusions on local fracture permeabilities and effective porosities
	4, 5, 11, 24	1, 8(1)	Episodic effect on faulting causes local changes in rock hydrologic properties, thereby destroying existing barriers to flow, creating barriers to flow, or creating new conduits for drainage	Same as above	Same as above	Same as above	Same as above	Annual probability of faulting events on Quaternary faults within 8 5 km of controlled area boundary Effects of fault motion on local fracture permeabilities and effective porosities
	4, 5, 11, 24	1 .1)	Changes in stress or strain in the controlled area resulting from episodic faulting, folding, or uplift causes changes in the hydrologic properties of the rock mass	Same as above	Same as above	Same as above	Same as above	Effects of changes of stress or strain on hydrologic properties of the rock mass

[a]EPPM = expected partial performance measure (Section 8 3 5 13)

DRAFT

Table 8.3.1.8.5(b). Investigation 8.3.1.8.3 Studies to provide information required on changes in unsaturated and saturated zone hydrology due to tectonic events (Study 3; alteration of rock properties along significant travel paths)

Performance parameter	Tentative parameter goal	Needed confidence	Characterization parameter	Testing basis: Current estimate (range or bound)	Testing basis: Confidence in current estimate	Needed confidence in final values	Investigations supplying data	Key studies or activities supplying data
Annual probability of significant igneous intrusions within 0.5 km of controlled area boundary	$< 10^{-6}$ per yr	Moderate	Probability calculation for volcanic events	10^{-7} to 10^{-8} per yr	Moderate	High	8.3.1.8.1	8.3.1.8.1.1.4 - Probability calculations and assessment
Effects of igneous intrusions on local fracture permeabilities and effective porosities	Show no significant changes in rock hydrologic properties	Low	Evidence of change in rock properties around dikes in the region	No data available	Low	Moderate	8.3.1.8.5	8.3.1.8.5.2.2 - Chemical and physical changes around dikes
Annual probability of faulting events on Quaternary faults within 0.5 km of controlled area boundary	Show $< 10^{-6}$ per yr for each fault	High	Location of Quaternary faults in and near site	See Figure 1.36	Moderate	High	8.3.1.17.4	8.3.1.17.4.6.1 - Evaluate Quaternary geology and potential Quaternary faults at Yucca Mountain
			Slip rate and recurrence interval for Quaternary faults in and near site	Slip rate < 0.01 mm per yr	Moderate	High	8.3.1.17.4	8.3.1.17.4.6.2 - Evaluate age and recurrence of movement on suspected and known Quaternary faults
Effects of fault motion on local fracture permeabilities and effective porosities	Show change in fracture permeability is < a factor of 2, and that fracture porosity increases	High	Evidence of episodic rock property changes along faults	See Section 1.3.2.2.2	Low	Moderate	8.3.1.4.2	8.3.1.4.2.2.3 - Borehole evaluation of faults and fractures 8.3.1.4.2.2.4 Geologic mapping of exploratory shaft and drifts 8.3.1.3.2.1.3 - Fracture mineralogy
Effects of changes of stress or strain on hydrologic properties of the rock mass	Show changes in conductivity and porosity of rock mass are < a factor of 2	Low	Potential stress and strain changes in the rock mass due to faulting or other tectonic processes	See Section 1.3.2.3	Low	Moderate	8.3.1.17.4	8.3.1.17.4.12.1 - Evaluate tectonic processes and tectonic stability at the site
			Hydrologic models of flow in the saturated and unsaturated zone	See Sections 3.9.2.1 and 3.9.3.2.2	Low	Moderate	8.3.1.2.2	8.3.1.2.2.9 - Unsaturated zone flow and transport modeling
							8.3.1.2.3	8.3.1.2.3.3.1 Conceptualization of saturated zone flow models

DRAFT

Table 8.3.1.8 6(a). Investigation 8.3.1.8.4 Studies to provide information required on changes in rock geochemical properties resulting from tectonic processes

SCP section requesting parameter	Potentially adverse condition addressed (10 CFR 60 122(c)) (Section 8 3 5 17)	Favorable condition addressed (10 CFR 60 122(b)) (Section 8 3 5 17)	Initiating event	Performance measure	Goal	Intermediate performance measure	Goal	Performance parameter
8 3 5 13 (Issue 1 1, total system performance) 8 3 5 17 (Issue 1 8, siting criteria) 8 3 5 18 (Issue 1 9, higher level findings postclosure)	8, 15, 24	1, 3	Igneous intrusion causes changes in rock geochemical properties	EPPM[a]	<< 1	Radionuclide transport time through UZ, given fixed thickness of UZ	For radionuclides with travel times less than 10,000 yr, the change in K_d will not be more than a factor of 2 in 10,000 yr with a high level of confidence	Annual probability of igneous intrusions within 0 5 km of the controlled area boundary Effects of intrusions on local rock geochemical properties
	8, 11, 24	1, 3	Offset on a fault causes changes in movement of ground water that result in mineralogical changes along fault zone	Same as above	Same as above	Same as above	Same as above	Probability of movement and location of Quaternary faults in controlled area Degree of mineral changes in fault zone in 10,000 yr
	8, 11, 24	1, 3	Offset on a fault changes travel pathway to one with different geochemical properties	Same as above	Same as above	Same as above	Same as above	Probability of total offsets > 2.0 m in 10,000 yr on a fault within 0 5 km of controlled area boundary Effects of fault offset on travel pathway
	8, 11, 24	1, 3	Tectonic processes cause changes in ground water table or movement that results in mineral changes in controlled area	Same as above	Same as above	Same as above	Same as above	Degree of mineral change in the controlled area resulting from changes in water table level or flow paths in 10,000 yr

[a]EPPM - expected partial performance measure (Section 8 3 5 13)

DRAFT

Table 8.3.1.8 6(b). Investigation 8 3 1 8.4 Studies to provide information required on changes in rock geochemical properties resulting from tectonic processes (page 1 of 2)

Performance parameter	Tentative parameter goal	Needed confidence	Characterization parameter	Testing basis: Current estimate (range or bound)	Testing basis: Confidence in current estimate	Testing basis: Needed confidence in final values	Investigations supplying data	Key studies or activities supplying data
Annual probability of significant igneous intrusions within 0 5 km of the controlled area boundary	$< 10^{-6}$ per yr	Moderate	Probability calculations for volcanic events	10^{-7} to 10^{-9} per yr	Moderate	High	8 3 1 8.1	8 3 1 8 1 1 4 - Probability calculations and assessment
Effects of intrusions on local rock geochemical properties	Show potential changes in mineralogy will not be extensive	Low	Evidence of change in geochemical properties around dikes in the region	Data not available	Low	Moderate	8 3.1 8.5	8 3.1.8.5.2 2 - Chemical and physical changes around dikes
Probability of movement within 2 km of surface and location of Quaternary faults in controlled area	$< 10^{-4}$ per yr for each fault	Moderate	Location of Quaternary faults in controlled area	See Figure 1 38	Moderate	High	8 3 1.17.4	8 3.1.17.4 8.1 - Evaluate Quaternary geology and potential Quaternary faults at Yucca Mountain
			Slip rate and recurrence intervals for Quaternary faults in the controlled area	< 0.01 mm per yr	Moderate	High	8 3 1.17.4	8 3 1.17 4 8 2 - Evaluate age and recurrence of movement on suspected and known Quaternary faults
Degree of mineralogic change in fault zone in 10 000 yr	Show adverse changes in mineralogy will not occur	Moderate	Nature and age of mineralogic changes on faults in the controlled area	See Section 1 3 2 3	Low	Moderate	8.3.1 4.2	8 3.1 4 2.2 3 - Borehole evaluation of faults and fractures 8 3.1.4 2 2 4 - Geologic mapping of shafts and drifts 8 3.1 3 2 1 3 Fracture mineralogy 8 3 1.3 2 2 History of mineralogic and geochemical alteration of Yucca Mountain
Probability of total offsets > 2 0 m in 10,000 yr on a fault within controlled area boundary	$< 10^{-1}$ per 10,000 yr	Moderate	Slip rates on Quaternary faults in and near site	< 0.01 mm per yr	Moderate	High	8 3 1 17 4	8 3 1 17 4 4 3 Evaluate Stage coach Road fault zone 8 3.1 17 4 8.2 - Evaluate age and recurrence of movement on suspected and known Quaternary faults

DRAFT

Table 8.3.1.8 6(b). Investigation 8 3 1.8 4 Studies to provide information required on changes in rock geochemical properties resulting from tectonic processes (page 2 of 2)

Performance parameter	Tentative parameter goal	Needed confidence	Characterization parameter	Testing basis: Current estimate (range or bound)	Testing basis: Confidence in current estimate	Testing basis: Needed confidence in final values	Investigations supplying data	Key studies or activities supplying data
Effects of fault offset on travel pathway	Show significant changes will not occur	Moderate	Hydrologic models of unsaturated and saturated zone flow	See Sections 8 3 1 2 1 and 8 3 1 2 2	Moderate	High	8 3 1 2 2 8 3 1 2 3	8 3 1 2 2 9 Unsaturated zone flow and transport modeling 8 3 1 8.3 3 1 - Conceptualization of saturated zone flow models
Degree of mineralogic change in the controlled area resulting from changes in water table level or flow paths in 10,000 yr	Show adverse changes in mineralogy will not occur	Low	Probability and magnitude of hydrologic changes	Data not available	Low	Moderate	8.3 1.8 3	8 3 1 8 3.2.2 - Assessment of the effects of igneous intrusion on water-table elevations 8 3 1 8 3 2.3 - Assessment of the effect of strain changes on water table elevation 8.3.1 8.3.2 4 - Assessment of the effect of folding, uplift, or subsidence on water-table elevation 8.3.1 8 3 2 6 Assessment of the effect of faulting on water-table elevation

DRAFT

performance parameters on which data is required by Issue 1.1 and Issue 1.11. Each table is linked to a specific performance or intermediate performance measure identified by Issue 1.1 or 1.11 and a specific postclosure tectonics program investigation. The first column in Part A of the tables identifies the performance or design issue that has requested information from the postclosure tectonics program. The second and third columns identify the potentially adverse and favorable conditions from Issue 1.8 that will be addressed by each initiating event.

The fourth column lists the initiating events identified by Issues 1.1 or 1.11 that are related to the performance measure or intermediate performance measure. Initiating events are tectonic events or processes that, if they should occur during the period of interest, could directly or indirectly lead to releases or adversely affect estimates of release at the accessible environmental boundary. An example of an initiating event that could directly lead to releases is the penetration of the repository by a volcanic event. Most initiating events only indirectly affect estimates of release by potentially altering another parameter (such as average percolation flux rates) that, if changed, could adversely affect estimates of releases at the accessible environmental boundary.

The fifth and sixth columns identify a performance measure and associated goal. Performance measures are high level measures of total system performance and are described in more detail in Section 8.3.5.13 (Issue 1.1) and Section 8.3.2.2 (Issue 1.11). The seventh and eighth columns describe an intermediate performance measure and associated goal that is related to a significant component of the radionuclide release calculation (e.g., average percolation flux rates) that could be altered by tectonic processes or events. The goal for the intermediate performance measure is not intended to indicate the expected value that will result from the analysis of the tectonics program or the value at which the site would fail to meet the system performance objective. Instead, the goal provides an estimate of when the initiating event may start to become significant in performance calculations and is intended to provide guidance to the tectonics program on the level of accuracy or precision required in the program's analyses. The intermediate performance measures and the scenario classes to which they belong are further described in Section 8.3.5.13 for Issue 1.1 or in Section 8.3.2.2 for Issue 1.11.

The final column in Part A describes the performance parameters that have been related by Issue 1.1 or Issue 1.11 to each initiating event. For each initiating event in the tectonics program there are usually two performance parameters. The first performance parameter provides the probability that the tectonic event described in the initiating event will occur during the period of interest. In many instances, estimating probabilities for a tectonic initiating event over 10,000 yr may be difficult. Evaluation of these probabilities are subject to considerable uncertainty, but these uncertainties are quantifiable using available data and judgment. The second performance parameter provides a description of the effects of the event on the concern described in the intermediate performance measure should such an event actually occur. The specific requirements of 10 CFR Part 960 are not explicitly addressed in the tables because it has been determined that no

additional data are needed to make the higher level findings of 10 CFR Part 960 over that required to resolve Issue 1.1 (total system performance, Section 8.3.5.13) and Issue 1.8 (10 CFR Part 60, NRC siting criteria, Section 8.3.5.17). Detailed discussion of the 10 CFR Part 960 higher level findings can be found in Section 8.3.5.18 (higher level findings--postclosure).

Part A of Tables 8.3.1.8-1 through 8.3.1.8-6 basically repeats the information called for in Tables 8.3.5.13-9 through 8.3.5.13-16 in Issue 1.1 and the requirements of Issue 1.11 (Section 8.3.2.2). Part B of the tables indicates the data that will be used and the activities supplying the data necessary in addressing the performance parameters. The first column of Part B repeats the performance parameters from Part A to provide a link between the two parts of the table. The second column provides a tentative parameter goal for the performance parameter. Like the goals for intermediate performance measure, performance parameter goals are intended to provide guidance on the level of accuracy or precision required in addressing the performance parameter rather than indicating anticipated results or levels at which total system performance objectives would not be met. The third column presents a subjective judgment on the needed level of confidence and relative importance of the performance parameters in order to demonstrate that the goals for the performance measure and intermediate performance measure are satisfied. These judgments combine a consideration of the level of detail that can reasonably be achieved in addressing the parameter, the probability of the initiating event having a significant impact on the component of the system performance calculation being considered, and the probability of the initiating event occurring. The information in this column is intended to provide guidance to the data gathering activities on the relative amount of effort that should be expended in addressing each performance parameter.

The fourth column identifies the characterization parameters associated with each performance parameter. A characterization parameter is an item of information necessary to prepare the analysis called for in the performance parameter. Characterization parameters are frequently higher level parameters themselves in that data supplied by other activities must generally be compiled and synthesized to supply the necessary information. The fifth column provides the current estimate of the characterization parameter. These estimates are based on the data presented in Chapter 1, the references supporting Chapter 1, and the technical judgments based on these data. The sixth and seventh columns provide a judgment of the confidence in the current estimate of the characterization parameter and a judgment of the confidence needed at the end of site characterization in the characterization parameter. These two columns are intended to provide guidance to the data collecting activities on the amount of additional effort that is required to complete the program. The final two columns in Part B identify the investigation number, and number and short title of the specific studies or activities that are called upon to supply data to satisfy the characterization parameter.

The approach used in this program to satisfy the data needs listed in the performance parameters is to have one activity associated with each initiating event whose role is to prepare a report that provides an assessment of that event. The assessment will address the performance parameters associated with the initiating event and provide an overview of the probability of significant changes in existing conditions that could affect

radionuclide release rates resulting from the tectonic process being considered. The report will provide the basis for deciding how the initiating event will be treated in repository performance assessment calculations. The data presented in Chapters 1 and 4 indicate that several of the initiating events (e.g., those related to uplift, folding, and geochemical changes) can be considered as non-credible in repository release calculations. In these cases, the reports prepared by this program will document this conclusion using existing data or bounding calculations, and little or no additional data will be gathered to directly address these initiating events.

Approach to satisfy performance and design requirements

Both the NRC technical criteria (10 CFR 60.2 and 10 CFR 60.122) and the DOE siting guidelines (10 CFR 960.4-2-7) require that prediction of future tectonic processes and events be determined from projections based on an examination of these processes and events during the Quaternary. The NNWSI Project, therefore, intends to base its analysis of performance measures on a projection of Quaternary rates of tectonic processes on geologic structures at and proximal to the site.

This program also supplies data for the resolution of Issue 1.8 (Section 8.3.5.17):analyses to determine the degree to which each of the favorable and potentially adverse conditions, if present, has been characterized and the extent to which it contributes to or detracts from isolation. Specific guidance on the scopes of these analyses is provided in 10 CFR 60.21(c)(1)(ii)(B): "For the purpose of determining the presence of the potentially adverse conditions, investigations shall extend from the surface to a depth sufficient to determine critical pathways for radionuclide migration from the underground facility to the accessible environment. Potentially adverse conditions shall be investigated outside of the controlled area if they affect isolation within the controlled area."

The data identified in the first four investigations will provide the additional detail necessary to accurately characterize the effects of tectonic processes operating at or near the site and to measure the rates at which they operated during the Quaternary. This information will then be used to provide the projection of future rates necessary to satisfy the performance parameters. Before each data gathering activity begins, the related performance parameters will be evaluated to determine if currently available data are sufficient to satisfy the parameter with the required level of confidence. If the performance parameter has been satisfied, then further studies will not be undertaken (Figure 8.3.1.8-2). If the parameter has not been satisfied, then the feasibility of planned or potential activities will be evaluated to determine if the activities will reasonably increase the level of confidence in the parameters that describe the process or not. If it is not feasible to increase the level of confidence, then no additional studies will be performed and the site performance will be evaluated on the basis of available data. The data gathering activities identified in the analysis and assessment investigations will be undertaken if they are found to provide the additional data or confidence necessary to resolve the performance parameter.

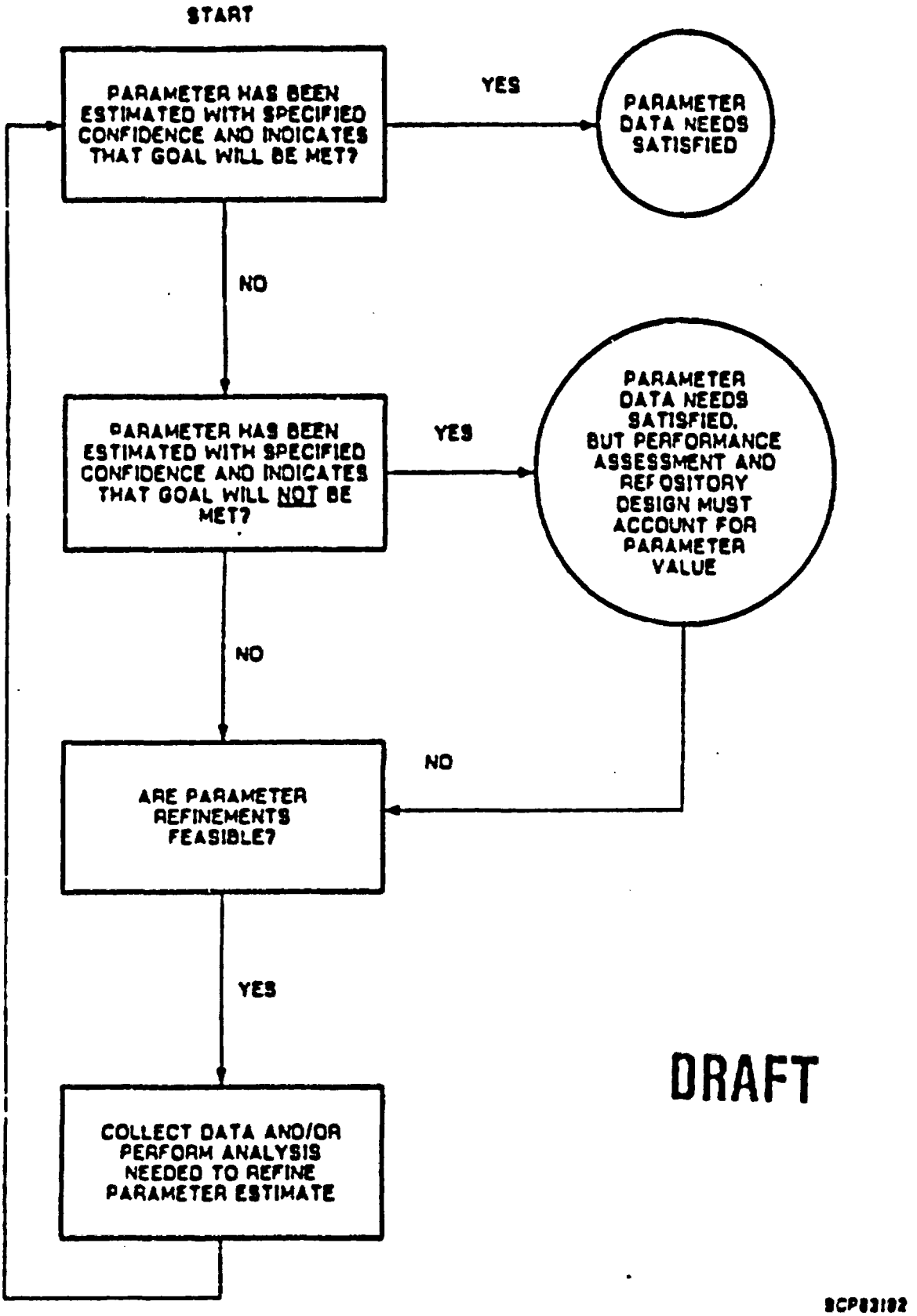


Figure 8.3.1.8-2. Parameter analysis

DRAFT

Various data are used to make the projections of tectonic processes and events into the future, including earthquake observations, fault measurements, geologic mapping, drilling, gravity and magnetic surveys, and other geophysical data. Alternative interpretations of the data will be explored and evaluated with respect to implications for repository performance. These multiple interpretations will be refined to the extent necessary to establish the degree of confidence in the parameter characterization that is specified by the intermediate performance measure goals and performance parameter goals (Tables 8.3.1.8-1 through 8.3.1.8-6).

Five investigations have been identified under the postclosure tectonics program. The first four investigations are related to the six intermediate performance measures in Tables 8.3.1.8-1 through 8.3.1.8-6. The studies and activities connected with these investigations provide the analysis and interpretation necessary to evaluate the site against the performance parameter. These analysis activities also identify the type and level of detail of the data necessary for the resolution of the performance parameter. Because the analysis and interpretation activities for different performance parameters repeatedly call for the same type of data, data gathering activities are grouped separately under a fifth investigation that feeds data as required to the analysis activities associated with the performance and characterization parameters. The interrelationships among the investigations in this program are shown in Figure 8.3.1.8-1. Much of the data required to resolve this issue will be collected by activities associated with other programs. These activities and the data they are required to provide are identified in the investigation descriptions and in their accompanying logic diagrams.

