72-22
See report

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

April 19, 1999

MEMORANDUM TO: Susan F. Shankman, Deputy Director
Licensing and Inspection Directorate
Spent Fuel Project Office
Office of Nuclear Material Safety
and Safeguards

FROM: Mark S. Delligatti, Senior Project Manager
Spent Fuel Licensing Section
Licensing and Inspection Directorate
Spent Fuel Project Office
Office of Nuclear Material Safety
and Safeguards

SUBJECT: SUMMARY OF THE FEBRUARY 18, 1999, MEETING BETWEEN THE NUCLEAR REGULATORY COMMISSION AND PRIVATE FUEL STORAGE, LIMITED LIABILITY CORPORATION

On February 18, 1999, a meeting was held between the Nuclear Regulatory Commission (NRC) staff and representatives of Private Fuel Storage, Limited Liability Corporation (PFS) to discuss the PFS response to the staff's first round request for additional information (RAI) on the geologic investigation program at the site of the proposed Private Fuel Storage Facility (PFSF) on the reservation of the Skull Valley Band of Goshute Indians. Also attending the meeting were representatives of Geomatrix Consultants (Geomatrix), PFS's technical support contractor for the geologic investigations; the Center for Nuclear Waste Regulatory Analyses; Harmon-Curran; Shaw-Pittman; and the Ibex Group. The attendance list is included as Attachment 1. This meeting was noticed on February 4, 1999.

NFØ7

As a result of the staff's first RAI, issued in April 1998, PFS undertook an extensive geologic investigation program at the proposed PFSF site. The results of the investigations were discussed at the meeting (see Attachment 2). It was noted by the staff that PFS had originally used a deterministic approach in formulating the design basis ground motion contained in the PFS Safety Analysis Report (see PFS SAR Rev. 0, pages 3.2-9 to 3.2-10). Therefore, PFS would need to consider whether the use of probablistic analyses demonstrating compliance with the associated regulatory requirements was consistent with the deterministic formulation. The staff believes that, at a minimum, an inconsistency currently exists between the SAR and the supporting information provided in the response to the RAI.

A representative of Geomatrix described the geological and geophysical investigations undertaken in response to the staff's RAI (see Attachment 3). Both geophysical and subsurface investigations were undertaken. Basically, three faults of interest are near to the site: the Stansbury Fault, the East Fault, and the West Fault. PFS believes that its analyses demonstrate that displacement from these faults is negligible and bounded by the analyses in the SAR.

Two representatives of Geomatrix discussed the Probablistic Seismic Hazard Analysis (PSHA) approach used in the investigations. This presentation included a discussion of the identification seismic sources, seismic source characterization, the ground motion attenuation model, and development of hazard curves. Attachments 4 and 5 summarize this presentation.

During this meeting, no regulatory decisions were requested or made.

If you would like to discuss this meeting summary further, I will be happy to do so.

Attachments: 1. Attendance List
2. Overview of the RAI Responses
3. Geological and Geophysical Investigations and Findings
4. PSHA Approach
5. Application of PSHA to PFSF Site

Docket No: 72-22

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NAME	MDelligatti:dd		VTharpe		CRChappell CRC			
DATE	04/14/99		04/16/99		04/19/99			

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Attendance List
Meeting between U.S. Nuclear Regulatory Commission
and Private Fuel Storage, L.L.C.
February 18, 1999

Name	Organization
Mark Delligatti	NRC/NMSS
Skip Young	NRC/NMSS
Eric Leeds	NRC/NMSS
Joseph Shea	NRC/NMSS
Fritz Sturz	NRC/NMSS
Susan Shankman	NRC/NMSS
Alex McKeigney	NRC/NRR
Sherwin Turk	NRC/OGC
Sue Gagner	NRC/OPA
John Donnell	PFS
Max DeLong	PFS
Kevin Coppersmith	Geomatrix
Robert Youngs	Geomatrix
Kathryn Hanson	Geomatrix
Colin Jones	BNFL
Steve Schulin	IBEX
Asad Chowdhury	CNWRA
John Stamatakos	CNWRA
Paul Gaukler	Shaw Pittman