Studies for Investigation 8.3.1.8.1 will provide the analyses to satisfy the performance parameters related to direct releases resulting from volcanic activity. These performance parameters address the initiating event related to the direct intrusion of magma into the repository or potential explosive episodes (hydrovolcanism) that may result from such intrusions which could directly result in releases to the accessible environment. As discussed in Sections 1.3 and 1.5, basaltic volcanism is considered the only credible scenario for igneous intrusion in the controlled area during the postclosure time period. Preliminary calculations of the probability of basaltic volcanism (Section 1.5.1.2.3) indicate that this type of igneous activity may fall into the range of unanticipated events (greater than between 10^{-8} and 10^{-6} annual probability). The performance goal assumes that annual probabilities of occurrence for this type of event are independent of time (Poisson recurrence model) and sets for a goal that this type of event will remain unanticipated with a high level of confidence (10^{-4} annual probability or 99 percent level of confidence that the event will not occur in 10,000 yr). The strategy used in this investigation is to gather more refined data on the age, occurrence, and relation to geologic structure of basaltic volcanism in the site area and to use these data to calculate more detailed probabilistic assessments of the potential for basaltic volcanism intersecting the repository or occurring in the controlled area. The possibility that the occurrence of volcanism is not random over the region, but controlled by geologic structures or other factors will also be considered in the assessment. A second part of the strategy will be an assessment of the effects on a repository of Strombolian or hydrovolcanic eruptions that penetrate the repository.

DRAFT

Investigation 8.3.1.8.2 will provide the analyses to resolve the performance measure related to the failure of waste packages due to tectonic events. Structural deformation resulting from tectonic processes such as faulting (including detachment faulting), uplift, subsidence, or folding could adversely affect the effective lifetime of the waste packages in containing the waste. If deformation was found to be significant enough that the requirements for waste package performance could not be met, the changes required in repository geometry may be such that the repository would no longer be able to accommodate the specified volume of waste (70,000 MTU). The goal (Table 8.3.1.8-2) for the performance measure is derived from the considerations discussed in Section 8.3.4.2. Section 8.3.4.2 sets design goals for rock-induced loads to the waste package. One goal states that less than 0.5% of the waste packages will be breached by anticipated tectonic processes and events that may occur during the first 1,000 yr. This level is designed to be compatible with the overall goal for waste package performance from all modes of failure of less than 5 percent in 300 yr and less than 20 percent in 1,000 yr. (Section 8.3.5.9). The level of confidence for the performance goal was set so that exceedance of the goal would be an unanticipated event.

The first initiating event considered under this intermediate performance measure is the possibility of igneous activity such as the intrusion of a dike or an explosive hydrovolcanic event which could lead to waste package failure (Table 8.3.1.8-2). The number of waste packages affected by a disruptive event such as a hydrovolcanic eruption has not been estimated. The performance parameter goal was set to have the penetration of the repository in 1,000 yr by igneous intrusions be an unanticipated event because waste package disruption scenarios only need to consider anticipated events.

The second initiating event considers the effect of fault displacement on waste package integrity. A value of 5 cm was selected as the performance parameter at which fault displacement becomes significant over a 1,000-yr period because at this value it is estimated that the 7.6-cm air gap around the waste package (Sections 6.2.6.2 and 7.3.1.3) would be substantially closed and any additional displacement might result in waste package failure.

The strategy for demonstrating that faulting will not lead to significant waste package failure in 1,000 yr will be to locate and characterize Quaternary faults in and proximal to the controlled area. Because these faults (such as Windy Wash and Paintbrush Canyon (Section 1.3.2.2.2)) have very low slip rates, it is anticipated that the demonstration can be made that the occurrence of 5 cm of displacement in 1,000 yr on even these longer, more significant faults is a very low probability event. The characteristics of the known Quaternary faults in the area will be compared to those of the faults that penetrate the repository block to demonstrate that these smaller faults are much less likely to support a slip rate comparable to the larger faults in the area. A second part of the strategy will be to estimate the number of waste packages a throughgoing fault would intersect in the repository. Using the formula of Link et al. (1982) to estimate the hazard posed by faulting, a randomly oriented fault would intersect nine to ten waste packages out of an inventory of 18,000 waste packages in a 510 ha repository. This type of analysis will be used to demonstrate that significant displacement would have to occur on several faults to create failures on more than 0.5 percent of the waste package inventory.

The third initiating event considers the possibility that high rates of folding operating over a 1,000-yr period could result in sufficient waste-emplacement borehole deformation to lead to waste package failure. The performance parameter goal was selected so that, if the goal is met, then bending of waste emplacement boreholes by folding or deformation due to distributed shear of more than 5 cm will not be a credible event (less than 10^{-8} annual probability). The value of 5 cm for the goal for borehole deformation was also selected on the basis of a substantially reduced air gap around the waste package. The strategy for demonstrating compliance with the performance parameter goal will be to demonstrate the absence of significant folding in the repository horizon during the last 10 million yr.

Regional uplift and subsidence are not considered credible processes that could lead to waste package failure. The only conceivable mechanism by which uplift could lead to waste package failure is for extreme uplift rates to occur, which could lead to the exposure of waste packages to erosional processes. This initiating event is considered separately in Investigation 8.3.1.6.3.

Investigation 8.3.1.8.3 addresses the effects tectonic processes may have on hydrologic characteristics in the controlled area. A set of three intermediate performance measures have been identified as the significant hydrologic factors that could be adversely affected by tectonic processes and events. The three intermediate performance measures are alteration of average percolation flux, changes in water-table altitude, and alteration of rock properties along significant potential travel paths (Tables 8.3.1.8-3 to 8.3.1.8-5 and Section 8.3.5.13).

The initiating events identified for the intermediate performance measure that addresses the alteration of average percolation flux are concerned with tectonic processes that could alter flux rates such as (1) the creation of impoundments due to volcanic flows or the formation of fault scarps, (2) the diversion of drainage due to volcanic activity, faulting, uplift, or subsidence, (3) the creation of perched aquifers above the repository due to faulting, (4) the creation of impermeable zones such as the injection of a sill, and (5) a change in dip of the repository rock due to faulting or folding. The basic strategy in addressing this intermediate performance measure will be to measure the Quaternary rate of igneous activity and tectonic deformation due to faulting, folding, uplift, and subsidence in the repository area and demonstrate that these rates are low enough that the performance parameter goal would not be exceeded in a 10,000-yr period.

The intermediate performance measure concerned with changes in water table altitude (Table 8.3.1.8-4) considers the possibility that tectonic events or processes could result in rises in the water table, changes in the potentiometric level of confined aquifers, or the creation of perched aquifers. Such changes could result in the shortening of the ground-water travel pathway in the unsaturated zone and altered radionuclide release rates to the accessible environment. Changes in water-table altitudes may also affect hydraulic gradients and the location of discharge points. The distance from the repository horizon to the water table is currently about 250 m. The intermediate performance measure goal was set at a distance of greater than 100 m because it is estimated that the reduction in unsaturated zone release rates would become significant at this point.

The effects of tectonic initiating events considered as possible causes for these changes in the length of the unsaturated zone pathway in Table 8.3.1.8-4 include (1) the creation of barriers to ground-water flow as a result of the formation of igneous dikes, (2) offsets that juxtapose units with differing hydrologic properties due to movement on a fault, (3) the change in elevation of the repository with respect to the water table due to folding or subsidence, and (4) the change in water-table altitude or potentiometric level that might result from strain changes through the faulting cycle.

The intermediate performance measure addressing the alteration of rock properties along significant potential travel paths is concerned with possible changes in rock properties due to tectonic processes that could result in changes in the hydrologic flow properties of the rocks in the controlled area. The effects of initiating events considered are (1) changes in rock properties due to an igneous intrusion, (2) change in rock properties along a fault due to fault movement that results in the creation or destruction of barriers to lateral flow or the creation of conduits of increased vertical flow, and (3) changes in the hydrologic properties of the rock mass due to episodic changes in strain due to faulting or folding (Table 8.3.1.8-5). This intermediate performance measure will also consider the effects that changes in rock properties could have on the movement of gaseous decay products in the unsaturated zone. The strategy for evaluating the magnitude of such changes will be to estimate the rate of tectonic activity in the area and estimate the impact of tectonic processes through hydrologic modeling.

Investigation 8.3.1.8.4 addresses the possibility that geochemical characteristics could be changed in the controlled area as a result of tectonic processes and events. This investigation addresses the concerns of the intermediate performance measure that addresses the possible changes in rock geochemical properties or ground-water chemistry resulting from tectonic processes and events (Table 8.3.1.8-6). The goal for this intermediate performance measure was set so that tectonic processes would not adversely affect the radionuclide release rate due to changes in the distribution coefficient (K_ds) of the rock by more than a factor of 2 in 10,000 yr for those radionuclides with expected travel times of less than 10,000 yr with a high level of confidence. The effects of initiating events that are considered for this intermediate performance measure are (1) alteration of the country rock caused by an igneous intrusion, (2) changes in the mineralogy along a fault zone due to changes in ground water flow paths caused by faulting, (3) changes in travel paths due to faulting, and (4) mineralogic changes caused by fluctuations in water level due to tectonic events. The principal strategy in addressing this intermediate performance measure will be to investigate the nature and extent of mineralogic changes that have occurred in the past around dikes and faults in the area around the site.

The studies and activities that provide the data for the analyses of the intermediate performance measures are collected under Investigation 8.3.1.8.5. The data-gathering studies and activities are aggregated separately from the investigations addressing the intermediate performance measures because each of the intermediate performance measures tends to call on the same data to analyze its initiating events. The separation of data-analysis activities from data-gathering activities by placing them in

different investigations is believed to improve and clarify the logic flow in the investigations related to the analysis of the intermediate performance measures and to identify more clearly the nature and level of detail of data that must be collected. The activities collected under Investigation 8.3.1.8.5 for this tectonics program are few because most of the data necessary for the resolving of the intermediate performance measures are supplied by activities in other programs. The data that are being supplied by activities in other programs are identified in Tables 8.3.1.8-1 to 8.3.1.8-6 and in the investigation descriptions.

Interrelationships of postclosure tectonics investigations

The interrelationship among issues, programs, investigations, favorable conditions, and potentially adverse conditions is shown in Tables 8.3.1.8-1 to 8.3.1.8-6, Figure 8.3.1.8-1, and in the logic diagrams accompanying the investigation descriptions.

The assessment of potential igneous activity in Investigation 8.3.1.8.1 will require an improved data base on the nature and rate of past activity in order to prepare a probabilistic calculation on the possibility of future igneous activity. The assessment will also include a consideration of possible structural controls on igneous activity and an evaluation of the possibility of magma sources underlying the site. A second study will evaluate the disruptive effects of Strombolian and hydrovolcanic eruptions should they occur at the repository.

Investigation 8.3.1.8.2 is composed of one study that will assess the likelihood and effects of each of the four initiating events on waste package integrity. Data for the assessment of waste package rupture due to igneous activity will come from Investigation 8.3.1.8.1. The assessment of waste package rupture due to faulting will use (1) data on the number of waste packages that could be intersected by a throughgoing fault and (2) data on the slip rate, recurrence interval and displacement of individual events, length, sense of movement, and width of zone of Quaternary deformation for the north-trending normal faults found in and near the controlled area from Investigations 8.3.1.17.4 and 8.3.1.4.2.

The performance parameter goals for folding indicate levels of significance that are so high in relation to natural rates that existing data and data from Investigation 8.3.1.4.2 are sufficient to make an assessment. Only minor studies to gather additional data on folding in the region are planned.

Investigation 8.3.1.8.3 will use data on the nature and rates of igneous activity, faulting, folding, uplift, and subsidence collected by the investigations listed in Tables 8.3.1.8-3 to 8.3.1.8-6 to perform an assessment of the amount of change that could be expected over the next 10,000 yr for the three hydrologic concerns discussed in the intermediate performance measures. In each instance, this assessment will have two parts and will be an iterative process. The first part will be an estimation of the probability of occurrence of tectonic processes that could affect hydrologic properties and a characterization of the type of changes that could occur and the volume of rock affected. The second part of the assessment will be hydrologic modeling of potentially significant changes in model parameters due to

tectonic processes to determine the expected amount of change in the hydrologic intermediate performance measures. This investigation therefore supplies the interface point needed for the integration of data between the geohydrology and postclosure tectonics program staff.

Investigation 8.3.1.8.4 will provide the analysis necessary to address the intermediate performance measure concerning changes in rock geochemical properties resulting from tectonic processes. The data necessary to perform the analysis will be supplied by activities in Investigations 8.3.1.17.4, 8.3.1.2.2, 8.3.1.2.3, and 8.3.1.4.2 (Table 8.3.1.8-6). The analysis will use data on mineral changes around dikes and faults in the area surrounding the site to project the amount of expected change in the next 10,000 yr. Other studies and activities will evaluate the probability of the initiating events and evaluate the potential mineral changes that could result from the occurrence of those events.

Investigation 8.3.1.8.5 will house the data-gathering studies and activities that are called for by the analysis activities. The studies contained in this investigation are related to the probability and effects of volcanic events and folding in region surrounding the repository. All other required data will be collected by investigations related to other programs.

8.3.1.8.1 Investigation: Studies to provide information required on direct releases resulting from volcanic activity

Technical basis for obtaining the information

Link to the technical data chapters and applicable support documents

The following sections of the SCP data chapters and support documents provide a technical summary of existing data relevant to this investigation:

SCP section	Subject
1.3.2.1	Volcanic history
1.5.1	Volcanism
1.8.1.3.1, 1.8.1.3.2	Significant results (structural geology and tectonics), discussion of significant results
1.8.1.5.1	Significant results (long-term regional stability)

Parameters

The following performance parameters (Table 8.3.1.8-1 and Section 8.3.5.13) will be measured or calculated as a result of the studies planned to satisfy this investigation:

1. Annual probability of a volcanic eruption that penetrates the repository.

DRAFT

2. Effects of a volcanic eruption penetrating the repository including area of repository disrupted and confidence bounds of estimate.

Purpose and objectives of the investigation

The purpose of this investigation is to provide the data required for an assessment of repository performance with respect to the possibility of direct releases resulting from volcanic events. The two performance parameters for this investigation have been identified by Issue 1.1 (Section 8.3.5.13 and Table 8.3.1.8-1). The evaluation of these two performance parameters is the subject of the two studies in this investigation (Figure 8.3.1.8-3). The two studies in this investigation will also supply the data required by Issue 1.8 (Section 8.3.5.17) to address the favorable and potentially adverse conditions of 10 CFR 60.122 listed in Table 8.3.1.8-1. Investigations 8.3.1.8.2 through 8.3.1.8.4 will also use the results of this investigation in their analyses of other intermediate performance measures.

Technical rationale for the investigation

This investigation considers the single initiating event of a volcanic eruption penetrating the repository and resulting in direct releases to the atmosphere or land surface. As discussed in Sections 1.3.2.1 and 1.5.1, basaltic volcanism is considered to be the only credible type of activity to have a possibility of occurrence in the next 10,000 yr. Releases could occur as the result of a dike that feeds a volcanic vent intersecting the repository and entraining some waste. The waste could be ejected in a Strombolian eruption as pyroclasts and incorporated in an ash fall and cinder cone. As an alternative, if the ascending magma intersects a body of ground water, a hydrovolcanic explosion could occur at depths great enough to cause disruption of the repository. This hydrovolcanic type of eruption might result in the ejection of waste fragments as a result of the explosions from a tuff-ring or maar volcano. Hydrovolcanic eruptions may change in time to a Strombolian eruption resulting in the formation of a cinder cone.

Study 8.3.1.8.1.1 correlates to the first performance parameter listed in the previous section. This study will analyze the data collected by the program and estimate the probability of a volcanic event intersecting the repository. The logic flow for the four activities contained in the study is shown in Figure 8.3.1.8-3. The probability calculations will be refined versions of the estimates presented in Section 1.5.1.2 and will assume that the occurrence of basaltic volcanism in the region is independent of time and location (Poisson recurrence model). It is possible that the occurrence of volcanism is not actually a completely random process but that the location of volcanic vents and the probability of their occurrence can be affected by regional structural trends, local structures, and even topography. The influence of regional structural trends was factored into the area ratio (area of repository/area to which volcanic event rate applies) of the probability calculations (Section 1.5.1.2.3). The possibility of local structural controls will be assessed by evaluating the location of late Cenozoic basaltic vents in relation to known structures and aeromagnetic, gravity, and seismic data. The results of these analyses will be incorporated into the final volcanic probability assessment as appropriate. Geophysical evidence will also be evaluated for indications that magma bodies

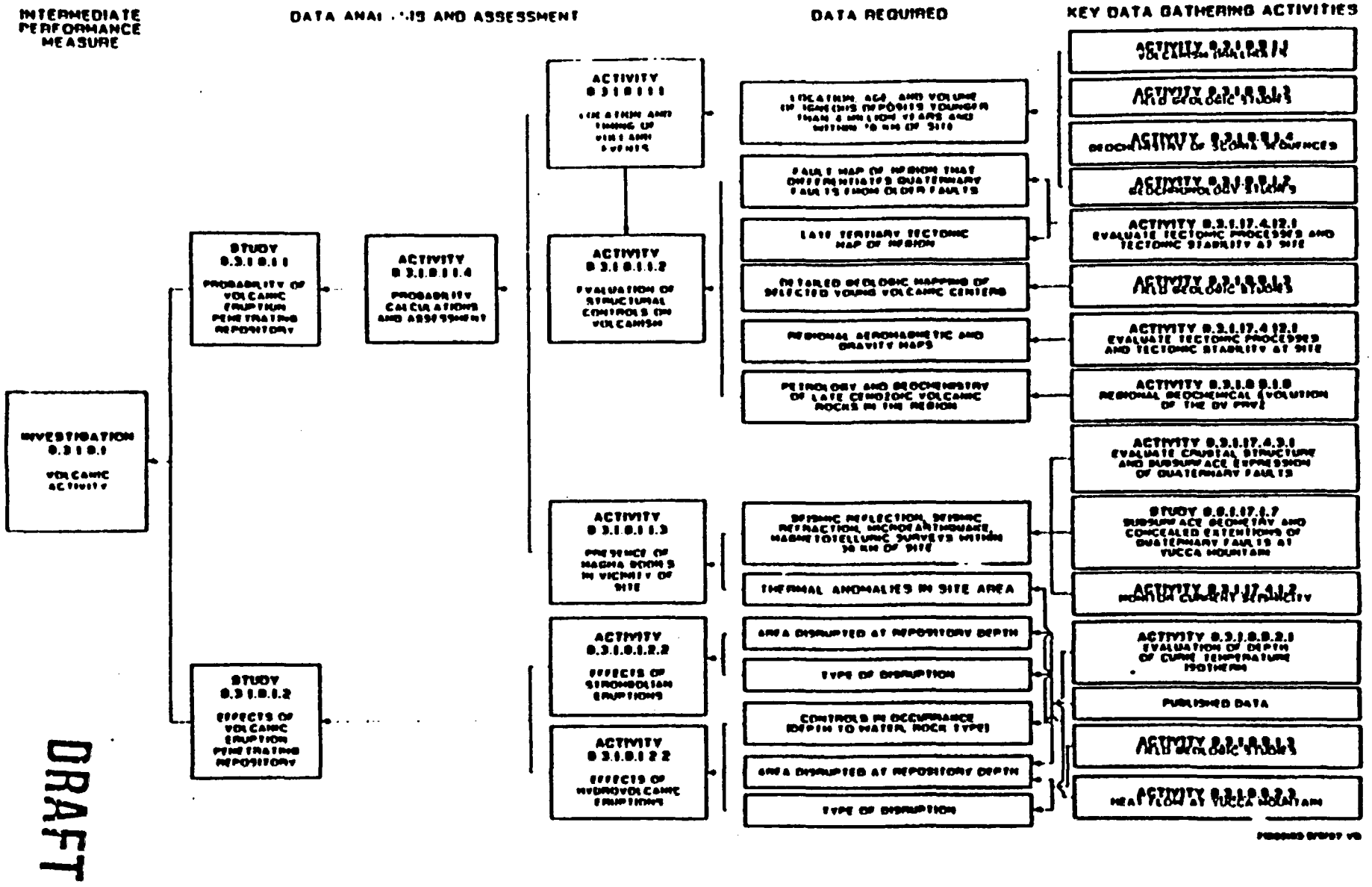


Figure 8.3.1.8-3. Logic diagram for Investigation 8 3 1 8 1 (volcanic activity)

may be present in the vicinity of the site. The evidence for the presence or absence of magma bodies will also be factored into the probabilistic estimates.

Study 8.3.1.8.1.2 correlates with the second performance parameter listed in the previous section and will consider the effects a basaltic eruption could have on repository performance if such an event should occur. Two types of eruptions have been found to be characteristic of past activity in the region: Strombolian and hydrovolcanic (Section 1.3.2.1.2 and 1.5.1.2). Sufficient data have been collected on the effects of Strombolian eruptions for an analysis of repository performance so no additional field data gathering is planned. Additional data are needed on the effects of and controls of hydrovolcanic eruptions. This study will integrate current and newly acquired data into a format that can be used for repository performance assessment.

DRAFT

8.3.1.8.2 Investigation: Studies to provide information required on rupture of waste packages due to tectonic events

Technical basis for obtaining the information

Links to the technical data chapters and applicable support documents

The following sections of the SCP data chapters provide a technical summary of existing data relevant to this investigation:

SCP section	Subject
1.3.2.1	Volcanic history
1.3.2.2	Structural history
1.4.1.5	Seismic hazard within the southern Great Basin
1.5.1	Volcanism
1.5.2	Faulting

Parameters

The following performance parameters will be measured or calculated as a result of the site studies planned as part of this investigation:

DRAFT

1. Probability of igneous intrusion penetrating repository.
2. Effects of igneous intrusion penetrating repository.
3. Effects on waste packages of a fault penetrating the repository.
4. Probability of faulting with displacement over 5 cm in repository.
5. Expected ground motion at emplacement boreholes in 1,000-yr period.
6. Rate of deformation due to folding or distributed faulting in repository horizon.

Purpose and objectives of the investigation

The purpose of this investigation is to provide the data necessary for an analysis and assessment of repository performance with respect to the possibility of tectonic processes and events affecting the lifetime of waste packages. The six performance parameters listed in the previous section have been defined to address the performance measure identified by Issue 1.11 (Section 8.3.2.2). The types of tectonic initiating events that may affect waste package performance and that will be considered in this analysis are listed in Table 8.3.1.8-2. The study and activities in this investigation will take data gathered by field studies in this and other programs and provide an analysis of the probability of the initiating events and their effects on waste package performance for use by Issue 1.11 (Section 8.3.2.2) in assessing layout and design of the underground facilities.

This investigation will also provide data on the nature of tectonic processes operating at the site for use by Issue 1.8 (Section 8.3.5.17, NRC siting criteria) in its analysis of favorable and potentially adverse conditions. The specific conditions addressed by this investigation are listed in Table 8.3.1.8-2.