ATTACHMENT 1

OVERVIEW OF RAI RESPONSES

Kevin Coppersmith
Geomatrix Consultants

ATTACHMENT 2

RAI 2-7
SAR CHAPTER 2 - SITE CHARACTERISTICS
Section 2.6.2 Vibratory Ground Motion

2-7 Provide detailed east-west structural cross-section(s) showing the relationship between the valley bounding structures, including the East Cedar Mountains and Stansbury faults, and stratigraphy primarily to show that the Stansbury fault is the master fault of this basin.

- The cross-section(s) should be drawn to include the entire width of the seismogenic crust.
- The basins in the Basin and Range are typically half-grabens comprised of a master fault and one or more antithetic subordinate faults.
- NUREG–1567 (Section 2.4.6.2), Vibratory Ground Motion, indicates this information should be provided.

RAI 2-5
SAR CHAPTER 2 - SITE CHARACTERISTICS
Section 2.6.2 Vibratory Ground Motion

2-5 Justify the declaration that surface features in the PFSF vicinity are not fault-related as reported by Currey (1996) in the SAR.

- Geology of nearby basins (such as the Tooele Basin) suggests that there may be active faults within the interior of similar basins.

- Additional information should include the following:

    - Aerial and field photographs supporting conclusion that the fault scarps identified by Sack (1993) are, in fact, not seismic features but surficial features related to lacustrine processes as reported by Currey (1996) in the SAR.

RAI 2-5 (cont'd)
SAR CHAPTER 2 - SITE CHARACTERISTICS
Section 2.6.2 Vibratory Ground Motion

– Additional information should include the following:

  - Low sun angle air photographs showing present land surfaces supporting the conclusion that no fault scarps are found near the PFSF.

  - Geophysical data (gravity or magnetic maps) supporting the conclusion that no active faults are located in the vicinity of the PFSF.

  - Discussion providing interpretation of faults shown in Figures 4-1 through 4-5 of the SAR.

– NUREG–1567 (Section 2.4.6.1), Basic Geology and Seismic Information, indicates this information should be included.

RAI RESPONSE SAR CHAPTER 2 - SITE CHARACTERISTICS: 2-5

- Addresses two issues:

(1) providing further documentation of the nontectonic interpretation of the surface features in the PFSF vicinity

(2) providing additional information on faults in the site vicinity

SURFACE FEATURES IN SITE VICINITY

- Don Currey concluded sandy beach ridges are not tectonically related
- Stratigraphic relationships exposed in test pits and continuous core samples confirm interpretation formed during the Stansbury oscillation and are not tectonic
- None of the lineaments appear to disrupt the beach ridges

FAULTS IN SITE VICINITY

- Extensive detailed geologic and geophysical investigations performed to evaluate faults that could pose a fault-displacement and/or vibratory-ground-motion hazard at the proposed site
- Stansbury and the East and West faults are the most important structures with respect to the assessment of seismic hazards in the vicinity of the site.
- Faults characterized by their recency, geometry, earthquake potential

FAULTS IN SITE VICINITY (cont'd)

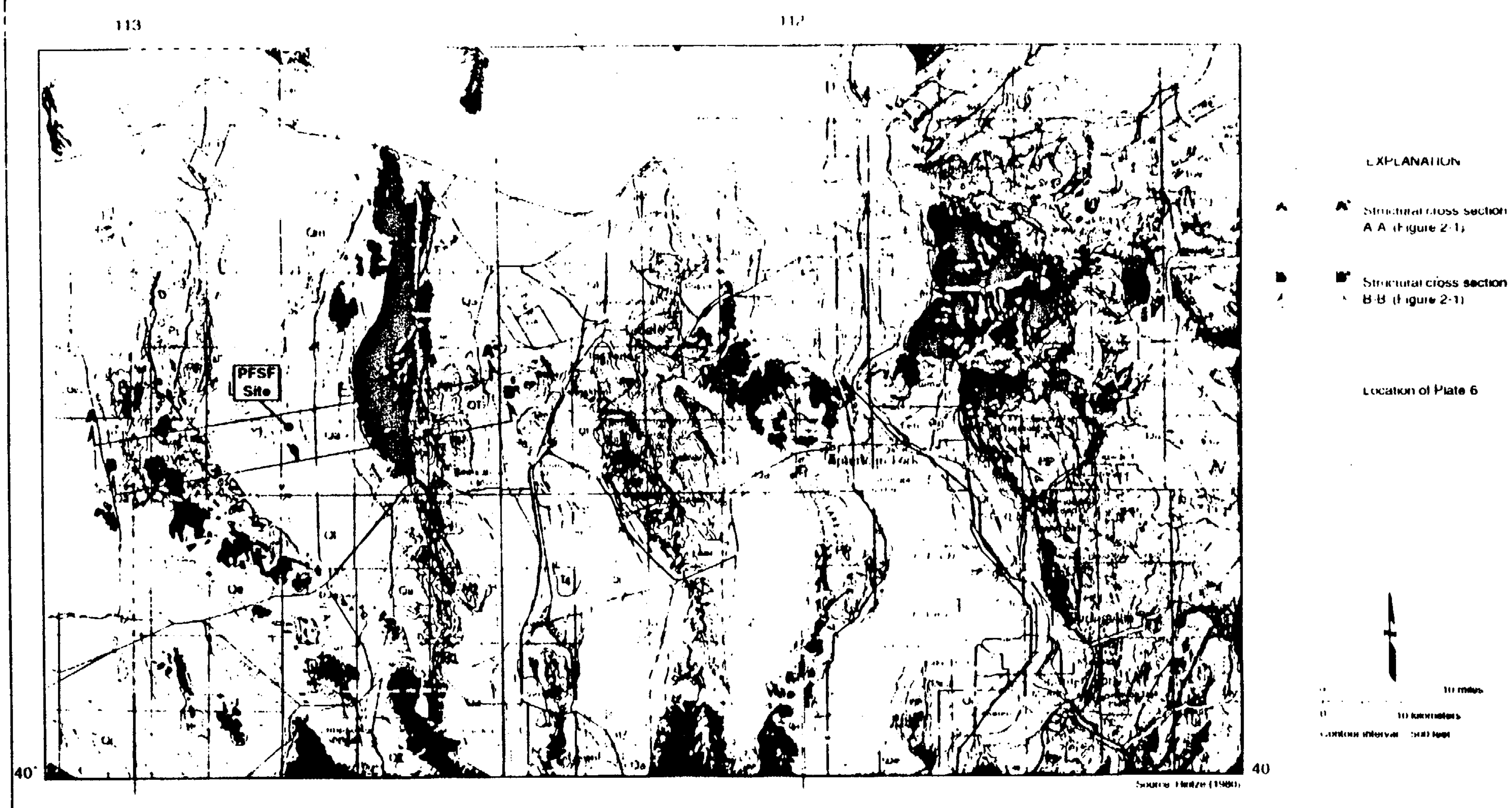
- Probabilistic ground motion and fault displacement hazard assessment conducted to incorporate uncertainties
- 2,000 year-ground motions 0.5g; SAR design basis: 0.67g
- SAR ground motion seismic design bases are conservative
- 2,000 year-displacement <0.1cm
  - Displacement is negligible
  - Bounded by SAR settlement analysis

ATTACHMENT 3

GEOLOGICAL AND GEOPHYSICAL INVESTIGATIONS AND FINDINGS

Kathryn Hanson

Geomatrix Consultants



PART OF GEOLOGIC MAP OF UTAH
SHOWING LOCATIONS OF SITE
AND REGIONAL CROSS SECTIONS
Private Fuel Storage Facility
Skull Valley, Utah