Parameter 5 indicates the need for data on the ground motion that would be expected during the waste package lifetime. This parameter and its related initiating event respond to the need identified in Issue 1.11 (Section 8.3.2.2, configuration of underground facilities (postclosure)) for such data. Issue 1.11 will use the ground motion data to evaluate the design of emplacement drifts and boreholes in order to assess their postclosure stability.

Technical rationale for the investigation

The flow of data and interconnections between activities is shown on Figure 8.3.1.8-4. The first initiating event considered in this program is the possibility that igneous intrusions penetrating the repository could adversely affect waste package performance. This initiating event is similar to the one considered in Investigation 8.3.1.8.1, but assumes that the basaltic dikes or sills that might penetrate the repository do not feed a volcanic vent and do not directly result in releases at the ground surface. Activity 8.3.1.8.2.1.1 will address this initiating event and satisfy parameters 1 and 2. The assessment of this initiating event will be similar

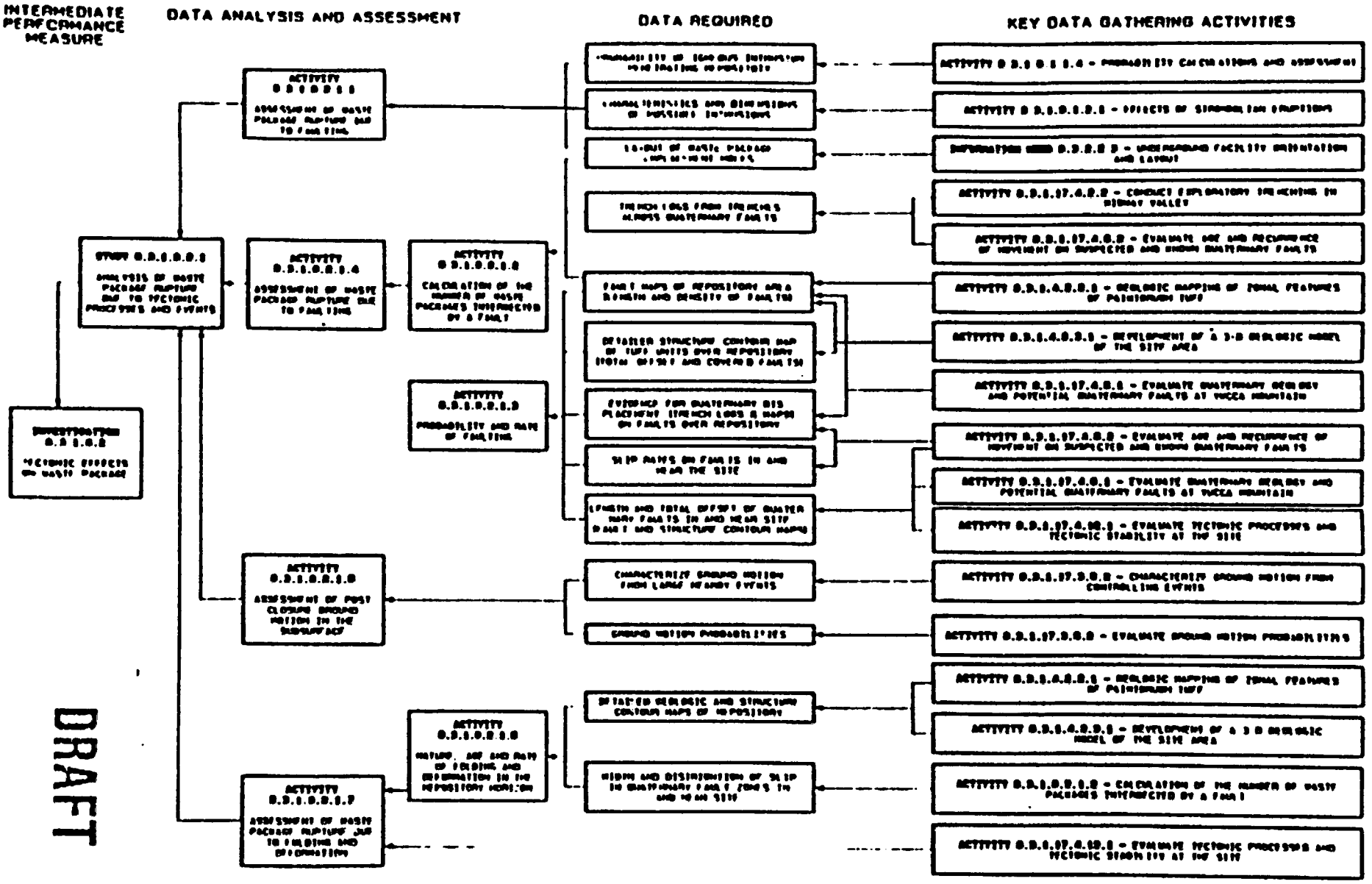


Figure 8.3.1.8-4. Logic diagram for Investigation 8 3 1 8 2 (tectonic effects on waste package).

DRAFT

to that in Investigation 8.3.1.8.1 and will use the data analyzed in that investigation to calculate the probability of igneous intrusions penetrating the repository. The number of waste packages that an intrusion might intersect will also be calculated using data on the probable length, width, and orientation of intrusions and current repository design concepts.

The second initiating event considers the possibility that failure of waste packages could occur due to a fault that intersects waste packages and experiences offset that is great enough to cause failure through shearing. Activities 8.3.1.8.2.1.2, 8.3.1.8.1.2.3, and 8.3.1.8.2.1.4 will assess this initiating event and satisfy parameters 3 and 4. This assessment will include calculating (1) the probability that faulting with offset great enough to cause waste package failure would occur in the repository and (2) the number of waste packages that a through going fault might intersect. These activities will organize and assess data collected by Programs 8.3.1.17 and 8.3.1.4 to characterize the nature and Quaternary activity of faults that penetrate the repository and those faults in and near the controlled area. Because of the scarcity of Quaternary deposits on Yucca Mountain, it may not be possible to directly demonstrate the degree of Quaternary activity present on all the faults that potentially penetrate the repository. It is therefore probable that the assessment of the probability and amount of movement on these faults will be characterized by comparison with the known Quaternary faults in the vicinity of the site that have a similar trend and sense of movement. Faults such as the Paintbrush Canyon, Solitario Canyon, and Windy Wash traverse areas underlain by Quaternary deposits of a variety of ages (Sections 1.2.2.3 and 1.3.2.2.2) that can be used to determine the nature and rate of Quaternary activity. The comparison of the faulting potential of these larger faults with faults penetrating the repository will incorporate a consideration of the differences in length and total displacement between the two classes of faults. When all these data are collected and coordinated, an annual probability of fault displacement exceeding 5 cm will be calculated for faults that may penetrate the repository.

The second part of the assessment will be a calculation of the number of waste packages that a fault might intersect should a faulting event, with sufficient offset to rupture waste packages, occur. Data will be compiled on the length and width of fault zones, and then calculations similar to those in Link et al. (1982) will be carried out using current repository designs to estimate the number of waste packages that might be affected.

The third initiating event considers the possibility that ground motion occurring during the postclosure period could cause spalling or failure in the underground workings that would result in corrosion or mechanical failure of waste packages due to closure of the air gap around them. Activity 8.3.1.8.2.1.5 will partially address this initiating event and address parameter 5 by calculating expected ground motion values in the repository during the lifetime of the waste packages. The performance of underground excavations under these ground motion conditions will be evaluated separately in Issue 1.11 (Section 8.3.2.2). In this investigation, the ground motion estimates for preclosure design in Investigation 8.3.1.17.3 will be reviewed. Appropriate ground motion parameters for the postclosure time period will then be calculated on the basis of this data.

DRAFT

The fourth initiating event considers the possibility that folding, or fault offset distributed across a broad zone of minor shearing, could sufficiently deform the waste-emplacement boreholes through a closure of the air gap surrounding the waste packages such that the waste packages would fail through bending. Activities 8.3.1.8.2.1.6 and 8.3.1.8.2.1.1 will address this initiating event and satisfy parameter 6. These activities will collect data on rates and amount of post-Miocene folding in the repository horizon by reviewing the detailed geologic and structure contour maps of the repository horizon generated by Program 8.3.1.4. Rates of deformation will then be calculated using these data, and a probability of significant waste package failure due to deformation processes calculated.

DRAFT

8.3.1.8.3 Investigation: Studies to provide information required on changes in unsaturated and saturated zone hydrology due to tectonic events

Technical basis for obtaining the information

Links to the technical data chapters and applicable support documents

The following sections of the SCP data chapters provide a technical summary of existing data relevant to this investigation:

SCP section	Subject
1.3.2.1	Volcanic history
1.3.2.2	Structural history
1.3.2.3	Existing stress regime
1.5.1.2	Basaltic volcanism
1.5.2	Faulting

DRAFT

SCP section	Subject
3.6	Regional hydrogeologic reconnaissance of candidate area and site
3.9	Site hydrogeologic system

Parameters

The following performance parameters will be measured or calculated as a result of the site studies planned as part of this investigation:

1. Annual probability of volcanic events within the controlled area.
2. Effects of a volcanic event on topography and average flux rates.
3. Annual probability of significant igneous intrusion within 0.5 km of the controlled area.
4. Effects of an igneous intrusion on average flux rates.
5. Probability of offset more than 2 m on a fault in the controlled area in 10,000 yr.
6. Probability of changing dip by greater than 2 degrees in 10,000 yr by faulting.
7. Effect of faulting on average flux rates.
8. Probability of changing dip by greater than 2 degrees in 10,000 yr by folding.
9. Probability of exceeding 30 m of altitude change in 10,000 yr.
10. Barrier-to-flow effects of igneous intrusions on water-table levels and hydraulic gradients.
11. Thermal effects of igneous intrusions on water-table levels and hydraulic gradients
12. Probability that strain-induced changes will increase potentiometric level to greater than 850 m mean sea level (MSL).
13. Probability that repository will be lowered by 100 m through action of folding, uplift, or subsidence in 10,000 yr.
14. Probability of total offsets more than 2.0 m in 10,000 yr on a fault within 0.5 km of controlled area boundary.
15. Effects of fault offset on water-table levels and hydraulic gradient.
16. Effects of igneous intrusions on local fracture permeabilities and effective porosities.

DRAFT

17. Annual probability of faulting events on Quaternary faults within 0.5 km of controlled area boundary.

18. Effects of fault motion on local fracture permeabilities and effective porosities.

19. Effects of changes of stress or strain on hydrologic properties of the rock mass.

Purpose and objectives of the investigation

The 19 performance parameters listed above have been identified by Issue 1.1 (Section 8.3.5.13 and Tables 8.3.1.8-3 to 8.3.1.8-5) to address the possibility that tectonic processes and events could produce the following changes in existing hydrologic conditions:

1. Alteration of average percolation flux over the repository.

2. Changes in water table altitude that affect the length of the unsaturated zone travel path or hydraulic gradients.

3. Alteration of rock hydrologic properties along significant travel paths.

The three studies in this investigation will provide assessments of the likelihood and magnitude of these hydrologic changes for use by Issue 1.1 in analysing total system performance of the repository in limiting radionuclide releases to the accessible environment. Several of the initiating events considered in this investigation probably will have no significant impact on repository performance because of the very low rates at which the related tectonic processes operate at Yucca Mountain (e.g., folding, uplifting, and subsidence). It is anticipated that little or no additional data will be required to complete the assessments of the initiating events related to these tectonic processes. The level of effort for the activities related to these initiating events is therefore anticipated to be low and to consist primarily of organizing and presenting existing data in order to provide the basis for eliminating these initiating events from consideration during performance assessment evaluations.

This investigation will also provide data on the nature of tectonic processes operating at the site for use by Issue 1.8 (Section 8.3.5.17, NRC siting criteria) in its analysis of favorable and potentially adverse conditions. The specific conditions addressed by this investigation are listed on Tables 8.3.1.8-3 to 8.3.1.8-5.

Technical rationale for the investigation

The flow of data and interconnections between activities in each study are shown on Figures 8.3.1.8-5 to 8.3.1.8-7. Study 8.3.1.8.3.1 considers the initiating events that may affect the average percolation flux over the repository. The first initiating event considered in this study is the possibility that volcanic events may alter topography as a result of the extrusion of volcanic flows or other effects and create impoundments or

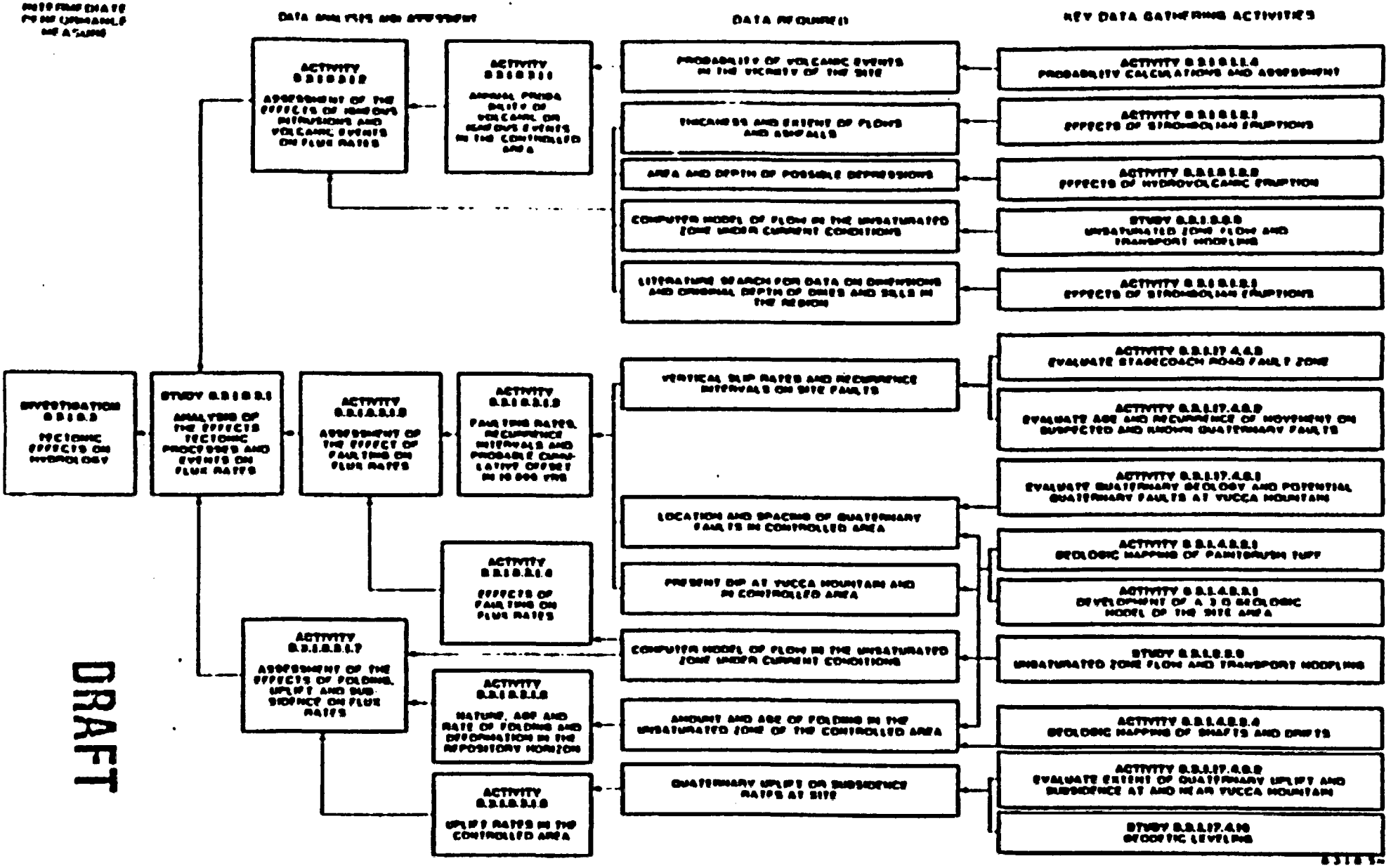


Figure 8.3.1.8-5. Logic diagram for Study 8.3.1.8.3.1 (analysis of the effects of tectonic processes and events on flux rates)

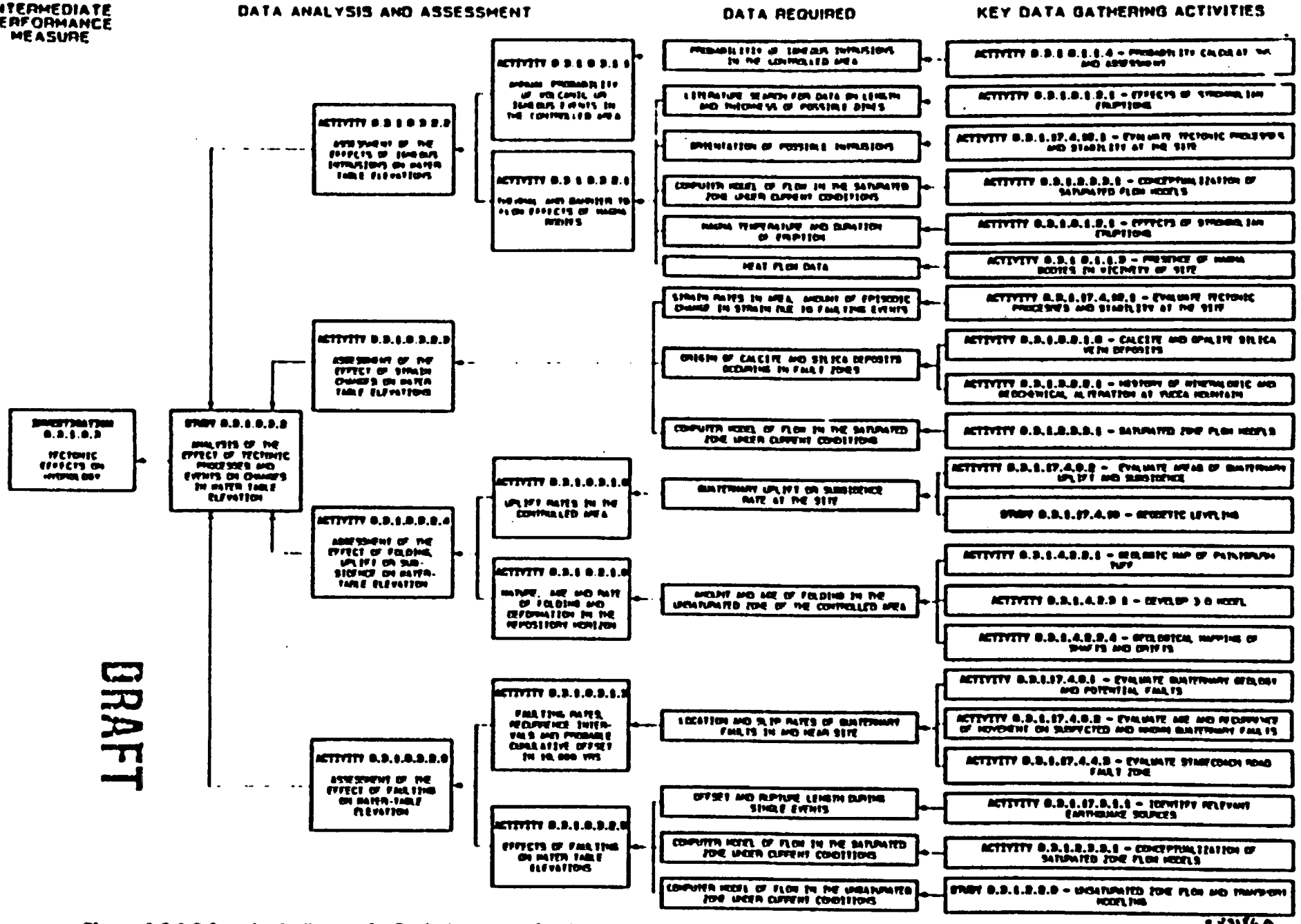


Figure 8.3.1.8-6. Logic diagram for Study 8 3 1 8 3 2 (analysis of effects of tectonic processes and events on changes in water-table elevation)

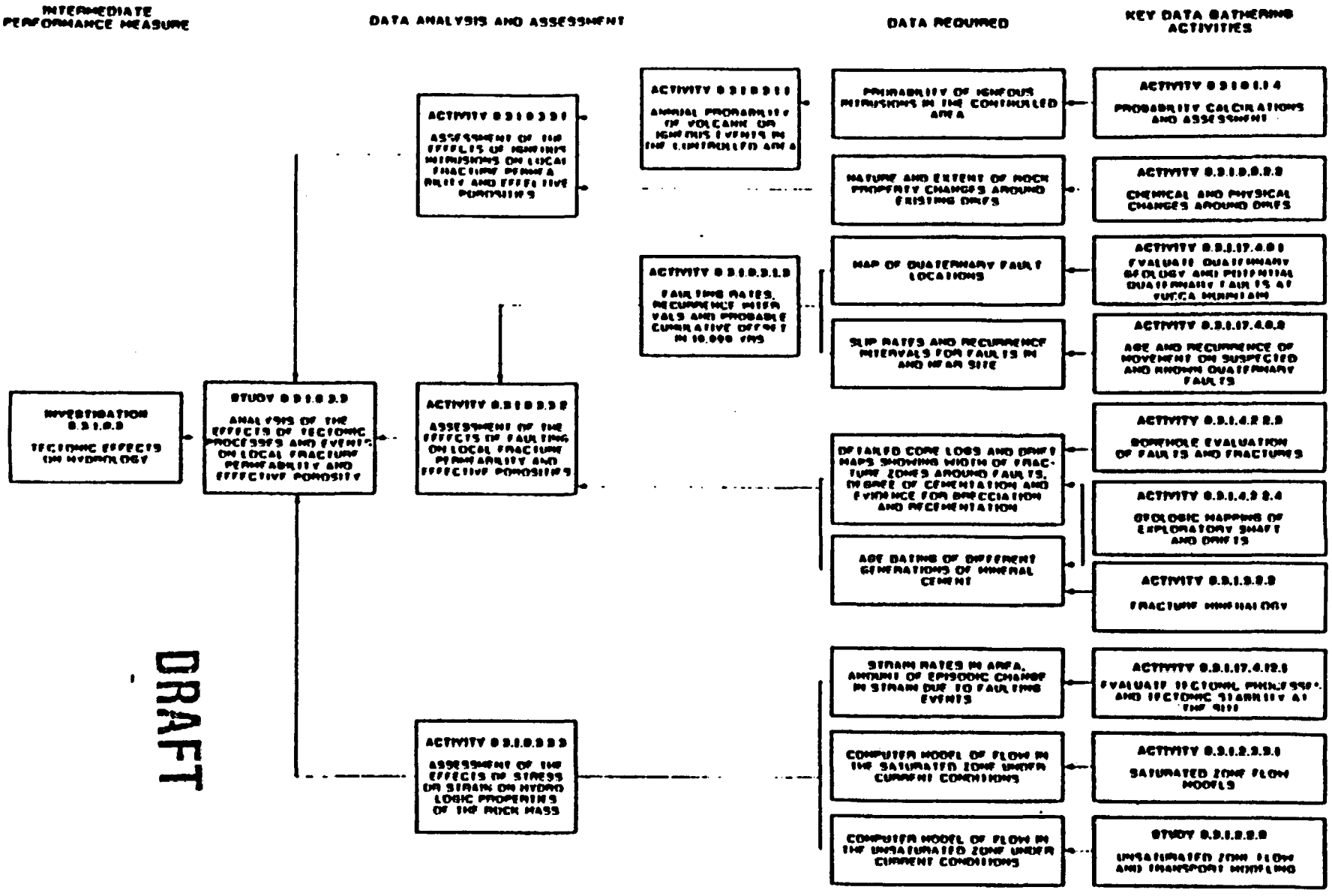


Figure 8.3.1.8-7. Logic diagram for Study 8 3 1 8 3 3 (effects of faulting on local fracture permeability and effective porosity)

diversions of drainage that could adversely affect average percolation flux rates. The second initiating event considers the possibility that an igneous intrusion such as a sill intruded above the repository horizon could divert downward percolating waters to the area above the repository and thereby increase average percolation flux rates. The first two activities in the study address these initiating events and will satisfy parameters 1 to 4. Activity 8.3.1.8.3.1.1 will use data from Activity 8.3.1.8.1.1.4 to calculate the probability of igneous events occurring in the larger area encompassing the controlled area and a buffer zone. Activity 8.3.1.8.3.1.2 will summarize the available data on the size and location of volcanic and igneous features that could occur in the area. This activity will also perform modeling studies to estimate the amount of change in flux rates that could occur as a result of an igneous event. The activity will then use this data and the data from Activity 8.3.1.8.3.1.1 to (1) provide an assessment of the possibility that significant changes could result from these initiating events and (2) prepare a report.

The third initiating event considered by Study 8.3.1.8.3.1 is the possibility that fault offset could affect average percolation flux rates. Effects to be considered include surface topographic changes such as the creation of a scarp that could create impoundments or divert drainage; and subsurface changes, such as the juxtaposition of units of different hydrologic properties or change in the dip of beds that could create perched aquifers or divert subsurface drainage toward the repository. Activity 8.3.1.8.3.1.3 will collect and summarize field data gathered by other activities and calculate slip rates, recurrence intervals and probable cumulative offset in 10,000 yr for faults in and near the controlled area. Activity 8.3.1.8.3.1.4 will perform hydrologic modeling studies to estimate the effect of faulting on flux rates. Activity 8.3.1.8.3.1.5 will use the data generated by the previous two activities to (1) generate an assessment of the effect of probable fault movement on flux rates that will satisfy parameters 5 to 7 and (2) prepare a report.

The fourth initiating event considers the possibility that folding processes could change the dip of beds in the repository area sufficiently to alter flux rates. This could occur where downward percolating waters are diverted laterally at the contact with a low permeability unit. The laterally moving waters at the contact could be diverted toward the repository by folding, thereby increasing repository flux rates. The fifth initiating event considers the possibility that rapid rates of area-wide uplift or subsidence could alter drainage patterns or gradients sufficiently to affect flux rates. These initiating events and parameters 8 and 9 associated with them will be addressed by Activities 8.3.1.8.3.1.6 and 8.3.1.8.3.1.7. Activity 8.3.1.8.3.1.6 will collect and summarize field data from other activities and calculate uplift and subsidence rates for the area including the site. Activity 8.3.1.8.3.1.7 will use these rates and rates of folding calculated by other activities to estimate the amount of folding uplift and subsidence expected in 10,000 yr. The activity will then (1) perform an assessment of the effect of these changes on average percolation flux rates using hydrologic modeling techniques and (2) summarize the assessment in a report.

DRAFT

Study 8.3.1.8.3.2 will analyze the possibility that tectonic processes and events could cause changes in the elevation of the water table or the potentiometric surface of confined aquifers. Rises in the water table would shorten the length of the unsaturated zone travel path and affect release rates. Such rises could also change the hydraulic gradient, alter the location of discharge points, or create perched aquifers in the area of the site. These effects could affect groundwater travel times or place locally saturated zones in close proximity to the waste. Four initiating events have been identified in connection with this study (Table 8.3.1.8-4).

The first initiating event considers the possibility that igneous intrusions could affect water table elevations by creating barriers to flow such as a dike or creating thermally driven circulation systems that could cause water to rise to repository levels as the result of an intrusion or volcanic event. Activity 8.3.1.8.3.2.1 will collect and summarize data from other activities (Figure 8.3.1.8-6) on the dimensions and orientations of probable intrusions and the thermal effects around such intrusions. Hydrologic models of existing conditions at Yucca Mountain will then be used to estimate the magnitude of the changes that could result from igneous events. Activity 8.3.1.8.3.2.2 will take the results of this activity and combine them with data on the probability of such intrusions (Activity 8.3.1.8.3.1.1) to produce an assessment of the effects igneous intrusions would have on water table levels and will satisfy parameters 10 and 11. This activity will also prepare a report summarizing the results of the assessment.

The second initiating event considers the possibility that episodic movement on faults could result in variations in stress and strain levels in the rock mass that produce relatively short-lived fluctuations in water-table or potentiometric levels. If these fluctuations are great enough, these episodic changes could result in the periodic saturation of the repository horizon due to a general rise in the water table or water moving upward along a conduit such as a fault from a confined aquifer. Activity 8.3.1.8.3.2.3 will provide an assessment of the probability and magnitude of these effects and satisfy parameter 12. The activity will collect data on strain rates in the region and calculate the amount and nature of expected changes during a faulting event. Modeling studies will then be performed to analyze the amount of water table fluctuation that could be expected. The assessment will also include a consideration of the field evidence that significant water-table or potentiometric surface fluctuations have occurred in the past near Yucca Mountain. The activity will also prepare a report summarizing the assessment and the supporting data.

The third initiating event considers the possibility that folding, uplift, or subsidence could significantly change the position of the repository with respect to the water table in 10,000 yr. Activity 8.3.1.8.3.2.4 will review the data collected by other activities on the rates of folding, uplift, and subsidence in the area to provide an assessment of the probability of significant changes of this type and satisfy parameter 13.

The fourth initiating event considers the possibility that offset on faults could be great enough to juxtapose lithologic units of differing hydrologic properties and produce changes in ground-water flow that result in

DRAFT

rises in the water table or the creation of perched aquifers. Activity 8.3.1.8.3.2.5 will conduct a hydrologic modeling study to estimate the amount of change in water table levels that could be expected for a range of displacements. Activity 8.3.1.8.3.2.6 will combine this data with data on the probability of significant offsets (Activity 8.3.1.8.3.1.3) to produce an assessment of the probability of significant changes in water levels in a 10,000-yr period and satisfy parameters 14 and 15. The activity will also produce a report summarizing the data and the results of the assessment.

Study 8.3.1.8.3.3 will consider the possibility that tectonic processes and events could alter the rock properties governing ground-water flow along significant travel paths. The initiating events are related to events or processes that could produce local changes in the saturated fracture permeability or fracture effective porosity. If such changes were to occur, they could result in the formation of barriers to ground-water flow or the creation of conduits to enhanced flow that could adversely affect the containment or transport rate of wastes. Three initiating events have been identified under this study (Table 8.3.1.8-5).

The first initiating event considers the possibility that an igneous intrusion could cause changes in the physical properties of the surrounding rocks. Activity 8.3.1.8.3.3.1 will collect and summarize data from the literature and field data gathering activities on the effects of the intrusion of dikes and sills in tuffs (Figure 8.3.1.8-7). This data will be combined with data on the probability of such intrusions in the controlled area (Activity 8.3.1.8.3.1.1) to produce an assessment that satisfies parameter 16 on the expected changes in local fracture permeability and fracture effective porosity resulting from igneous intrusions. The activity will result in a report summarizing the data and the results of the assessment.

The second initiating event considers the possibility that periodic offset on Quaternary faults in and near the controlled area could cause temporary changes in physical properties along the fault. These changes could result in the fault becoming a barrier to lateral ground-water flow or a conduit to vertical flow until mineralization or other processes return conditions to present values. Activity 8.3.1.8.3.3.2 will collect and summarize data from other activities on the width of fracturing around fault zones and evidence of significant fracturing and recementation along faults. These data will then be used to predict the variation in physical properties that can occur along faults through the faulting cycle. This information will then be combined with data on the probability of faulting events in the controlled area (Activity 8.3.1.8.3.1.3) to produce an assessment of the effects of the initiating event and satisfy parameters 17 and 18. The activity will also produce a report summarizing the data and the results of the assessment.

The third initiating event considers the possibility that episodic faulting, folding, uplift, or subsidence could result in cyclic changes in the physical properties of the rock mass because of changes in the stress and strain regime. Activity 8.3.1.8.3.3.3 will address this possibility and satisfy parameter 19 by summarizing data on strain rates in the area and modeling the changes in rock fracture permeability and porosity that could

DRAFT

result. The activity will also produce a report summarising the data and the results of the assessment.

DRAFT

8.3.1.8.4 Investigation: Studies to provide information required on changes in rock geochemical properties resulting from tectonic processes

Technical basis for obtaining the information

Links to the technical data chapters and applicable support documents

The following sections of the SCP data chapters provide a technical summary of existing data relevant to this investigation:

DRAFT

SCP section	Subject
1.3.2.1	Volcanic history
1.3.2.2	Structural history
1.5.1.2	Basaltic volcanism
1.5.2	Faulting
4.1.3.7	Geochemical retardation of the host rock and surrounding units--anticipated conditions
4.1.3.8	Geochemical retardation of the host rock and surrounding units--unanticipated conditions
4.4.2	Potential effects of natural changes

Parameters

The following performance parameters will be measured or calculated as a result of the site studies planned as part of this investigation:

1. Effects of igneous intrusions on local distribution coefficients.
2. Degree of mineralogic change in fault zones in 10,000 yr.
3. Effects of fault offset on travel pathway.
4. Degree of mineralogic change in the controlled area resulting from changes in water-table level or flow paths due to tectonic processes in 10,000 yr.

Purpose and objectives of the investigation

The four performance parameters listed in the previous section have been identified by Issue 1.1 (Section 8.3.5.13, total system performance, and Table 8.3.1.8-6) to address the possibility that tectonic processes and events could produce significant changes in the geochemical properties of the rocks of the controlled area that control the rate of radionuclide movement (distribution coefficients (K_ds)). The study and activities in this investigation will address these requirements by providing assessments of the probability that the tectonic initiating events that have been recognized by Issue 1.1 could significantly alter distribution coefficients. These results will be used by Issue 1.1 to analyze total system performance of the repository in limiting radionuclide releases to the accessible environment. The initiating events considered in this investigation probably will have no significant impact on repository performance because of the very low rate at which mineral alteration occurs in the site area (see Section 4.1.1.4). It is anticipated that the data to be gathered in the geochemistry program (Section 8.3.1.3) to address other concerns will provide the data necessary to evaluate the rate of geochemical change. The level of effort for the activities related to these initiating events is therefore anticipated to be

DRAFT

low and to consist primarily of organizing and presenting the data collected in other programs to provide the basis for evaluating the credibility of the initiating events in performance assessment activities.

This investigation will also provide data on the nature of tectonic processes operating at the site for use by Issue 1.8 (Section 8.3.5.17, NRC siting criteria) in its analysis of favorable and potentially adverse conditions. The specific conditions addressed by this investigation are listed on Table 8.3.1.8-6.

Technical rationale for the investigation

The flow of data and interconnections between activities in the single study of this investigation are shown on Figure 8.3.1.8-8. The first tectonic initiating event considered in this investigation is the possibility than an igneous intrusion could alter the mineralogy of the surrounding host rocks. Activity 8.3.1.8.4.1.1 will provide an assessment of this initiating event and satisfy parameter 1 by considering (1) the probability of an igneous intrusion occurring in the controlled area and (2) the extent and nature of mineral changes that have been found to occur around dikes and sills in tuffs during field studies. The activity will combine these data in an assessment of the probability that significant changes would occur.

The second initiating event considers the possibility that offset on a fault could result in significant mineral changes along the fault that could affect local distribution coefficients. Changes in distribution coefficients could result from the growth of mineral fillings in the fault zone itself or from the sealing effect of the mineral fillings that prevent interaction between fluids moving through the fault zone and the surrounding country rock. Activity 8.3.1.8.4.1.2 will provide an assessment of this initiating event and satisfy parameter 2 by analyzing data from core and the mapping of drifts and shafts to review the evidence of significant changes during past faulting events to determine the age, type, and extent of mineral changes that have occurred. The probability and location of faulting events will be determined from mapping and trenching activities that will provide data on slip rates, recurrence intervals, and locations of Quaternary faults. The assessment will integrate these data.

The third initiating event considers the possibility that offset on a fault could significantly affect distribution coefficients by diverting flow to pathways with significantly different mineral properties or water chemistry as a result of the juxtaposition of different lithologic units. Activity 8.3.1.8.4.1.3 will provide an assessment of this initiating event and satisfy parameter 3 by conducting modeling studies to determine the amount of offset necessary to produce significant changes. The results of the modeling activity will be combined with the probability that such offsets could occur using data on slip rates and recurrence intervals of faults in and near the controlled area as part of the assessment. The activity will summarize the results of the assessment in a report.

The fourth initiating event considers the possibility that changes in water-table levels or ground-water movement as a result of tectonic processes could produce significant mineral alteration in the formerly unsaturated rocks. Activity 8.3.1.8.4.1.4 will provide an assessment of this initiating

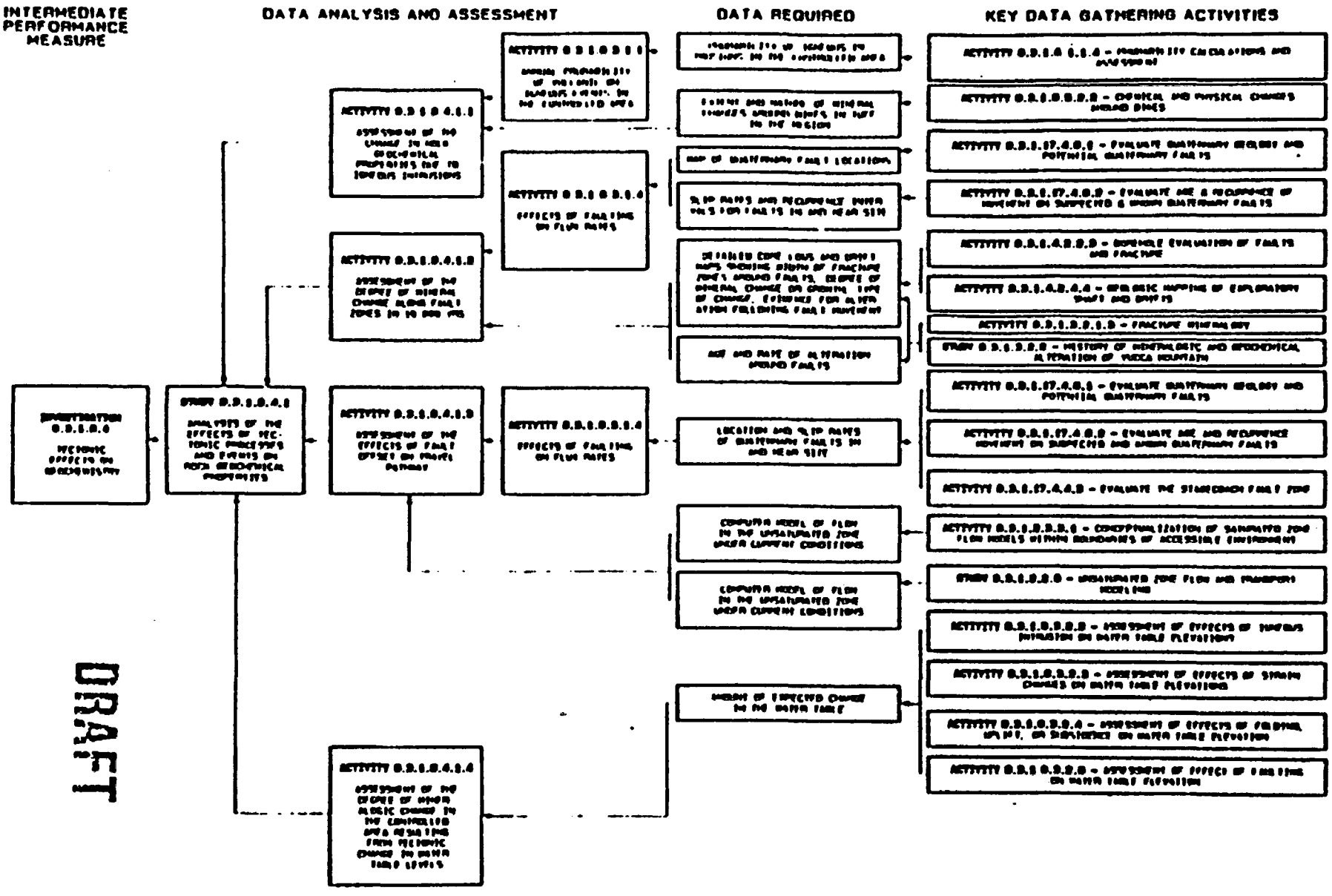


Figure 8.3.1.8-8. Logic diagram for Study 8 3 1 8 4 1 (analysis of the effects of tectonic processes on rock geochemical properties)

DRAFT

event and partially satisfy parameter 4 by calculating the probability of significant faulting events and the nature of water-table fluctuations that could be expected from such events. Activity 8.3.1.3.7.1.2 will complete the characterization of this parameter by calculating the rate that mineral changes could occur in this environment using data on the history of mineral and geochemical alteration at Yucca Mountain and incorporating the results in the integrated geochemical transport calculations. These data will be combined with the results of Study 8.3.1.8.3.2 on the probability of significant water-level changes occurring as the result of tectonic processes to complete the assessment. The activity will summarize the results of the assessment in a report.

DRAFT

8.3.1.8.5 Investigation: Studies to provide the information required by the analysis and assessment investigations of the tectonics program

Technical basis for obtaining the information

Links to the technical data chapters and applicable support documents

The following sections of the SCP data chapters provide a technical summary of existing data relevant to this investigation:

DRAFT

SCP section	Subject
1.3.2.1	Volcanic history
1.3.2.2	Structural history
1.5.1	Volcanism

Parameters

The following parameters will be measured or calculated during the studies planned to satisfy this investigation:

1. Location, age, and volume of igneous deposits younger than 4 million yr and within 70 km of the site.

2. Detailed maps showing the relation of geologic structures to selected young volcanic centers.

3. Map showing depth to Curie isotherm.

4. Chemical and physical changes around dikes in tuff.

5. Petrology and geochemistry of late Cenozoic volcanic rocks in the region.

6. Evaluation of folding in the region and its relation to faulting or detachments.

7. Evaluation of heat-flow data.

Purpose and objectives of the investigation

The studies and activities in this investigation will collect the field data called for by the analysis and assessment activities in Investigations 8.3.1.8.1 through 8.3.1.8.4. Because most of the data required by these analysis and assessment activities are being collected by other programs, the activities in this investigation are limited to a small number providing data to support the analysis of volcanic, igneous intrusion, and folding processes. Figures 8.3.1.8-3 through 8.3.1.8-8 and Tables 8.3.1.8-1 through 8.3.1.8-6 show the relationship of the data gathering activities in this section to the analysis and assessment investigations.

Technical rationale for the investigation

One of the main requirements in the evaluation of the hazard of volcanic or igneous events is the calculation of the probability that such events would actually occur in the repository or the controlled area. Parameter 1 indicates the data required by Activities 8.3.1.8.1.1.1 and 8.3.1.8.1.1.4 to carry out this calculation. Activities 8.3.1.8.5.1.1 through 8.3.1.8.5.1.4 are designed to improve the existing data base on the age, location, and volume of young volcanic and igneous rocks in the region surrounding the site. These activities refine the dating of known occurrences using a

DRAFT

variety of techniques, many of which have not previously been employed, and determine by drilling the nature of suspected buried deposits.

Another concern related to the probability of volcanism in the site area is that the location of any intrusion may not be entirely random across the area but controlled by structural features. To address this possibility, parameter 2 has been identified as one of the data requirements of Activity 8.3.1.8.1.1.2. Activity 8.3.1.8.5.1.3 will satisfy the requirement by completing detailed geologic mapping around selected volcanic features to clarify the relationship that might exist between the volcanic features and local structures. Parameter 5 has also been identified as a data requirement of Activity 8.3.1.8.1.1.2; this parameter will be used to address tectonic models for the time-space patterns of igneous events in the Yucca Mountain area and the structural controls for volcanic sites or future volcanic sites at or adjacent to Yucca Mountain. These data will be factored into probability calculations. Activity 8.3.1.8.5.1.5 will evaluate petrologic and volume trends of volcanic fields through time to test for indications of waning volcanism or increases in the rate of eruptive activity associated with decreasing eruption volumes.

For data on thermal anomalies in the area that might be related to magma bodies that could be sources of volcanic or igneous activity, parameters 3 and 7 have been identified as a data requirements of Activity 8.3.1.8.1.1.3. Activities 8.3.1.8.5.2.1 and 8.3.1.8.5.2.3 will satisfy the requirement by generating maps showing the depth to the Curie isotherm and heat-flow data in the area surrounding the site.

Parameter 4 has been identified as a data requirement of both Activities 8.3.1.8.3.3.1 and 8.3.1.8.4.1.1 and will provide information on the nature and extent of physical and geochemical changes around dikes and other intrusions. Activity 8.3.1.8.5.2.2 will satisfy this requirement by collecting the required data from field studies of known intrusions in the region around the site and from literature reviews.

Parameter 6 will provide general regional data on the relationship of Neogene folding in the region to faults and detachments. Activity 8.3.1.8.5.3.1 will satisfy this parameter by reviewing the available literature and possible detailed mapping in selected areas.

DRAFT

8.3.1.17 Overview of preclosure tectonics: Description of tectonic and igneous events required by performance and design requirements

Summary of performance and design requirements for preclosure tectonics information

The preclosure tectonics program (Program 8.3.1.17) is designed to develop an understanding of and to characterize the tectonic events and processes that could impact proposed repository structures, systems, or components considered to be important to safety through the operational phase; i.e, until permanent closure is achieved. In addition, characterizations of tectonic processes and events will be developed for consideration in the design and operation of certain structures, systems, and components required for exercising the retrieval option. Tectonic processes and events that are relevant to waste isolation following permanent closure will be investigated within the postclosure tectonics program (Program 8.3.1.8).