GEOMATRIX	Project No.	Figure
	4790	1-1

SCOPE
GEOLOGICAL AND GEOPHYSICAL INVESTIGATIONS

- **Aerial Photo Survey**
  - 1:20,000, black and white, low-sun-angle photograph coverage of site area and Stansbury fault zone
- **Geologic Mapping Investigations**:
  - Bedrock mapping of Hickman Knolls
  - Quaternary mapping in site area and along Stansbury fault zone
  - Topographic profiling of Stansbury bar
- **Age-dating**
  - Radiocarbon Analysis; Tephrachronology

SCOPE
GEOLOGICAL AND GEOPHYSICAL INVESTIGATIONS (cont'd)

- **Geophysical Investigations – Site Area**
  - High-resolution seismic S-wave reflection survey – 8.5 kilometers
  - Magnetometer Survey – 9.6 km
  - GPR Feasibility-Electrical Conductivity Tests
- **Subsurface Investigations**
  - Drilling Program – 30 Boreholes
  - Trenching Program – 25 Test Pits; 2 Trenches (200 ft long, 20 ft deep)

SCOPE
GEOLOGICAL AND GEOPHYSICAL INVESTIGATIONS (cont'd)

- **Structural Cross-sections and Map Interpretation of Fault Geometry**
  - Additional discussions with researchers
  - Existing geologic map data
  - Reprocessing and Interpretation of Proprietary Seismic Reflection Profile
  - Proprietary Regional Gravity Data

SUMMARY OF RESULTS GEOLOGIC AND GEOPHYSCIAL INVESTIGATIONS

- Stratigraphy
- Bedrock geology
- Regional cross-section
- Nature and timing of deformation
- Fault characterization

Mosaic combining frames 4-11 and 4-12, Olympus Aerial Surveys, Inc. 98240

EXPLANATION

- Limit of bedrock exposure
- Stansbury sand ridge
- Stansbury gravel bar
- Shoreline
- Lineament in bedrock
- Lineament in Quaternary deposits, dotted where less distinct
  - ld - linear drainage
  - tc - tonal contrast
  - vl - vegetation lineament
  - ldp - linear depression
- Qaf - Alluvial fan mantled by lacustrine deposits
- 1998 PFSF High resolution seismic survey line (S-wave)
- Location of geologic cross section
  - C-C' see Figure 3.1
  - D-D' see Plate 4

0 — 0.5 mile

0 — 1 kilometer

PHOTOGEOLOGIC MAP OF SITE VICINITY
Private Fuel Storage Facility
Skull Valley, Utah