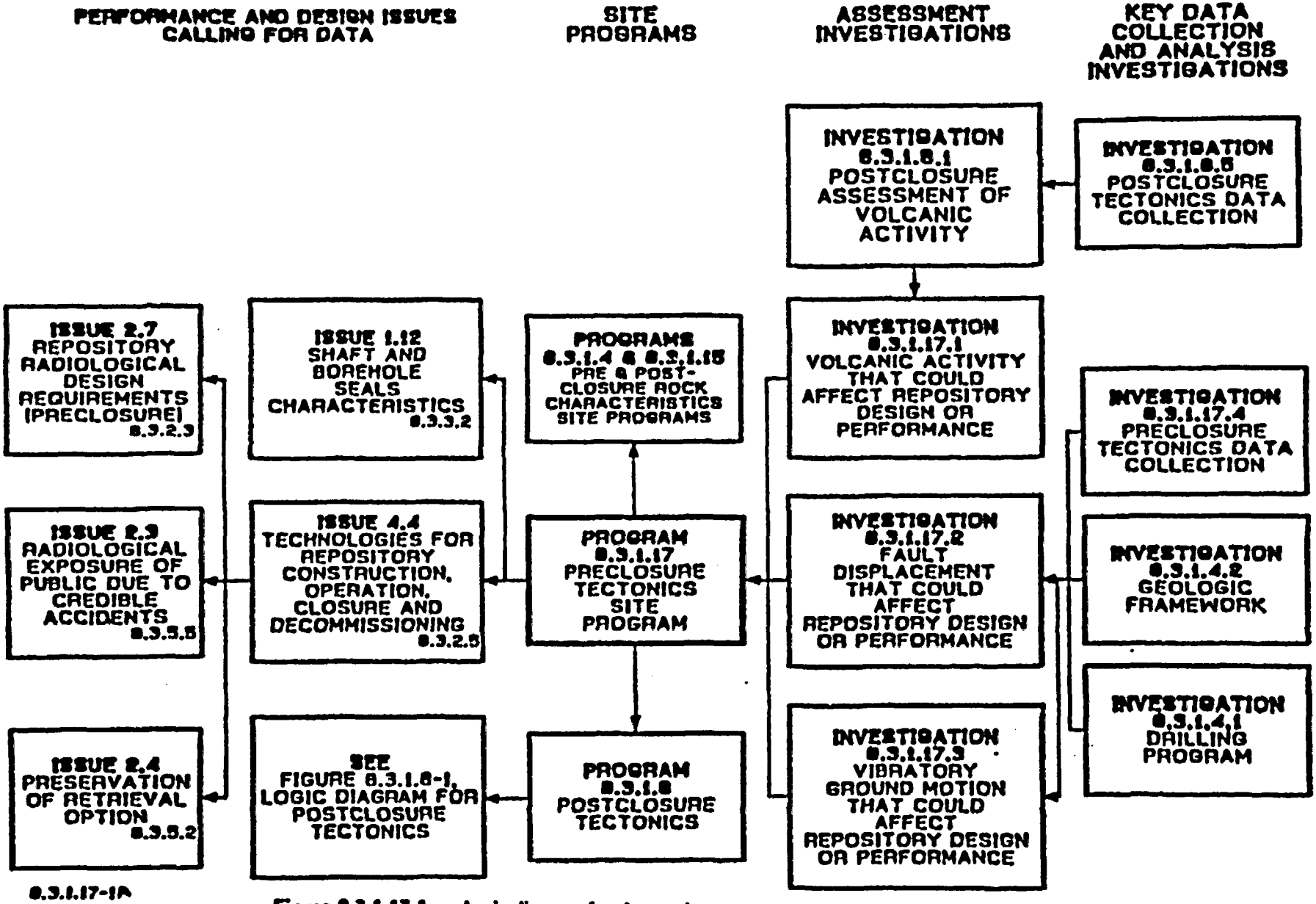
Performance and design issues that require data from the preclosure tectonics program are indicated in the left half of Figure 8.3.1.17-1; the right half of the figure indicates investigations that provide the requested data. Data requirements come from Issue 4.4 (Section 8.3.2.5), which evaluates the technical feasibility of repository construction, operation, closure, and decomissioning, and from postclosure Issue 1.12 (Section 8.3.3.2), which considers the design of seals for shafts, drifts, and boreholes. Investigations of technical feasibility include data requirements from three additional performance and design issues, also noted in Figure 8.3.1.17-1. These three issues are preclosure radiological safety (Issue 2.7, Section 8.3.2.3), potential radiologic exposure to the public due to credible accidents (Issue 2.3, Section 8.3.5.5), and prtservation of the waste retrieval option (Issue 2.4, Section 8.3.5.2). In addition, data developed by the preclosure tectonics program will be used by the postclosure tectonics program (Programs 8.3.1.8) and the preclosure and postclosure rock characteristics programs (Programs 8.3.1.15 and 8.3.1.4).

The evaluation of technical feasibility (Issue 4.4, Section 8.3.2.5) establishes the major requirement for characterizing potentially disruptive tectonic events.

The required characterization data are summarized in the (a) parts of Tables 8.3.1.17-1 through 8.3.1.17-6; the (b) parts of these tables provide summary information on the characterization program designed to provide the required data. The technical content of these tables is discussed in detail below. The data requirements are organized by the type of potential tectonic event: volcanic, including eruption and ashfall; faulting; and vibratory ground motion from natural earthquakes and underground nuclear explosions. Two tables are presented for each type of event, one for considerations of surface facilities and one for underground facilities.

The following information is used to specify each data requirement: design and performance parameter, to specify the type of data that is required; goal, to establish the precision or level of conservatism that is required; and needed confidence, to indicate the degree of certainty that the goal will be met. The needed confidences are specified using the terms high, medium, and low to denote the relative importance of each parameter-goal pair

DRAFT



8.3.1.17-1A

Figure 8.3.1.17-1. Logic diagram for the preclosure tectonics site program.

Table 8.3.1.17 1(a). Design and performance parameters related to surface facilities and preclosure volcanic activity

Design or performance parameter[a]	Goal	Needed confidence	Characterization parameters
Probability of volcanic eruption that would disrupt surface facilities	Less than 1 chance in ~~1,000~~ *10,000* in 100 yr	High	Annual probability of volcanic eruption at the site
Design-basis ash-fall thickness for facilities important to safety (FITS) ventilation systems	Less than 1 chance in 10 of exceeding design-basis ash fall thickness in 100 yr	Low to Medium	Probability of [illegible] at the site as a function of ash-fall thickness 1,000 yr(±) ash-fall thickness at the site
Ash-fall particle density and size distribution	TBD[b]	Low to Medium	Potential density and distribution of ash-fall particles

[a]These parameters are from Issue 4.4 (technical feasibility, Section 8.3.2.5), and corresponding performance measures are given in that issue.
[b]TBD is to be determined.

Table 8.3.1.17-1(b). Characterization parameters related to surface facilities and preclosure volcanic activity

Characterization parameters	Testing basis			Key studies/activities supplying parameters
	Current estimate (range)	Confidence in current estimate	Needed confidence in final values	
Annual probability of volcanic disruption at the site	10^{-7} to 10^{-9} per yr	Moderate	Medium to high	8.3.1.8.1.1.4 (Probability calculation (of volcanic disruption) and assessment)
Probability of ash fall at the site as a function of ash-fall thickness	TBD[a]	TBD	Low to medium	8.3.1.17.1.1.2 (Assess potential ash-fall thickness at the site)
1,000 yr(•) ash-fall thickness at the site	0.1–2.0 cm	Low	Low to medium	8.3.1.17.1.1.2 (Assess potential ash-fall thickness at the site)
Potential density and distribution of ash-fall particles	TBD	TBD	Low to medium	8.3.1.17.1.1.3 (Assess potential density and particle size distribution of ash-fall at the site)

[a]TBD = to be determined.

Table 8.3.1.17-2(a). Design and performance parameters related to underground facilities and preclosure volcanic activity

Design or performance parameter[a]	Goal	Needed confidence	Characterization parameters
Probability of volcanic eruption through the underground facilities	Less than 1 chance in ~~1,000~~ 10,000 in 100 yr	High	Annual probability of volcanic disruption of the underground facilities
Design-basis ash-fall thickness (at ventilation shaft locations)	Less than 1 chance in 10 of exceeding design-basis ash fall thickness in 100 yr	Low to Medium	Probability of ash fall at the site as a function of ash-fall thickness 1,000-yr(+) ash-fall thickness at the site
Ash-fall particle density and size distribution	TBD[b]	Low to Medium	Potential density and size distribution of ash-fall particles

[a]These parameters are from Issue 4.4 (technical feasibility, Section 8.3.2.5), and corresponding performance measures are given in that issue.
[b]TBD = to be determined.

Table 8.3.1.17-2(b). Characterization parameters related to underground facilities and preclosure volcanic activity

Characterization parameters	Testing basis: Current estimate (range)	Testing basis: Confidence in current estimate	Testing basis: Needed confidence in final values	Key studies/activities supplying parameters
Annual probability of volcanic disruption of the underground facilities	4.7×10^{-8} to 3.3×10^{-8} per yr	Medium	Medium to high	8.3.1.8.1.1.4 -- Probability calculation (of volcanic disruption) and assessment
Probability of ash fall at the site as a function of ash-fall thickness	TBD[a]	TBD	Low to medium	8.3.1.17.1.1.2 -- Assess potential ash-fall thickness at the site
1,000 yr(•) ash-fall thickness	0.1-2.0 cm	Low	Low to medium	8.3.1.17.1.1.2 -- Assess potential ash-fall thickness at the site
Potential density and size distribution of ash-fall particles	TBD	TBD	Low to medium	8.3.1.8.1.1.3 -- Assess potential particulate size distribution of ash-fall at the site

[a]TBD = to be determined.

Table 8.3.17-3(a). Design and performance parameters related to surface facilities and preclosure fault displacement. (page 1 of 2)

Design or performance parameter[a]	Goal	Needed confidence	Characterisation parameters
Identification of any fault within 100 m of facilities important to safety (FITS) with greater than 1 chance in 100 of producing more than 8 cm of surface offset during the preclosure period (approximately 100 yr)	Determine existence	High	Identification and characterisation of potentially significant Quaternary faults within 5 km of FITS
If existence is determined, establish			
Identification	Standard practice	High	Identification and characterisation of faults within 100 m of FITS that have apparent Quaternary slip rates >0.001 mm/yr or that measurably offset materials less than 10,000 yr old
Location at surface	±5 m	High	
Orientation at surface	±10°	High	

Table 8.3.P.17-3(a). Design and performance parameters related to surface facilities and preclosure fault displacement (page 2 of 2)

Design or performance parameter	Goal	Needed confidence	Characterization parameters
Total probability of exceeding 5 cm fault displacement at location proposed for FITS	Less than 1 chance in 100 of exceeding 5 cm displacement beneath surface FITS in 100 yr	High	Estimate of total probability for >5 cm displacement beneath FITS, considering known and possibly concealed faults and tectonic interrelationships among local faults

[1] These parameters are from Issue 4.4 (technical feasibility, Section 8.3.2.5), and corresponding preclosure measures are given in that issue.

Table 8.3.1.17.3(b). Characterization parameters related to surface facilities and preclosure fault displacement

Characterization parameters	Testing basis: Current estimate (range)	Testing basis: Confidence in current estimate	Testing basis: Needed confidence in final values	Key studies/activities supplying parameters
Identification and characterization of potentially significant Quaternary faults within 5 km of facilities important to safety (FITS)	4 such faults	Low	Medium to high	8.3.1.17.4.6.1 -- Evaluate Quaternary geology and potential Quaternary faults at Yucca Mountain
Identification and characterization of faults within 100 m of FITS that have apparent Quaternary slip rates > 0.001 mm/yr or that measurably offset materials less than 100,000 yr old	No such faults	Low	High	8.3.1.17.4.2.2 -- Conduct exploratory trenching in in Midway Valley
Estimate of total probability for >5 cm displacement beneath FITS, considering known and possibly concealed faults and tectonic interrelationships among local faults	Less than 1 chance in 100 of exceeding 5 cm displacement beneath FITS in 100 yr	Low	High	8.3.1.17.2.1.1 -- Assess the potential for surface faulting at prospective sites of surface FITS

Table 8.3.1.17.4(a). Design and performance parameters related to underground facilities and preclosure fault displacement (page 1 of 2)

Design or performance parameter[a]	Goal	Needed confidence	Characterization parameters
Identification and characterization of significant late Quaternary faults in the repository block:			Surface locations of faults in the repository with > 1 m offset of Quaternary materials or with > 100 m offset of Tertiary rocks
Classification	Standard practice	High	
Location at surface	±5 m	High	
Orientation at surface	±10°	High	
Identification and characterization of any fault within the waste emplacement area with greater than 1 chance in 100 of producing more than 7 cm (waste package air-gap distance) of subsurface offset during the preclosure period (approximately 100 yr)	Determine existence; for any such faults (none are now known to exist), determine location within the waste emplacement area	High	Surface and subsurface locations of faults with Quaternary slip rates > 0.005 mm/yr that intersect underground facilities

DRAFT

Table 8.3.1.17.4(a). Design and performance parameters related to underground facilities and preclosure fault displacement (page 2 of 2)

Design or performance parameter[a]	Goal	Needed confidence	Characterization parameters
Total probability of exceeding 7 cm fault displacement on any fault that intersects areas of waste emplacement	Less than 1 chance in 10 in 100 yr of exceeding 7 cm displacement on any fault that intersects areas of waste emplacement	Medium	Estimated total probability of fault displacement exceeding 7 cm in areas of emplaced waste, considering known and possibly concealed faults and tectonic interrelationships among local faults

[a]These parameters are from Issue 4.4 (Technical Feasibility, Section 8.3.2.5), and corresponding performance measures are given in that issue.

Table 8.3.1.17 4(b). Characterization parameters related to the underground facilities and preclosure fault displacement.

Characterization parameters	Testing basis: Current estimate (range)	Testing basis: Confidence in current estimate	Testing basis: Needed confidence in final values	Key studies/activities supplying parameters
Surface locations of faults in the repository block with >1 m offset of Quaternary materials or with >100 m offset of Tertiary rocks	2 such faults exist	Low to medium	Medium	8.3.1.17.4.6.1 -- Evaluate Quaternary geology and potential Quaternary faults at Yucca Mountain
Surface and subsurface locations of faults with Quaternary slip rates >0.005 mm/yr that intersect underground facilities	No such faults exist	Medium	Medium to High	8.3.1.17.4.6.1 -- Evaluate Quaternary geology and potential Quaternary faults at Yucca Mountain 8.3.1.17.4.6.2 -- Evaluate age and recurrence of movement on suspected and known Quaternary faults within the site area 8.3.1.17.4.7 -- Subsurface geometry and concealed extensions of Quaternary faults at Yucca Mountain
Estimated total probability of fault displacement exceeding 7 cm in areas of emplaced waste, considering known and possibly concealed faults and tectonic interrelationships among local faults	Less than 1 chance in 100 in 100 yr of exceeding 7 cm displacement in areas of emplaced waste	Medium	Medium	8.3.1.17.2.1.2 -- Assess the potential for rupture on faults that intersect underground facilities

Table 8.3.1.17-5(a). Design and performance parameters related to surface facilities and preclosure vibratory ground motion (page 1 of 3)

Design or performance parameter[a]	Goal	Needed confidence	Characterization parameters
Design-basis ground motion time histories (minimum band width = 0.5 to 33 Hz) and corresponding response spectra (at 1 Hz intervals) for surface facilities important to safety (FITS)	Representative of exceptional earthquakes on nearby faults, or maximum potential underground nuclear explosions (UNEs) that could control site ground motion at any frequency between 0.5 and 33 Hz (including any effect of local geology or building embedment.)	Medium to high	Identification of potential earthquake sources in the controlled area Potentially relevant earthquake sources in the region (≥100 km) Magnitude of exceptional earthquakes on local sources Magnitude of exceptional earthquakes on regional sources Maximum future UNE Closest distance of future UNEs Ground motion attenuation with distance Spectral modification due to local geology

VI

DRAFT

8/10/87

Table 8.3.1.17 5(a). Design and performance parameters related to surface facilities and preclosure vibratory ground motion (page 2 of 3)

Design or performance parameter[a]	Goal	Needed confidence	Characterization parameters
			Controlling ground motion event(s)
			Time histories and reponse spectra representative of controlling event(s)
Combined potential for vibratory ground motion at FITS, considering all faults	Less than 1 chance in 10 of exceeding design basis ground motion in 100 yr	Medium to high	Identification of potential earthquake sources in the controlled area
			Potentially relevant earthquake sources in the region (@100 km)
			Earthquake recurrence relationships for local and regional sources
			Ground motion attenuation with distance
			Spectral modification due to local geology
			Ground motion exceedance probabilities

DRAFT

Table 8.3.1.17-5(a). Design and performance parameters related to surface facilities and preclosure vibratory ground motion (page 3 of 3)

Design or performance parameter[a]	Goal	Needed confidence	Characterization parameters
Probability versus peak acceleration, peak velocity, and peak velocity response at selected frequencies, at surface locations of FITS	Values estimated for annual probabilities ranging from 10^{-3} to 10^{-6} per yr	Medium	Identification of potential earthquake sources in the controlled area Potentially relevant earthquake sources in the region (≥100 km) Earthquake recurrence relationships for local and regional sources Ground motion attenuation with distance Spectral modification due to local geology Ground motion exceedance probabilities

[a]These parameters come from Issues 4.4 (technical feasibility, Section 8.3.2.5) and 1.12 (seal characteristics, Section 8.3.3.2), and corresponding performance measures are given in those issues.

DRAFT

Table 8.3.1.17 5(b). Characterization parameters related to surface facilities and preclosure vibratory ground motion (page 1 of 3)

Characterization parameters	Current estimate (range)	Testing basis Confidence in current estimate	Needed confidence in final values	Key studies/activities supplying parameters
Identification of potential earthquake sources in the controlled area	See Chapter 1	Medium	Medium to high	8.3.1.17.3.1.1 -- Identify relevant earthquake sources
Potentially relevant earthquake sources in the region (≥100 km)	See Chapter 1	Low to medium	Medium	8.3.1.17.3.1.1 -- Identify relevant earthquake sources
Magnitude of exceptional earthquakes on local sources	≈ 6 1/2	Low to medium	Medium to high	8.3.1.17.3.1.2 -- Define exceptional earthquakes for relevant sources
Magnitude of exceptional earthquakes on regional sources	6 1/2 to 8 1/2	Low	Medium	8.3.1.17.3.1.2 -- Define exceptional earthquakes for relevant sources
Maximum future underground nuclear explosion (UNE)	150 750 kt	Medium	Medium	8.3.1.17.3.2.2 -- Determine maximum UNE source(s)
Closest distance of future future UNEs	23 km (Buck board Mesa area)	Medium	Medium	8.3.1.17.3.2.2 -- Determine maximum UNE sources

DRAFT

Table 8.3.1.17-5(b). Characterization parameters related to surface facilities and preclosure vibratory ground motion (page 2 of 3)

Characterization parameters	Current estimate (range)	Testing basis Confidence in current estimate	Needed confidence in final values	Key studies/activities supplying parameters
Ground motion attenuation with distance	Published models for California and western U.S.	Low to medium	Medium	8.3.1.17.3.3 -- Ground motion from earthquakes and UNEs
Spectral modification at facilities important to safety due to local geology	1/2 to 4	Low	Medium	8.3.1.17.3.4 Effects of local geology on surface and subsurface motions
Controlling ground motion event(s)	≈ 6 1/2 M earthquake on Paintbrush Canyon	Low to medium	Medium to high	8.3.1.17.3.5.1 -- Identify controlling seismic events
Time histories and response spectra representative of controlling event(s)	THD[a] (0.4 0.6g peak acceleration)	Low to medium	Medium to high	8.3.1.17.3.5.2 -- Characterize ground motion from controlling seismic events
Earthquake recurrence relationships for local and regional sources	See section 1.4.2	Low to medium	Medium	8.3.1.17.3.6.1 -- Evaluate earthquake sources

DRAFT

Table 8.3.1.17 5(b). Characterization parameters related to surface facilities and preclosure vibratory ground motion (page 3 of 3)

Characterization parameters	Current estimate (range)	Testing basis Confidence in current estimate	Needed confidence in final values	Key studies/activities supplying parameters
Ground motion exceedance probabilities	1.5×10^{-4}/yr for 0.5g	Low to medium	Medium	8.3.1.17.3.6.2 -- Evaluate ground motion probabilities

[a]TBD = to be determined.

Table 8.3.1.17-6(a). Design and performance parameters related to underground facilities and preclosure vibratory ground motion (page 1 of 3)

Design or performance parameter[a]	Goal	Needed confidence	Characterization parameters
Design-basis ground motion time histories and corresponding response spectra for underground facilities (at various depths) (minimum band width = 0.5 to 33 Hz; 1 Hz interval for response spectra)	Representative of exceptional earthquakes or nearby faults, or maximum potential underground nuclear explosions (UNEs) that would control site ground motion at any frequency between 0.5 and 33 Hz (including any effects of local geology or depth of burial)	Medium	Identification of potential earthquake sources in the controlled area Potentially relevant earthquake sources in the region (≥100 km) Magnitude of exceptional earthquakes on local sources Magnitude of exceptional earthquakes on regional sources Future maximum UNE Closest distance of future UNEs Ground motion attenuation with distance Spectral modification due to local geology and depth of burial

DRAFT

Table 8.3.1.17-6(a). Design and performance parameters related to underground facilities and preclosure vibratory ground motion (page 2 of 3)

Design or performance parameter[a]	Goal	Needed confidence	Characterization parameters
repre			Controlling ground motion event(s) Time histories and response spectra sentative of controlling event(s)
Combined potential for vibratory ground motion at underground facility locations, considering all faults	Less than 1 chance in 10 of exceeding design basis ground motion in 100 yr	Medium	Identification of potential earthquake sources in the controlled area Potentially relevant earthquake sources in the region (≥100 km) Earthquake recurrence relationships for local and regional sources Ground motion attenuation with distance Spectral modification due to local geology and depth of burial

DRAFT

Table 8.3.1.17-6(a). Design and performance parameters related to underground facilities and preclosure vibratory ground motion (page 3 of 3)

Design or performance parameter[a]	Goal	Needed confidence	Characterization parameters
Probability versus peak acceleration, peak velocity, and peak velocity response at selected frequencies at underground facility locations	Values estimated for annual probabilities ranging from 10^{-3} to 10^{-8} per yr	Low to medium	Ground motion exceedance probabilities Identification of potential earthquake sources in the controlled area Potentially relevant earthquake sources in the region (≥100 km) Earthquake recurrence relationships for local and regional sources Ground motion attenuation with distance Spectral modification due to local geology and depth of burial Ground motion exceedance probabilities

[a]These parameters are from Issues 1.4 (technical feasibility, Section 8.3.2.5) and 1.12 (seal characteristics, Section 8.3.3.2), and corresponding performance measures are given in those issues.

DRAFT

Table 8.3.1.17 6(b). Characterization parameters related to underground facilities and preclosure vibratory ground motion (page 1 of 3)

Characterization parameters	Current estimate (range)	Testing basis Confidence in current estimate	Needed confidence in final values	Key studies/activities supplying parameters
Identification of potential earthquake sources in the controlled area	See Chapter 1	Medium	Medium	8.3.1.17.3.1.1 -- Identify relevant earthquake sources
Potentially relevant earthquake sources in the region (≤100 km)	See Chapter 1	Low to medium	Medium	8.3.1.17.3.1.1 Identify relevant earthquake sources
Magnitude of exceptional earthquakes on local sources	≈ 6 1/2	Low to medium	Medium to high	8.3.1.17.3.1.2 -- Define exceptional earthquakes for relevant sources
Magnitude of exceptional earthquakes on regional sources	6 1/2 to 8 1/2	Low	Medium	8.3.1.17.3.1.2 -- Define exceptional earthquakes for relevant sources
Maximum future underground nuclear explosion (UNE)	150 750 kt	Medium	Medium	8.3.1.17.3.2.2 -- Determine maximum UNE source(s)
Closest distance of future future UNEs	23 km (Buck board Mesa area)	Medium	Medium	8.3.1.17.3.2.2 -- Determine maximum UNE source(s)

DRAFT

Table 8.3.1.17 6(b). Characterization parameters related to underground facilities and preclosure vibratory ground motion (page 2 of 3)

Characterization parameters	Current estimate (range)	Testing basis Confidence in current estimate	Needed confidence in final values	Key studies/activities supplying parameters
Ground motion attenuation with distance	Published models for California and western U.S.	Low to medium	Medium	8.3.1.17.3.3 - Ground motion from earthquakes and UNEs
Spectral modification due to local geology and depth of burial	1/4 to 1	Low	Medium	8.3.1.17.3.4 -- Effects of local geology on surface and subsurface motions
Controlling ground motion event(s)	≈ 6 1/2 M earthquake on Paintbrush Canyon fault	Low to medium	Medium	8.3.1.17.3.5.1 -- Identify controlling seismic events
Time-histories and response spectra representative of controlling event(s)	TBD[a]	Low to medium	Medium	8.3.1.17.3.5.2 -- Characterize ground motion from controlling seismic events
Earthquake recurrence relationships for local and regional sources	See section 1.4.2	Low to medium	Medium	8.3.1.17.3.6.1 -- Evaluate earthquake sources

DRAFT

Table 8.3.1.17.6(b). Characterization parameters related to underground facilities and preclosure vibratory ground motion (page 3 of 3)

Characterization parameters	Current estimate (range)	Testing basis Confidence in current estimate	Needed confidence in final values	Key studies/activities supplying parameters
Ground motion exceedance probabilities	10^{-4}/yr for 0.5g	Low	Low to medium	8.3.1.17.3.6.2 -- Evaluate ground motion probabilities

[a]TBD = to be determined.

for contributing to the resolution of design and performance issues. High confidence indicates that the parameter is of primary importance, and, consequently, that the goal should be met by a characterization of the parameter that conservatively accounts for residual uncertainties. Low confidence indicates that resolution of design and performance issues is not strongly influenced by the parameter and that the goal should be met by a best estimate of the parameter, based on limited data. Medium confidence is used for parameters of intermediate importance.

Investigations performed to satisfy the data requirements will produce information that will also be used by the Postclosure Tectonics Program (8.3.1.8), and conversely, investigations performed by that program will provide information that will be used in the preclosure tectonics program. The postclosure tectonics program requires information on (1) current seismicity, to help evaluate tectonic processes, including the presence of magma bodies; (2) the potential for earthquake ground motions, to support evaluations of the stability of underground facilities; (3) the potential for fault displacement, to support evaluations of possible disruption of waste packages and to support evaluations of possible changes in the hydrologic environment; and (4) tectonic stress and rate of tectonic deformations, to support evaluations of possible changes in the hydrologic environment. The postclosure tectonics program will supply information on the potential for local volcanic eruptions to support the preclosure tectonics program in the characterization of such events. Technical considerations of the information contained in Tables 8.3.1.17-1 through 8.3.1.17-6 are discussed in the next section, on the approach to satisfying the performance and design requirements.

Approach to satisfying performance and design requirements

General methodology

The approach that has been developed to satisfy performance and design requirements is based on current knowledge and uncertainties about the local tectonic environment, and consideration has been given to state-of-the art capabilities for resolving or bounding the effects of these uncertainties. The design and characterization parameters that will be used to satisfy performance and design requirements are listed in Tables 8.3.1.17-1(b) through 8.3.1.17-6(b).

For each data requirement presented in the tables, one or more characterization parameters have been identified to serve as the technical basis for satisfying the requirement. The tables also present current estimates for the characterization parameters (where available and quantifiable) along with assessments of the current confidence in these estimates and the confidences needed to satisfy the data requirement. Differences between the current and needed confidence for each characterization parameter provide a measure of the remaining amount of work that is required to finalize the result. The last column of Tables 8.3.1.17-1(b) through 8.3.1.17-6(b) lists the key studies or activities that will be providing results for each characterization parameter, and the corresponding section numbers where descriptions of these studies and activities are provided. The technical considerations summarized in these tables are discussed below.

DRAFT

The tectonic characteristics of the site will be investigated in sufficient scope and detail to provide reasonable assurance that the processes are understood and that the characterization parameters are determined with the confidences specified in Tables 8.3.1.17-1 through 8.3.1.17-6. The investigations will use data from a variety of sources, including scientific literaure, current and historical seismicity, geologic maps, logs from boreholes and surface trenches, gravity surveys, aeromagnetic and paleomagnetic observations, seismic reflection and refraction profiles, and magnetotelluric soundings.

The planned approach is to use both deterministic and probabilistic methods for analyzing the effects of tectonic events during the preclosure period. The deterministic approach will be used to model cause-and-effect mechanisms and to develop particular tectonic event scenarios in greater detail than is typically provided by probabilistic methods. In addition, all final results for volcanic, faulting, and ground-motion events will be evaluated using probabilistic methods (1) to ensure that adequate consideration is given to the full range of potential tectonic processes and to their associated uncertainties, and (2) to help identify those processes that are key to characterizing the geologic hazards at the site.

Using the deterministic approach, results (e.g., ground motions) will be determined for specific events that are postulated to occur (e.g., an earthquake or an underground nuclear explosion). Judgment is required for postulating the specific source events to ensure adequate conservatism. The deterministic approach will be used to establish ground-motion conditions to be considered in the next phase of design (advanced conceptual design) and, if appropriate, in the final design. This approach is suited to the determination of detailed ground-motion conditions that would likely be produced by postulated earthquakes and underground nuclear explosions (UNEs), including the amplitude and duration of shaking over the frequency band relevant to design. Because source events that will be postulated are not likely to change as more refined fault data become available, the resulting motions are expected to provide a stable basis for use in design.

The probabilistic approach will be used to characterize the range of possible seismic-source interpretations as constrained by contemporary knowledge about the local tectonic framework, including uncertainties. In addition to the cause-and-effect relationships basic to the deterministic approach, the probabilistic approach facilitates consideration of the full range of potential source events (e.g., earthquakes of varying magnitude and distance) in conjunction with probability estimates that the various source events will occur (e.g., spatially varying recurrence relationships for earthquakes of varying magnitude) and probability estimates that a particular outcome will result from the various source events, assuming they do occur. The probabilistic approach will explicitly quantify the effect of including uncertainty in interpretations on the estimated seismic hazard.

The current plan is to apply probabilistic methods for evaluating adequacy of deterministic final results. These methods will also be useful for constraining the technical judgments required for postulating deterministic source events and to help focus field investigations on the resolution of those conditions most relevant to satisfying the performance and design requirements. Probabilistic methods will also be used to provide input for the assessment of risk of accidental release of radionuclides.

DRAFT

Review of the local tectonic environment

Consideration of local faults with evidence of movement during the Quaternary period (about the last 2 million years) is essential to the characterization of the potential for fault displacement and vibratory ground motions at the site of repository facilities. Fault data that are particularly relevant to the characterization approach are reviewed here; more detailed information is presented in Section 1.3.2.2.2.

Figure 8.3.1.17-2 shows north-trending faults with evidence of Quaternary movement on both the east and west side of Yucca Mountain. Midway Valley, the proposed location of the waste handling facilities on the east side of Yucca Mountain, is bounded to the east and west, respectively, by the Paintbrush Canyon and Bow Ridge faults. The Solitario Canyon fault passes just west of the proposed underground facilities, and the Windy Wash fault lies a few kilometers farther to the west. The Ghost Dance fault, on the east side of the repository block, may not have moved in the Quaternary, but evidence confirming this has not yet been obtained.

It is possible that other faults in the site area have experienced movement during the Quaternary period. (The site area is defined here as the rectangular 237 km^2 (91 mi^2) area encompassing the central Yucca Mountain block and its structural and physiographic boundaries (Fortymile Wash, Yucca Wash, Solitario Canyon, and the Stagecoach Road fault.) These faults include the northeast-trending Stagecoach Road and Rock Valley faults and postulated detachment faults (the Rock Valley fault, outside the area shown in figure 8.3.1.17-2, is discussed in Section 8.3.1.17.4.4). The approach discussed here for evaluating faulting and ground motion potential is intended to include conservative characterizations of such faults. As yet unidentified Quaternary faulting is particularly likely at the southern extent of the site area, as discussed subsequently.

The Paintbrush Canyon, Bow Ridge, Solitario, and Windy Wash faults show evidence of normal dip-slip movement along surfaces that dip steeply to the west (see Figure 1-32 of Section 1.3.2.2.2). The lengths of these faults have not been precisely determined, either because their projected trace is obscured by late Quaternary deposits without recognized geomorphic expression of the faults, or because potential linkages between discrete faults segments have not been unambiguously established. However, on the basis of published mapping, the length of the Paintbrush Canyon Fault is inferred to be 17 to 31 km, the Bow Ridge fault 10 to 19 km, the Solitario Canyon Fault 15 to 17 km, and the Windy Wash Fault 6 to 19 km (Table 1-8, Section 1.3.2.2.2). The Paintbrush Canyon Fault could be longer than the estimate given above if it links at its southern end to the Stagecoach Road Fault (see Figure 8.3.1.17-2).

Quaternary deposits are demonstratably offset by the faults at scattered localities along their trace. Preliminary study of the faults at a few of these localities, using trenching and dating of offset Quaternary deposits, indicates that reliably dated middle-to late Quaternary soils have been offset by dip-slip movement on the faults at rates up to approximately 0.01 mm/yr. Uncertainty in slip-rate values exists due to uncertainty in the age of soil layers, particularly ash layers. Slip-rate values will have to be revised if

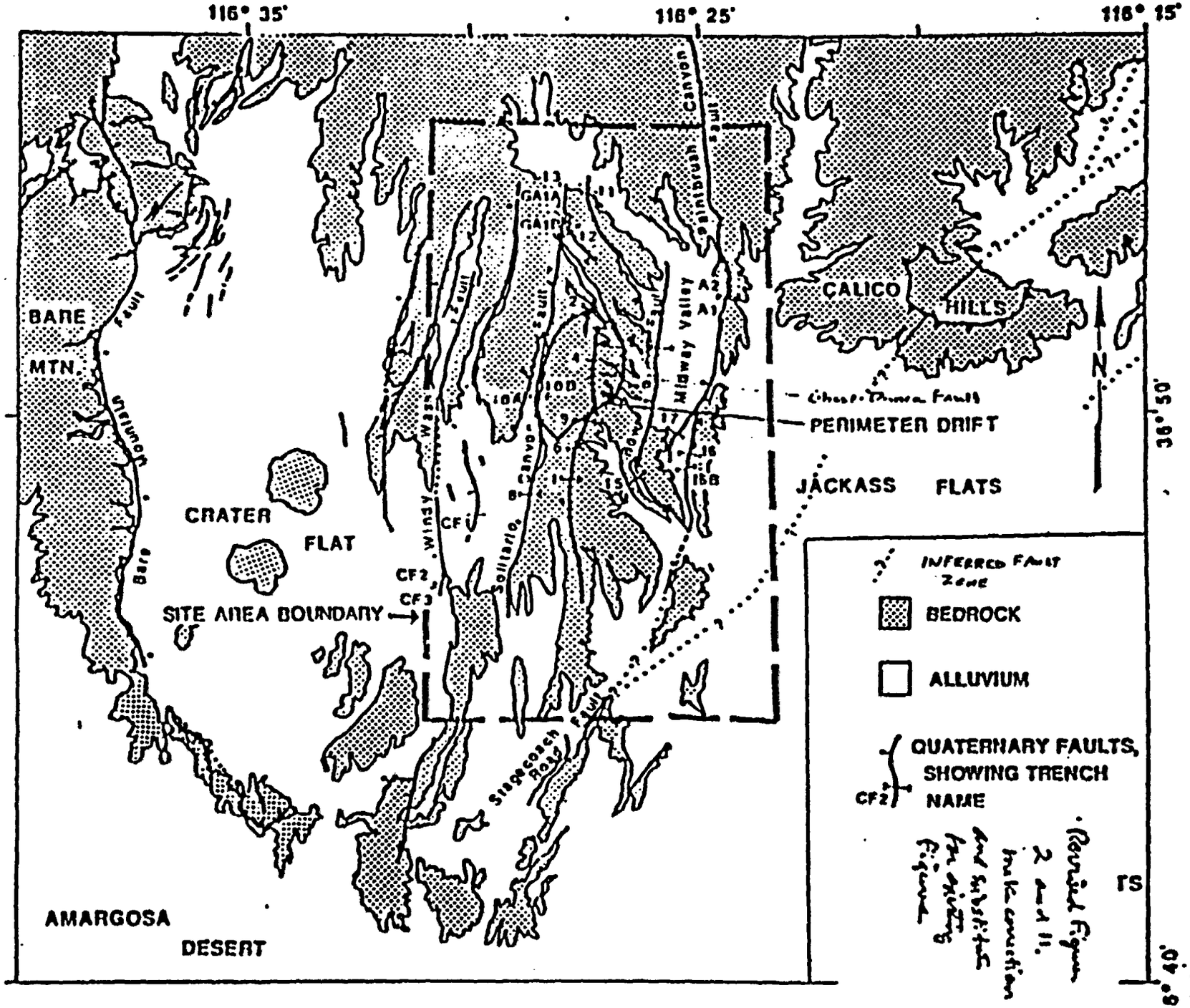


Figure 8.3.1.17-2 Quaternary normal faults, and postulated detachment faults on or near Yucca Mountain. Modified from Swadley et al. (1984) and USGS (1984).

new age dates become available. Lateral offset of Quarternary deposits that indicate a strike-slip component of fault movement have not been recognized but cannot be ruled out on the basis of available data.

The Paintbrush Canyon fault, which dips under Midway Valley, is particularly important for evaluating the potential for future vibratory ground motion at the proposed site of the waste-handling facilities. Considering the length and nature of this fault, it could have been the source of moderate earthquakes (M 6 1/2) in the past, although such events would appear to be rare based on the low rate of movement. Assuming the Quaternary rate of displacement for the Paintbrush Canyon fault is about 0.01 mm/yr, the recurrence time between magnitude 6 1/2 earthquakes on this fault should be about 50,000 yr (Slemmons and Depolo, 1986). If larger-magnitude earthquakes were postulated for this feature, their recurrence times would be longer. Long recurrence intervals appear to be typical of the local faults (Sections 1.3 and 1.5). Whitney et al. (1986) have estimated the recurrence interval between faulting events on the Windy Wash fault to be about 70,000 yr. Further investigations will be performed to test this conclusion.

The Bare Mountain fault, about 18 km west of Midway Valley, appears to be a more likely source of a moderate earthquake than the local faults (Section 1.4.2). Dated displacements presented in Table 1-8 indicate that this fault appears to be over ten times as active as the local faults. Thus, the Bare Mountain fault may be a significant contributor to probabilistic assessments of future ground motions at the site. Also, this fault, which dips eastward and southeastward (along its northern extent), may be tectonically linked at depth to the local faults (which dip to the west) via a detachment fault or graben structure.

The east-west spacing between adjacent local faults, illustrated in Figure 8.3.1.17-2, is less than their mapped lengths, and less than the 10 to 15 km thickness of the seismogenic zone found in this area (Section 1.4). The close proximity of the local faults suggests the possibility of interconnections at depth, most notably betwee. the Paintbrush Canyon and the Bow Ridge faults, which appear to converge near their southern extent. One important hypothesis is that the local north-trending faults flatten with depth and merge into a detachment fault that dips gently to the west (See Section 1.3.2). Another possibility that must also be considered is that the local faults continue downward at a steep dip through the seismogenic zone with possible interconnections at intermediate depths. Until such uncertainties are resolved, the evaluation and characterization of potential ground motion and faulting at the site must allow for alternate interpretations of the local tectonics.

Considerations of volcanic activity

A volcanic eruption within close proximity to the repository facilities could be highly disruptive. Current estimates described in Section 1.5.1.2.3 indicate that the probability of such an event is well below that considered to be significant for the preclosure time period. Additional work will be conducted under the postclosure tectonics program (Investigation 8.3.1.8.1) to develop increased confidence in the probability estimates for a local eruption.

Significant deposition of volcanic ash on the surface of the repository could temporarily disrupt operations. However, the nearest silicic volcanism during the Quaternary is at the margins of the Great Basin (Crowe et al., 1983b). A thousand-year ashfall event will be characterized, but because of the considerable distances and infrequent occurrences, the event is not expected to be a significant design factor.

Tables 8.3.1.17-1(a) and 8.3.1.17-2(a) show information on ash fall thickness and particle size distribution for the design of ventilation systems for the surface and underground facilities, respectively. Analyses will be conducted using data already available in the literature (Investigation 8.3.1.17.1). Probabilistic methods will be used to characterize the results.

Consideration of fault displacement

As noted previously, faults with evidence of Quaternary displacement are present in the site area, and the possibility exists that additional, undetected faults may also be present. Significant displacement on a fault or along a distributed zone of faulting immediately adjacent to repository facilities could disrupt operations and damage facilities. Performance and design issues require characterization of the potential for fault displacement at the proposed site for surface facilities that are considered important to safety (Table 8.3.1.17-3(a)) and at the location of the underground facilities (Table 8.3.1.17-4(a)). Currently, the waste handling facilities are the only facilities considered to be important to safety (Section 6.2).

Faulting considerations are particularly important for establishing a suitably stable site for the waste handling facilities, currently planned for Midway Valley. The concern is for avoiding relative displacement at the base of the structural foundation in excess of a few inches; smaller displacement is not expected to cause serious damage. The primary goal expressed in Table 8.3.1.17-3(a) is to demonstrate, with a high degree of confidence, that there is less than a one-percent chance of exceeding 5 cm of fault displacement at the site of the waste handling facility in 100 yr.

This goal, which establishes the maximum allowable annual probability for exceeding 5 cm of fault displacement at 10^{-4}/yr, appears to be consistent with safety considerations for this and other types of facilities. For example, comparable and higher annual probabilities have been found to be acceptably conservative for the seismic designs of nuclear power plants to withstand vibratory motions (Reiter and Jackson, 1983). While this comparison is not analogous in several respects, the risk resulting from fault displacements in excess of 5 cm at the site of the waste handling facilities is probably less than the risk resulting from vibratory ground motions that exceed the design basis for a nuclear power plant, and therefore the comparison does provide a useful check on the acceptance goal for faulting.

Another useful comparison can be made with criteria used to identify repository structures, systems, and components considered important to safety. Importance to safety is established if the probability of failure is

greater than 10^{-5}/yr and if the failure would lead to radiation exposures of 0.5 rem or greater at or beyond the restricted area (Draft, Methodology for Formulating a List and the Applications of Graded Quality Assurance to a MGDS, April, 1986). The annual probability that failure of this magnitude would result from faulting is expected to be less than 10^{-6}/yr for a site in which the annual probability for 5 cm of displacement is less than 10^{-4}/yr. This line of reasoning indicates that the goal for siting the waste handling facilities provides adequate safeguards to avoid areas of potentially significant faulting.

Additional field data are needed to achieve the required high degree of confidence in the determination of faulting probabilities. This need is indicated in Table 8.3.1.17-3(b) in which the current confidence in the values of the characterization parameters is considered to be low and the needed confidence is generally high.

Significant faulting is sometimes accompanied by sympathetic displacement at other locations. The first consideration then is to identify and characterize those faults within 5 km that could have significant impact on faulting at the proposed site. Geomorphic and other evidence that a Quaternary fault might trend toward Midway Valley in the vicinity of the site will be evaluated and characterized. Additional information will be obtained on the properties of the Paintbrush Canyon fault, which dips under the east side of Midway Valley, to evaluate the possibility of it becoming listric at shallow depth. Midway Valley will be carefully examined for geomorphic evidence of faulting, and trenching may be required to confirm the existence of suspected faults at distances up to one kilometer or more from the proposed site.

The most important data for constraining the possibilities for faulting at facilities important to safety are expected to come from extensive field investigations in the immediate site vicinity. Geologists will work with engineers in siting the waste-handling facilities to ensure that adequate stability is provided with respect to the possibility of faulting. Preliminary surveys may include small test pits or trenches to evaluate the stratigraphy and the possibility of previous local faulting. One or more trenches will be excavated across the site (or adjacent to the site) and extended to the east and the west beyond the proposed boundaries of the waste handling building, as needed. It is anticipated that these exploratory trenches will intersect surficial units that were deposited at least 100,000 yr ago (based on the results of mapping by Swadley et al., 1984). Cross Section B-B' in Scott and Bonk (1984) indicates that the alluvium of Midway Valley varies in thickness from zero meters at Exile Hill on the west side of the valley, to an undetermined amount in the valley center, to about 50 m in borehole UE-25 WT#5 near the Paintbrush Canyon fault on the east side of the valley.

Data on potentially significant faults in the area and data obtained in the immediate vicinity of the proposed site will be evaluated to estimate the annual probability for experiencing 5 cm of displacement at the site of the waste-handling facilities. This analysis will consider possible effects of known and unknown faults. Displacement amplitudes will also be estimated for annual probabilities ranging from 10^{-2} to 10^{-6} per yr for use in risk assessments.

DRAFT

Faulting conditions for underground facilities will also be evaluated. The primary issue here is that significant fault displacement could disrupt normal operations or impede execution of the option for waste retrieval. Possible release of radionuclides due to fault displacement in the underground facilities is considered too implausible during the preclosure period to be a significant issue (See SCP-CDR (SNL, 1987).

The first requirement presented in Table 8.3.1.17-4(a) is to identify and characterize late Quaternary faults within close proximity of the proposed underground facilities. This requirement is to aid in developing the layout and design of underground facilities. The second part of the table notes that current data provide low to moderate confidence that two such faults exist; namely, the Bow Ridge fault and the Solitario Canyon fault. Further work is required to provide added confidence that there are no additional late Quaternary faults in this area.

A further requirement is presented in Table 8.3.1.17-4(a) to identify, characterize. and locate at the repository horizon any fault with greater than a one-percent chance of displacing more than 7 cm in the area of waste emplacement during the preclosure period. This requirement is to ensure viability of the waste-retrieval option. Less than 7 cm of fault displacement is not expected to significantly impact normal retrieval operations because the diameter of the waste package will be about 7.6 cm smaller than the diameter of the emplacement hole (See Section 8.3.2.5). Larger displacements might bind or shear the waste packages thereby creating off-normal conditions for waste retrieval.

Assuming a preclosure period of 100 yr, the requirement just discussed is to identify, characterize, and locate at depth any fault passing through the area of waste emplacement that has an annual probability greater than 10^{-4}/yr for displacing more than 7 cm. Assuming event recurrences are random in time, the average rate of slip for such a fault would need to be considerably larger than 7 cm per 10^4 yr (i.e., 0.007 mm/yr) to account for excess displacement from events that produce less than and more than 7 cm. Accordingly, the screening criterion presented in Table 8.3.1.17-4(b) for locating faults in the underground, an average Quaternary slip rate greater than 0.005 mm/yr, provides considerable margin with respect to requirements presented in the (a) part of this table.

As noted above, the Bow Ridge fault and the Solitario Canyon fault are late Quaternary faults within close proximity to the proposed underground facilities. The Bow Ridge fault crosses the planned access ramp that enters the repository block from the east. The rate of Quaternary displacement for the Bow Ridge fault is not well constrained. However, assuming the rate of activity is similar to other faults in the area, long recurrence intervals between faulting events would be expected. For example, Whitney et al. (1986) have identified four faulting sequences within about 270,000 yr on the Windy Wash fault, giving an average recurrence interval of about 70,000 yr between faulting events (Section 1.3.3.3.3). Preliminary estimates, assuming the local Quaternary faults have a similar rate of activity, indicate that the annual probability for exceeding 10 cm of displacement on faults such as the Bow Ridge fault is about 1×10^{-5}/yr (URS/Blume, 1986). Additional field investigations will be conducted to develop more information about the

characteristics of this fault, particularly with respect to its Quaternary rate of activity. Design measures are being implemented to minimize possible fault-induced damage and to facilitate rapid repair in the unlikely event that movement should occur on this fault during the preclosure period.

The western boundary of the underground facilities will extend to the proximity of the Solitario Canyon fault, which is known to have Quaternary displacement. As with other local faults, the probability for experiencing significant displacement during the preclosure period appears to be well below that required by considerations for waste retrieval. Additional investigations will be conducted to further constrain fault characteristics, particularly the possibility of extension of the Solitario Canyon fault into the repository block.

Analyses will be performed to estimate the total probability for experiencing significant fault movement anywhere in the underground facilities during the preclosure period. These estimates will consider possible effects from known and unknown faults in the area.

Consideration of vibratory ground motion

Repository facilities will be designed and constructed to withstand the effects of vibratory ground motions. Conventional standards will be used for most facilities; however, more conservative design measures will be used for those facilities considered important to safety, specifically the waste handling facilities. Thus, the requirement is to determine ground-motion characteristics for consideration in the design of facilities important to safety.

Performance and design requirements for characterizing the potential for vibratory ground motion are presented in Table 8.3.1.17-5(a). The design-basis ground motions are to be characterized over the frequency band relevant to facilities important to safety (from 0.5 to 33 Hz) such that there is less than a 10-percent chance for being exceeded during 100 yr. Accordingly, the design basis motions are to have an annual exceedance probability less than 10^{-3}/yr, which translates to an average recurrence period greater than 1,000 yr. This goal appears to be consistent with the level of conservatism used for other facilities with important considerations for safety.

An important precedent is provided by nuclear power plants where annual probabilities for exceeding the design-basis motions have been found to be on the order of 10^{-3}/yr to 10^{-4}/yr for several operating plants (Reiter and Jackson, 1980). Based on estimates presented in the SCP-CDR (SNL, 1987), the risk associated with ground motions in excess of the design basis for the waste handling facilities appears to be substantially less than that for a nuclear power plant, suggesting that ample conservatism is provided by the stated goal.

Based on current understanding of design needs, the approach that has been developed here uses both deterministic and probabilistic methods to their best advantage. The role of the deterministic approach is primary. It provides the level of detail needed by design engineers in the characterization of ground motions. The probabilistic approach provides a logical,

structured procedure for integrating the range of possible earthquakes that contribute to the ground-motion hazard at the site. This capability will be used to guide, test, and substantiate the deterministic analyses. Sensitivity analyses will be performed using probabilistic methods to evaluate the effect of uncertainties on the ground motion potential. Results from these analyses will be used to help focus field investigations toward refinement of those seismic parameters that most strongly influence ground-motion potential at the site. In addition, probabilistic methods will be used as needed to provide input for the assessment of risk of accidental release of radionuclides.

Vibratory ground motions at the site can result from natural earthquakes on local and regional faults, and from underground nuclear explosions (UNEs) detonated at the Nevada Test Site. Preliminary analyses indicate that, for recurrence intervals over 1,000 yr, the ground motions resulting from natural earthquakes will exceed those from potential UNEs (URS/Blume, 1986; SCP Section 1.4.2). Much of the discussion to follow on the current approach for developing design-basis ground motions focuses on issues of natural earthquakes. The deterministic methods that will be applied for analyzing ground motions from UNEs parallel, in most respects, those described for dealing with natural earthquakes.

The ground-motion potential near Yucca Mountain differs considerably from that in much of California where a major portion of the relative plate motions are being accommodated, and also from that in the true plate interior regions of the midwestern and eastern U.S. There is an abundance of faults local to the site, but their rate of movement appears to be low. On the basis of fault data and historical seismicity, severe earthquakes are probably not as common in the vicinity of Yucca Mountain as in the more active regions surrounding much of the Great Basin.

To adequately characterize the local earthquake hazards, some of the terminology and procedures used in characterizing potential ground motions elsewhere are being refined to meet the needs of a waste repository. For example, in the determination of design ground motions for some types of critical facilities, professional practice has been to define maximum earthquake magnitudes with the understanding that a larger earthquake magnitude may be possible, although very unlikely. This practice is being made more explicit for characterizing this site. In particular, exceptional earthquakes will be identified for consideration in repository design. An exceptional earthquake is tentatively defined here to have a recurrence time of about 10,000 yr and be at or near the best-estimate for the maximum magnitude. A detailed discussion of the exceptional-earthquake concept is provided in the description of Activitiy 8.3.1.17.3.1.2.

An important advantage of this refinement is that an exceptional earthquake magnitude, being associated with a particular recurrence interval, can be determined with greater confidence than a true maximum magnitude. Because large earthquakes occur infrequently, few observational data are available for calibrating the maximum seismogenic potential of individual faults. This is particularly true for faults of the type found in the southern Great Basin, where recurrence intervals for large earthquakes appear to range from about 10,000 to 100,000 yr (see Section 1.4.2). Therefore, conventional

methods for determining maximum earthquake magnitudes from the physical characteristics of local faults appear to be subject to larger uncertainties than for the more active faults associated with plate motions. Use of slip-rate data (to constrain recurrence times) in conjunction with more conventional fault data provides added assurance that adequately conservative assessments of the local seismogenic potential will be accomplished.

The planned procedure for characterizing ground motions at the site from exceptional earthquakes is as follows: First, the active surface faults and potentially active fracture zones at depth that could produce locally severe ground motions will be identified. Second, exceptional earthquakes, as defined previously, will be determined. Third, controlling earthquakes will be identified as those exceptional earthquakes that produce the most severe motions at the site. The resulting vibratory ground motions will then be characterized by a suite of representative time histories and response spectra that have been scaled to the magnitudes and distances of the controlling earthquakes and modified, as needed, to account for the effects of local site geology. A suite of representative strong-motion records may be needed for more than one controlling earthquake, to cover the possibility that different source regions could control ground motions at the site in different frequency bands.

To characterize potential ground motions from UNEs, a similar procedure will be followed. First, the possible locations and upper limits on the yields of future UNEs at the NTS will be identified. With this information, the maximum UNEs with respect to generating ground motions at the site will be determined. If the resulting site ground-motion estimates are comparable to those for the controlling earthquake sources, the UNE ground motions will be further characterized by a suite of representative time histories and spectra.

Preliminary evaluations of potential earthquake sources in the vicinity of Yucca Mountain have identified several local faults as long as 20 km or more. If, as is currently planned, the waste handling facilities were located on Midway Valley, the controlling source would appear to be the north-south trending Paintbrush Canyon fault, which bounds Midway Valley on the east. The closest approach of the Paintbrush Canyon fault to the proposed site of the waste handling facilities is about one kilometer. This fault may be capable of producing a moderate earthquake (M about 6.5) with a recurrence interval greater than ten thousand years. Site characterization will determine which fault or faults control the ground motion at frequencies within the range of engineering interest.

Because the annual probability for the controlling earthquake is expected to be low (less than about 10^{-4} for the Paintbrush Canyon fault), and because the components required to contain radioactive materials within the waste-handling building can be expected to survive ground motions more severe than those used for design, ample conservatism can be achieved by using the most probable motions from the exceptional earthquake(s) on the controlling earthquake source(s) as the basis for seismic design. Probabilistic calculations will be performed to test and verify that the resulting ground motions exceed the thousand-year estimate from the combined hazard from natural earthquakes and underground nuclear explosions.

DRAFT

Interrelationships of preclosure tectonics investigations

The interrelationships of the investigations in the preclosure tectonics site characterization program are shown in Figure 8.3.1.17-1. There are three analysis and assessment investigations that correspond to potentially disruptive volcanic activity, fault displacements, and vibratory ground motion, respectively. These three investigations are designed to provide the required characterization parameters. A fourth investigation comprises a number of data collection and synthesis activities that support one or more of the three analysis and assessment investigations.

8.3.1.17.1 Investigation: Studies to provide required information on volcanic activity that could affect repository design or performance

Technical basis for obtaining the information

Link to technical data chapters and applicable support documents

The following SCP sections provide a technical summary of existing data relevant to this investigation:

SCP section	Subject
1.3.2.1	Volcanic history
1.5.1	Volcanism
1.8.1.3.1	Significant results
1.8.1.3.2	Discussion of significant results
1.8.1.5.1	Significant results

Parameters

This investigation will provide the following characterization parameters related to potential ash fall at the site from distal silicic volcanic centers (see Tables 8.3.1.17-1(a), -1(b), -2(a), and -2(b)):

1. Probability of ash fall at the site as a function of ash-fall thickness.

2. Expected ash-fall thickness at the site in a 1,000-yr period.

3. Potential ash-fall particle densities and size distributions.

Investigation 8.3.1.8.1 (direct releases resulting from volcanic activity--postclosure) will provide the following characterization parameters related to the potential for a basaltic volcanic eruption at the site (Table 8.3.1.8-1):

1. Location and timing of volcanic events near the site.

2. Evaluation of structural controls on the occurrence of basaltic magmatism.

3. Presence of magma bodies in the vicinity of the site.

4. Effects of Strombolian eruptions.

5. Effects of hydrovolcanic eruptions.

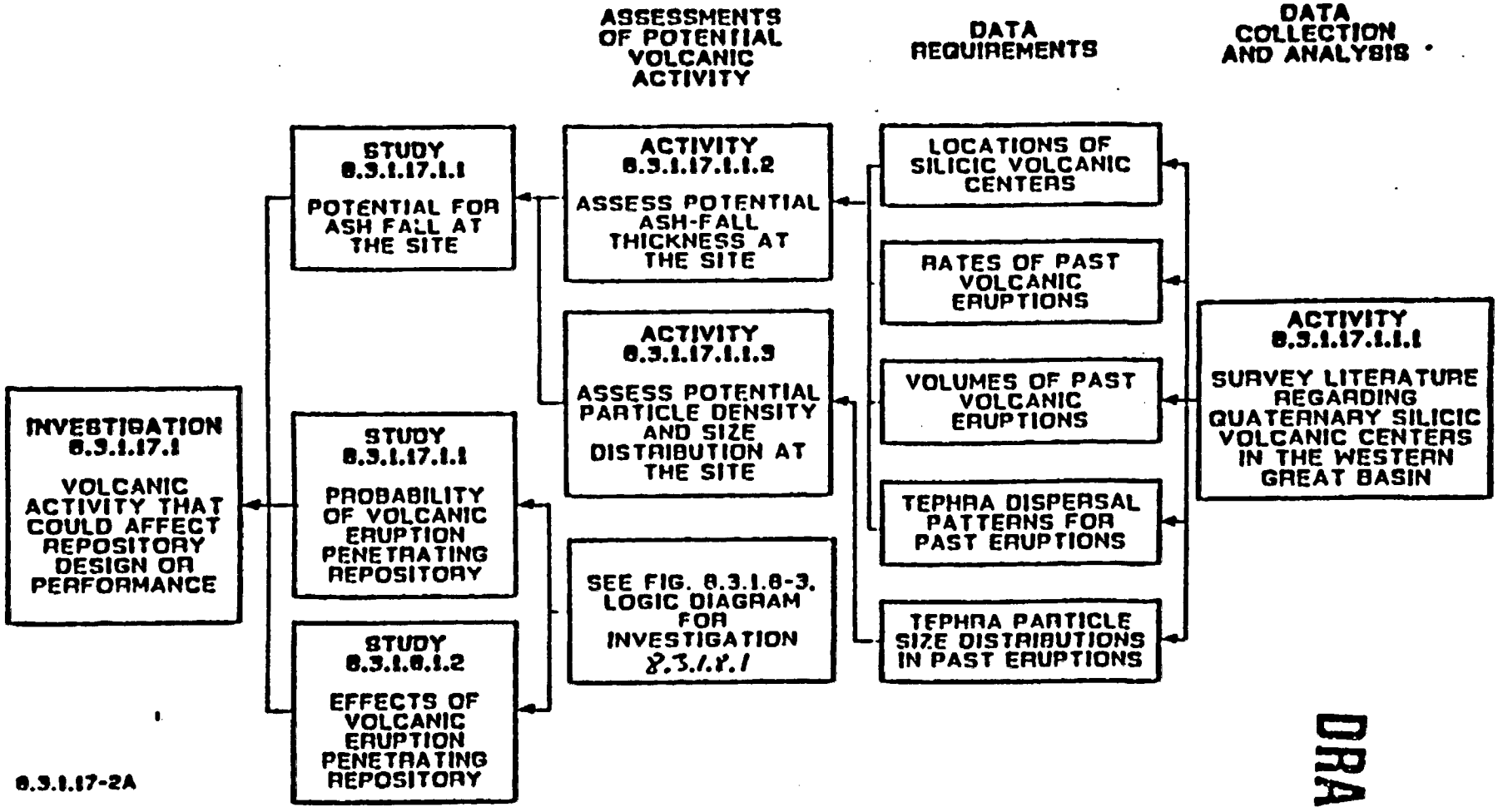
Purpose and objectives of the investigation

Two types of volcanic hazards that could credibly affect preclosure repository performance will be characterized: (1) ash fall from distal silicic volcanic centers in the western Great Basin and (2) a basaltic volcanic eruption at the site. Ash fall is being addressed under preclosure tectonics because of its potential impact on surface and subsurface ventilation systems (dust filters). However, the study of basaltic volcanism in the site region will be conducted under the postclosure tectonics program (Section 8.3.1.8), because the probability of basaltic volcanism at the site is greater over the longer postclosure time frame. The probability of a basaltic volcanic eruption at the site during the preclosure period will be estimated there. No studies are planned of potential silicic volcanism in the site region because a silicic volcanic eruption at the site is not considered a credible event (Section 1.5.1).

The characterization parameters related to ash fall are being provided so that the filtration systems of the surface-facility and mining ventilation systems can be designed to accommodate potential ash falls at the site. The characterization parameters related to basaltic volcanism are intended to provide assurance that the probability of a volcanic eruption at the site is acceptably low (i.e., as interpreted here, less than one chance in 10,000 in 100 yr).

Technical rationale for the investigation

A logic diagram for the investigation of preclosure volcanic activity is presented in Figure 8.3.1.17-3. The potential for ash falls at the site from distal silicic volcanic centers will be addressed in Study 8.3.1.17.1.1. Since much work has already been published on silicic volcanism in the region, data will be compiled primarily through a literature survey in Activity 8.3.1.17.1.1.1. For the western Great Basin, locations of silicic volcanic centers, rates and volumes of past eruptions, tephra dispersal patterns for past eruptions, and tephra particle-size distributions in past eruptions will be compiled. The ash-fall potential at the site will be assessed by assuming that silicic volcanic eruptions are a stationary random process and, hence, that observed Quaternary rates and distributions can be projected into the future.



DRAFT

Figure 8.3.1.17-3. Logic diagram for the investigation of preclosure volcanic activity

The potential ash-fall thickness at the site will be assessed in Activity 8.3.1.17.1.1.2 and expressed in terms of the characterization parameters listed in Tables 8.3.1.17-1(a), -1(b), -2(a), and -2(b). A probability-versus-thickness function will be estimated, and a particular ash-fall thickness that has less than one chance in 10 of occurring in 100 yr (i.e., a greater-than-1,000-yr ashfall) will be estimated for consideration in the design of mining and surface ventilation systems. The potential particle density and particle-size distribution of an ash fall at the site will be assessed in Activity 8.3.1.17.1.1.3.

The potential for a basaltic volcanic eruption to directly disrupt the repository is being addressed in Investigation 8.3.1.8.1, under postclosure tectonics. The probability of a basaltic eruption penetrating the repository will be estimated in Study 8.3.1.8.1.1, and the potential geologic effects of such an eruption on the site will be assessed in Study 8.3.1.8.1.2. The supporting activities and data requirements for these two studies are indicated in the logic diagram for Investigation 8.3.1.8.1 (Figure 8.3.1.8-3).

DRAFT

8.3.1.17.2 Investigation: Studies to provide required information on fault displacement that could affect repository design or performance

Technical basis for obtaining the information

Link to the technical data chapters and applicable SCP support documents

The sections of the SCP data chapters that summarize existing data relevant to this investigation are as follows:

SCP section	Subject
6.1.4	Surface structures, systems, and components considered important to safety
1.3	Structural geology and tectonics
1.5	Long-term stability with respect to tectonics and geologic processes

Parameters

This investigation will compile or develop the following characterization parameters related to the potential for fault displacement beneath surface facilities considered important to safety (see Tables 8.3.1.17-3(a) and -3(b)):

1. Identification and characterization of potentially significant Quaternary faults within 5 km of facilities important to safety (FITS).

2. Identification and characterization of faults within 100 m of FITS that have apparent Quarternary slip rates > 0.001 mm/yr or that measurably offset materials that are less than 100,000 yr old.

3. Estimated total probability of exceeding 5 cm displacement beneath FITS, considering known faults, possibly concealed faults, and tectonic interrelationships among local faults.

The following characterization parameters related to the potential for underground fault displacement in areas of emplaced waste will also be compiled or developed in this investigation (see Tables 8.3.1.17-4(a) and -4(b)):

1. Surface locations of faults in the repository block that offset Quaternary materials by more than 1 m or Tertiary rocks by more than 100 m.

2. Surface and subsurface locations of any faults that intersect prospective underground facilities and that have average Quaternary slip rates greater than 0.005 mm/yr.

3. Estimated total probability of exceeding 7cm displacement on any fault in the the area of emplaced waste, considering known and possibly concealed faults and the tectonic interrelationships among local faults.

Purpose and objectives of investigation

The siting objective vis-a-vis potential surface faulting is to avoid fault displacement in excess of a few inches beneath the structural foundations of surface facilities considered important to safety. The corresponding goal of this investigation, expressed in Table 8.3.1.17-3(a), is to demonstrate, with a high degree of confidence, that there is less than a one percent chance of exceeding 5 cm of fault displacement beneath surface facilities important to safety during the preclosure period (approx. 100 yr). (A discussion of the reasonableness of this goal is provided in the overview of this section.)

The primary concern regarding faulting in the underground facilities during preclosure is that waste packages might be sheared or become jammed in their waste-emplacement boreholes, making retrieval more difficult and time consuming than it otherwise would be. The corresponding goal (see Tables 8.3.1.17-4(a) and -4(b)) is to demonstrate with a moderate degree of confidence that there is less than a ten percent chance of exceeding 7 cm of fault displacement in areas of emplaced waste in 100 yr, considering all faults that may intersect these areas. (A displacement of 7 cm is the minimum value at which the sides of a faulted waste-emplacement borehole would be expected to contact a waste package.) No single fault with the potential to exceed this goal is currently thought to exist, but if such a fault is identified, an attempt will be made to determine its location underground for consideration in the positioning of waste-emplacement boreholes.

Technical rationale for investigation

A logic diagram for the investigation of preclosure fault displacement is presented in Figure 8.3.1.17-4.

The potential for surface faulting at locations of surface facilities important to safety (FITS) will be assessed in Activity 8.3.1.17.2.1.1 and expressed in terms of the characterization parameters listed in Table 8.3.1.17-3(b). The most important information pertaining to potential fault displacement beneath FITS is expected to come from detailed geologic mapping of alluvial deposits in Midway Valley and from exploratory trenching in the immediate vicinity of prospective surface FITS. Exploratory trenches are expected to intersect surficial units that are at least 100,000 yr old. Any faults that measurably displace units less than 100,000 yr old and any faults found to have Quarternary slip rates exceeding 0.001 mm/yr (10 cm/100,000 yr) will be indentified.

Because significant faulting is sometimes accompanied by sympathetic displacements in adjacent areas, information on fault-zone widths and recurrence of movement on Quaternary faults within 5 km of surface FITS will

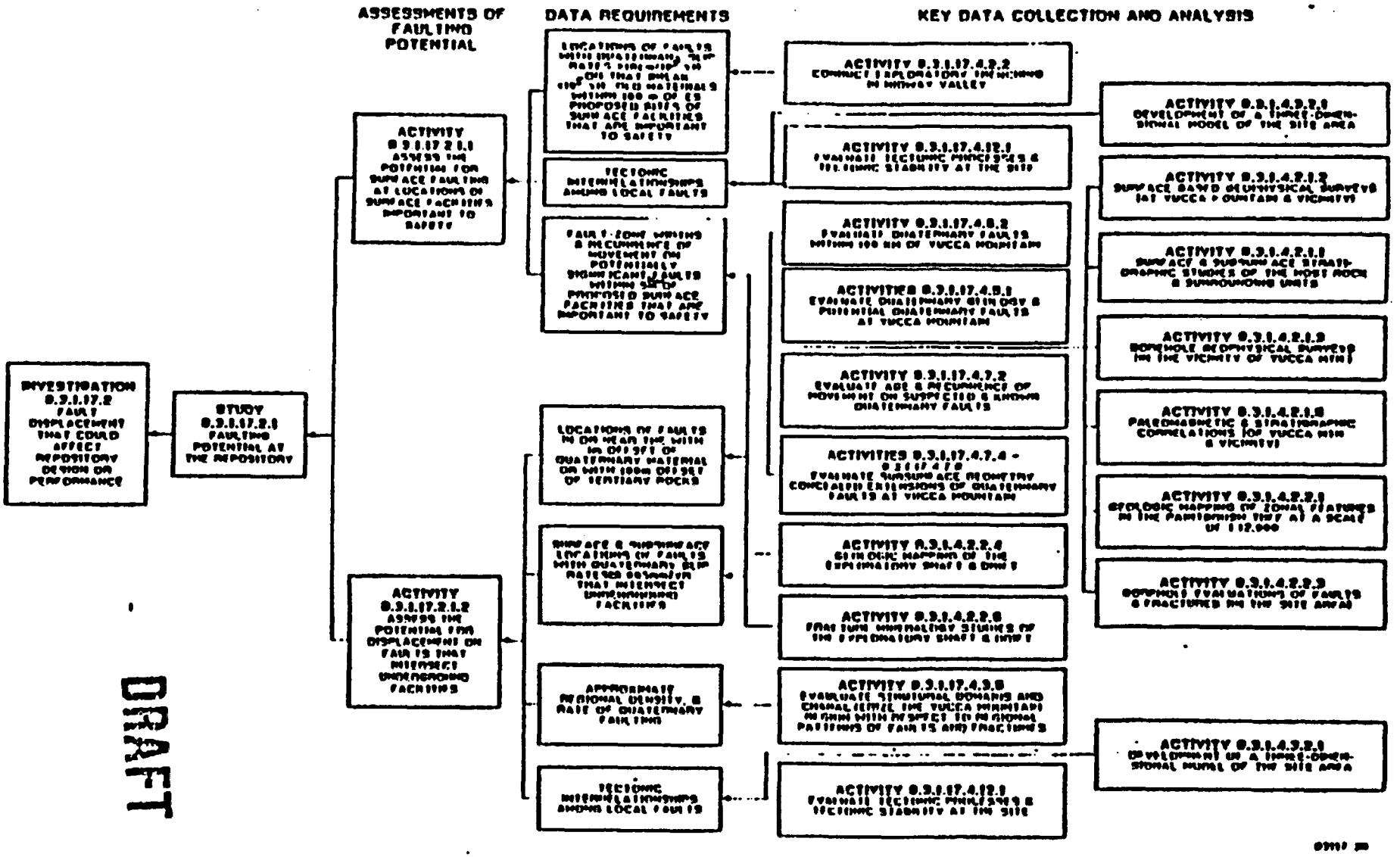


Figure 8.3.1.17-4. Logic diagram for the investigation of preclosure fault displacement.

also be analyzed. Of particular interest for any such fault will be any evidence of concealed extensions that may trend toward Midway Valley and the sites of prospective FITS.

The probability of exceeding 5 cm displacement on any fault beneath prospective surface FITS will be estimated in Activity 8.3.1.17.2.2.1, considering, in addition to the information cited previously, the tectonic interrelationships between local faults, the possible existence of concealed faults, and the potential for the surface trace of a fault to change locations from event to event. The goal is to locate the surface FITS in an area where there is less than a one percent chance of exceeding 5 cm of displacement in 100 yr, with high confidence. Any site without faults having apparent Quaternary slip rates greater than 0.001 mm/yr and faults that measurably offset materials less than 100,00 yr old is expected to meet this goal conservatively, even if an undetected component of strike-slip motion exists that is as large as the measured dip-slip components.

The potential for displacement on faults that intersect underground facilities will be assessed in Activity 8.3.1.17.2.1.2; the corresponding design parameters and characterization parameters are listed in Tables 8.3.1.17-4(a) and -4(b).

To meet the design-parameter goal of identifying and characterizing significant late Quaternary faults in the repository block, the locations of faults with more than 1-m offset of Quaternary materials, or with more than 100-m offset of Tertiary rocks, will be determined. Current data provide low-to-moderate confidence that only two such faults exist, namely the Bow Ridge and Solitario Canyon faults. Further work will be performed in Study 8.3.1.17.4.6 (Quaternary faulting within the site area) to provide added confidence that there are no additional significant late-Quaternary faults in the repository block.

A second design-parameter goal is to identify, characterize and locate within the waste-emplacement area any fault with more than a one percent chance of producing displacement greater than 7 cm during the preclosure period. Faults with slip rates less than 0.005 mm/yr would be very unlikely to exceed this threshold (see overview discussion of the preclosure tectonics site program in this section), and current data indicate that, with moderate confidence, no faults with Quaternary slip rates greater than 0.005 mm/yr exist in the repository block. Further work will be performed in Study 8.3.1.17.4.7 to achieve a moderate-to-high level of confidence in this finding.

Information on particular Quaternary faults in the repository block, data on the regional spacing and rate of movement of Quaternary faults, and interpretations of tectonic interrelationships among local faults will be synthesized in Activity 8.3.1.17.2.1.2 to estimate a total probability of exceeding 7 cm displacement on faults that intersect areas of emplaced waste. This work is expected to corroborate the current assessment that, with moderate confidence, the total probability of exceeding 7 cm displacement in 100 yr on any fault in the area proposed for waste emplacement is less than one percent.

DRAFT

8.3.1.17.3 Investigation: Studies to provide required information on vibratory ground motion that could affect repository design or performance

Technical basis for obtaining the information need

Link to the technical data chapters and applicable support documents

Sections 1.3, 1.4, and 1.5 of the SCP data chapters provide a technical summary of existing data relevant to this investigation.

Parameters

This investigation will provide the following characterization parameters related to potential vibratory ground motion at the site from natural and man-made seismic sources (see Tables 8.3.1.17-5(a), -5(b), -6(a), and -6(b)):

1. Identification of potential earthquake sources in the controlled area.

2. Identification of earthquake sources within 100 km of the site that could be relevant to the site (i.e., that could conceivably control the design-basis ground motions at the site in any frequency band of engineering significance).

3. Magnitudes of exceptional* earthquakes on local earthquake sources.

4. Magnitudes of exceptional* earthquakes on regional earthquake sources.

*Exceptional earthquakes are tentatively defined here to be earthquakes that are at or near the maximum magnitude for a particular source and that have average recurrence times of about 10,000 yr; see discussion of Activitiy 8.3.1.17.3.1.2.

5. Maximum potential yields of future underground nuclear explosions (UNEs) at the NTS.

6. Closest distance between the site and potential future UNEs at NTS.

7. Ground-motion models/attenuation relationships for the site region (i.e., mathematical models for predicting the values of ground-motion parameters as a function of the distance from and the strength of the earthquake or UNE source).

8. Spectral amplification functions that represent the effects of local site geology on surface seismic motions and the effects of depth on underground seismic motions.

9. Identification of controlling seismic events--those exceptional earthquakes and/or potential largest and closest UNEs that would generate the most severe ground motions at the site in any frequency band of engineering significance, taking into account any local-geologic or depth effects on the ground motion.

10. Time histories and response spectra that are representative of potential ground motion at the site from the controlling seismic event(s).

11. Magnitude-recurrence relationships for all regional earthquake sources that could contribute to the earthquake hazard at the site.

12. Probabilities of exceeding selected ground-motion parameters at the site, developed through probabilistic seismic hazard analysis.

Purpose and objectives of investigation

The purposes of this investigation are to (1) develop a seismic-design basis for repository facilities that are important to safety, and (2) provide other information that will facilitate the assessment of the adequacy of the seismic-design basis and the identification of credible accidents that might be initiated by seismic events and lead to release of radioactive materials. The seismic-design basis will account for both the potential occurrence of earthquakes on nearby faults and potential future underground nuclear explosions at the Nevada Test Site.

The planned methodology for developing the seismic-design basis is, as is discussed in detail below, intended to result in design levels such that the probability of the design level being exceeded is comparable to typical exceedance probabilities for the seismic-design bases of operating nuclear power plants in the United States (i.e., annual probabilities of exceedance on the order of 1×10^{-3} to 1×10^{-4}). On the basis of information presented in the SCP-CDR (SNL, 1987) the potential radiological consequences of seismically induced damage appear to be less severe at the prospective repository than at a nuclear power plant. Thus, seismic-design levels with equivalent exceedance probabilities are expected to result in a lower risk of radioactive releases due to seismic events from the repository than from a typical nuclear power plant.

DRAFT

Although this investigation is motivated by the need to develop a seismic-design basis and other information related to the design of facilities important to safety (FITS), the resulting design-basis ground-motion descriptions also may be considered in the design of other repository facilities. (Presently, only components of the waste-handling facilities are considered potentially important to safety; See Sandia National Laboratory report SAND86-1965C.) Current plans call for the FITS seismic-design basis to be considered also in the design of underground facilities (Information Need 4.4.1, site and performance assessment information needed for design, Section 8.3.2.5.1).

The approach that is currently considered appropriate for developing a seismic design basis is deterministic, meaning that the design-basis ground-motion description will correspond to the postulated occurrence of a discrete seismic event or events (e.g., the occurrence of an earthquake of specified magnitude on a particular fault). This type of approach parallels that used to develop the seismic design bases of all nuclear power plants in the United States. In addition, probabilistic estimates of the seismic hazard at the site will be developed that integrate individual contributions to the site's ground-motion potential from earthquake sources at different distances and with different earthquake recurrence characteristics. The probabilistic seismic hazard estimates will be used to evaluate and constrain required technical judgments in the deterministic approach, evaluate the adequacy of the deterministic results, and help identify and focus efforts to refine those parameters that are most important for the deterministic calculations. The probabilistic hazard estimates will also provide input needed to determine credible accidents that are applicable to the repository (Information Need 2.3.1, Section 8.3.5.5.1).

In summary, probabilistic seismic hazard estimates will be an important adjunct to the deterministic estimates that will be developed for consideration in the seismic design of FITS. A discussion of the reasons for using deterministic and probabilistic methodologies in this fashion is given in the Overview section for this investigation.

Technical rationale for investigation

Exceptional earthquakes are tentatively defined here to be earthquakes that are at or near the maximum magnitude for a given earthquake source and that have average recurrence times of about 10,000 yr (see detailed discusssion in descriptiuon of Activity 8.3.1.17.3.1.2). Controlling seismic events are those exceptional earthquakes and/or potential largest and closest UNEs that would generate the most severe ground motions at the site in any frequency band of engineering significance. The seismic design basis for FITS will be suites of ground-motion time histories and corresponding response spectra that are representative of the controlling seismic events.

A logic diagram for this investigation is presented in Figure 8.3.1.17-5.

Study 8.3.1.17.3.1 will identify and characterize earthquake sources that could potentially be relevant to a deterministic seismic hazard analysis of the site, i.e., sources that could conceivably produce exceptional

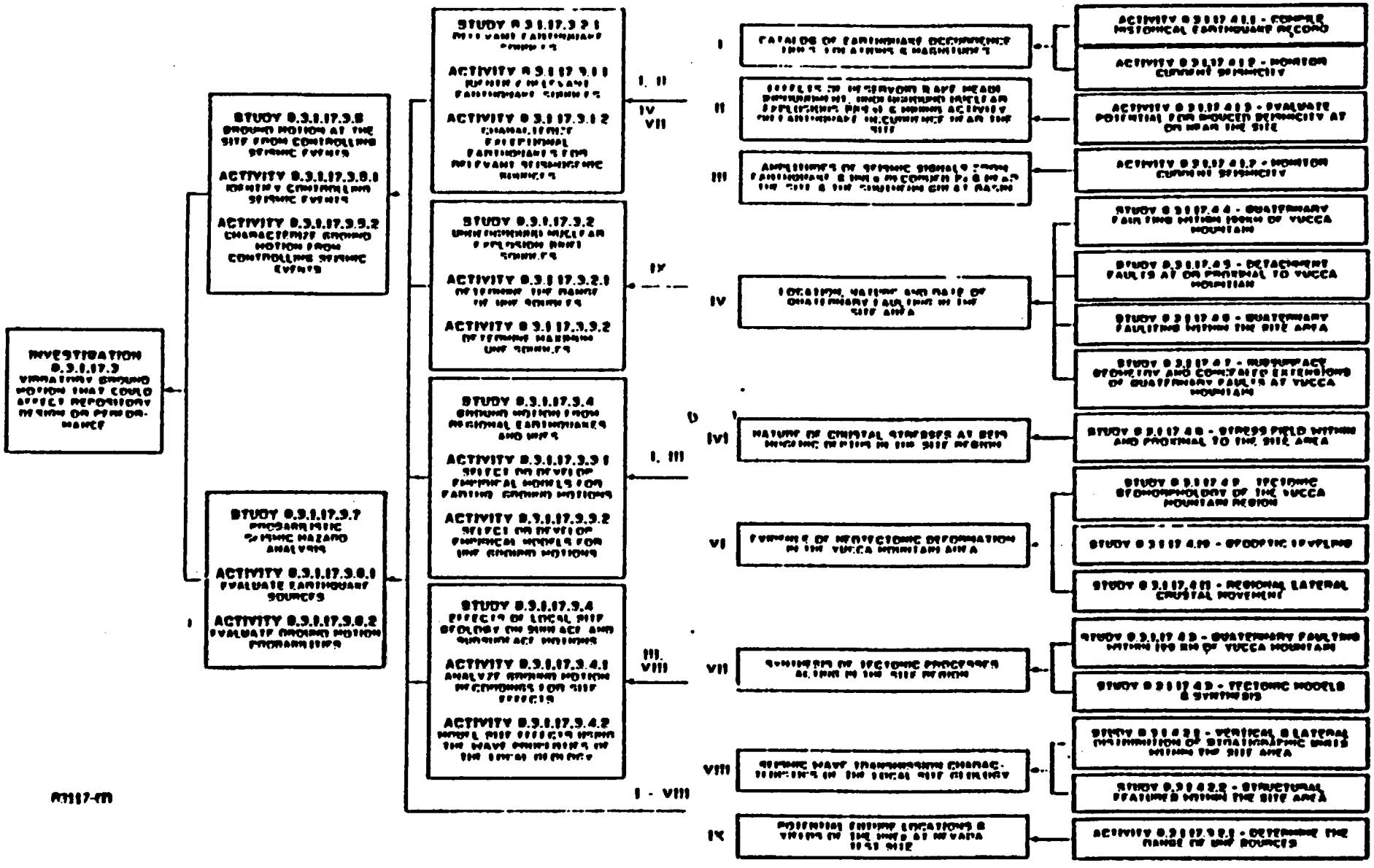


Figure 8.3.1.17-5. Logic diagram for the investigation of preclosure vibratory ground motion (Roman numerals indicate data flow)

earthquakes that would control the seismic-design basis in any frequency band of engineering significance. Characterization of earthquake sources for the deterministic hazard assessment will include a determination of each source's location, orientation, depth, likely style of faulting, and an evaluation of exceptional-earthquake magnitude. Here, and elsewhere, uncertainty in the determination of input parameters will be estimated so that the sensitivity of the final results to key assumptions can be estimated.

The identification and characterization of relevant earthquake sources will consider the historical record of regional seismicity; the potential for seismicity to be induced at the site by human activities; the location, nature, and rate of Quaternary faulting in the site area; crustal stresses at seismogenic depths; evidence of neotectonic deformation in the Yucca Mountain area; and the overall tectonic framework of the region.

Study 8.3.1.17.3.2 will determine the potential locations and maximum yields of future UNEs at the NTS, considering constraints such as damage thresholds in Las Vegas. The UNE(s) that would cause the most severe ground motions at the site will then be identified using a predictive model for UNE ground motions.

Models for predicting UNE ground motions and models for predicting earthquake ground motions will be selected or developed in Study 8.3.1.17.3.3. Published ground-motion models for UNEs at NTS will be used where appropriate. If published models are not available for all ground-motion parameters needed, available data will be compiled and the needed models will be developed through regression analyses. Earthquake ground-motion data from the Great Basin and tectonically analogous areas will be tested for statistically significant deviations from published earthquake ground-motion models that have been developed for California and western North America. If the deviations are not statistically significant, a published model will be selected. If needed, new models will be developed through regression analyses.

Systematic effects on surface and subsurface ground motions resulting from the local site geology will be identified and used to correct predictions of the regional ground-motion models developed in Study 8.3.1.17.3.3. These correction factors will be based, to the extent possible, on actual ground-motion recordings obtained in Study 8.3.1.17.4.1. Theoretical models based on the wave properties of the local geology will be developed to the degree necessary to explain the observations to first order and then used to extrapolate the observations to locations and depths where ground motions must be predicted but where recordings are not available.

Identification of controlling seismic events and characterization of the resulting ground motion at the site will be accomplished in Study 8.3.1.17.3.5. Identification of the controlling seismic events will follow directly from the identification of exceptional earthquakes on relevant sources in Study 8.3.1.17.3.1, the determination of potential maximum future UNEs in Study 8.3.1.17.3.2, the earthquake and UNE ground-motion models developed in Study 8.3.1.17.3.3, and the local site correction factors developed in Study 8.3.1.17.3.4.

DRAFT

Controlling-event ground motions will be characterized by suites of strong-motion time histories that are representative in terms of expected amplitudes, frequency content, and duration. Methodologies for constructing these time histories will be evaluated. Two different methodologies may be implemented and the results compared to help assess the uncertainty in the final results.

The probabilistic seismic hazard analysis of the site constitutes Study 8.3.1.17.3.6. The first step in the analysis is to identify and characterize earthquake sources that contribute to the hazard (the probability of exceeding different ground-motion levels) at the site. Sources that are more distant and sources with smaller earthquake potential than the "relevant" sources addressed in Study 8.3.1.17.3.1 will be characterized so that exceedance probabilities for ground-motion levels below the design-basis levels can be estimated. (Exceedance probabilities for motions beyond the design-basis will also be estimated.) Each seismic source will be characterized as to location, depth, shape, and magnitude-recurrence characteristics, including maximum-magnitude potential. The considerations in characterizing the contributing earthquake sources in the probabilistic analysis are essentially the same as those in characterizing relevant sources in the deterministic analysis, and so the same types of data are required.

There are different methodologies available for encoding uncertainty in seismic-source-zone interpretations and for aggregating the results of multiple interpretations in a probabilistic seismic hazard analysis. The advantages and disadvantages of available methodologies will be assessed before an approach is chosen.

A probabilistic seismic hazard analysis of the site is expected to be performed concurrently with the deterministic analysis and repeated one or more times, with detail increasing as more data become available. The sensitivity of estimated hazard to various input parameters is easy to assess within the probabilistic framework, and the preliminary analyses will help to identify the parameters of greatest importance to both the probabilistic and deterministic analyses: this information will be used to re-direct and focus the characterization activities. The calculated probabilistic hazard levels will also be used to help assess the adequacy of the deterministically derived design-basis ground motions. As was stated earlier, a measure of adequacy that is adopted here is that the annual probability of the design-basis ground motions being exceeded is 10^{-5} to 10^{-6} per year, which is the range of probabilities that appears to correspond to seismic-design bases that have been accepted for nuclear power plants in the United States.

DRAFT

8.3.1.17.4 Investigation: Preclosure tectonics data collection and analysis

Technical basis for obtaining the information

Link to technical data chapters and applicable support documents

The following SCP sections provide a summary of existing data relevant to this investigation:

Section	Subject
1.3.1	Tectonic framework
1.3.2	Tectonic history
1.4.1	Seismology of the southern Great Basin
1.4.2	Seismology of Yucca Mountain
1.5.1	Volcanism
1.5.2	Faulting
1.5.3	Vertical and lateral crustal movement
1.8.1	Summary of significant results

Parameters

Information to be provided by the studies under this investigation include the following:

1. Catalog of historical earthquake occurrence times, locations, and magnitudes.

2. Analysis of potential for UNEs, mining activity, or reservoir (Lake Mead) impoundment to induce seismicity near the site.

3. Recordings obtained at the site and at other locations in the southern Great Basin of ground motions from earthquakes and UNEs.

4. Geological and geophysical evidence of large-scale Quaternary faulting within 100 km of the site and of smaller-scale Quaternary faulting in the site area.

DRAFT

5. Analysis of the seismogenic potential of detachment faults in the site area.

6. Evaluation of crustal stresses at seismogenic depths in the site region.

7. Morphologic and morphometric analysis of neotectonic deformation in the site region.

8. Geodetic and survey evidence of recent crustal movements in the site region.

9. Synthesis of tectonic processes acting in the site region (development of tectonic models).

Purpose and objectives of investigation

The primary purpose of this investigation is to provide data and analyses that are required by Investigation 8.3.1.17.2, assessment of fault displacement that could affect repository design or performance, and Investigation 8.3.1.17.3, assessment of vibratory ground motion that could affect repository design or performance (refer to logic diagrams for these two investigations, Figures 8.3.1.17-4 and 8.3.1.17-5). The limited data collection and analysis that is required by Investigation 8.3.1.17.1, volcanic activity that could impact the repository, will be performed within that investigation (Figure 8.3.1.17-3).

Technical rationale for investigation

The data-collection-and-analysis studies have been aggregated under this fourth investigation for two reasons. Much of the information that will be provided by the data-collection-and-analysis studies is needed for more than one assessment. For example, information on Quaternary faulting near the site is germane to both the faulting- and the ground-motion potential at the site. Also, most of the studies are most naturally organized around a geological problem, the solution of which may require a broader focus than the repository site itself. All studies are intended to contribute to the resolution of design or performance issues, even though the linkage may sometimes be indirect for studies that have a broad focus, such as the evaluation of tectonic models (Study 8.3.1.17.4.12).