GEOMATRIX	Project No.	Figure
	4790	1-3

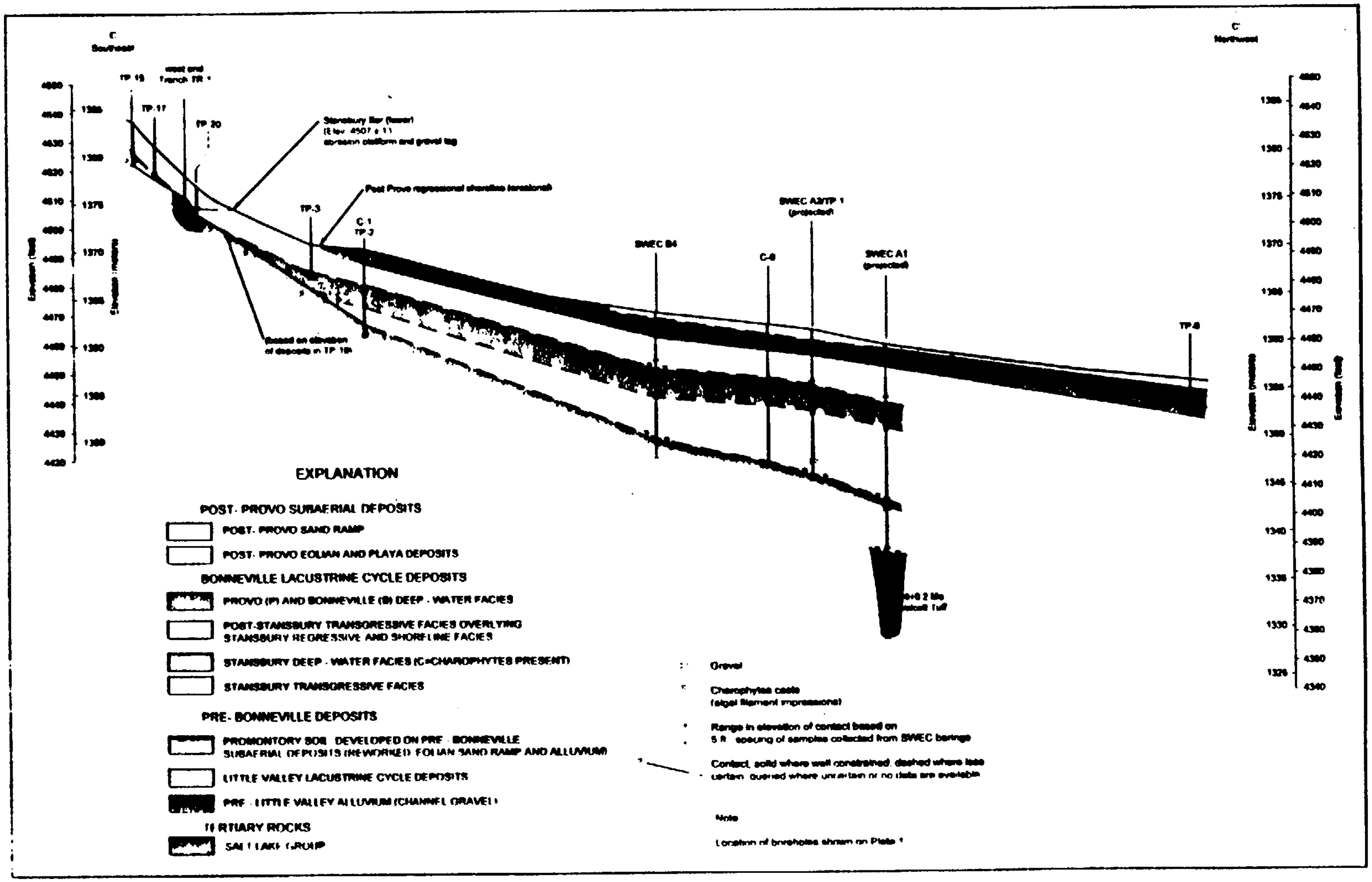
TABLE 3-2

SUMMARY OF AGES OF MAJOR STRATIGRAPHIC UNITS IN THE SITE AREA

Private Fuel Storage Facility
Skull Valley, Utah

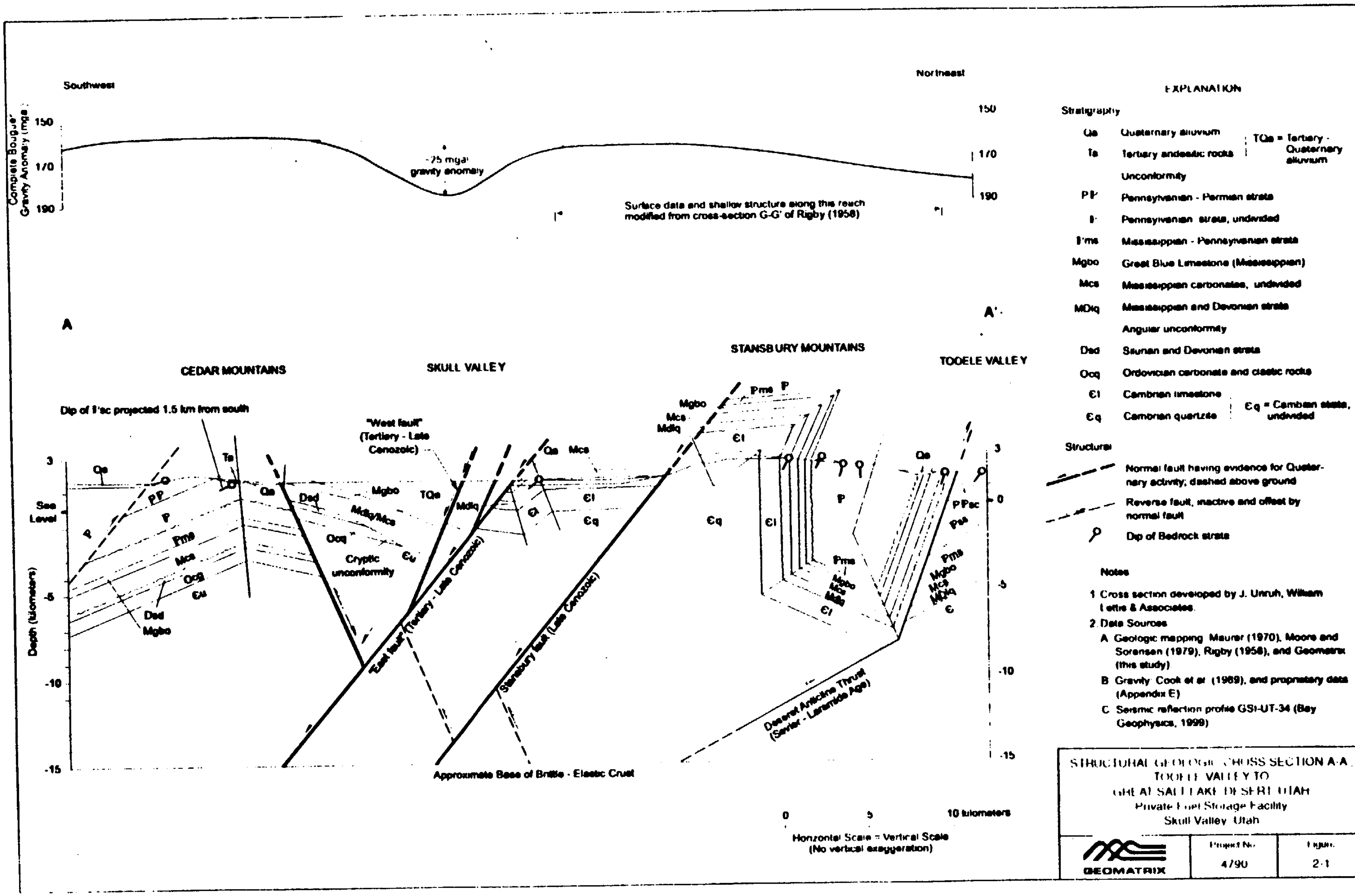
Unit/Associated Geomorphic Surfaces	Estimated Age (ka)	Climatic Condition	Marine Oxygen Isotope Stage[1]
Post-Provo Deposits	≤ 12 ka	Interpluvial	Stage 1
Bonneville Alloformation	28 ka to 12 ka	Pluvial	Stage 2
Provo Shoreline	~14.3 ka[2] to ~12 ka		
Bonneville Shoreline	~16 ka to ~14.5 ka		
Stansbury Shoreline	~22 ka to ~20 ka		
Stansbury Deep-water facies	~24 ka to 22 ka		
End of Late Pinedale Alluvial Fan Deposition	35 ± 5 ka	Glacial/ Interglacial Transition	Stage 2/3
Cutler Dam Alloformation (not observed at PFSF site)	~ 60 ka	Pluvial	Stage 4
Early Pinedale Alluvial Fan	~60 to 70 ka	Glacial/ Interglacial Transition	Stage 4/5
Qp Unconformity	130 ka to 28 ka	Interpluvial	Stage 5
Promontory Soil formed in pre-Bonneville subaerial deposits			
Little Valley Alloformation	~150 ka to 130 ka	Pluvial	Stage 6
Bull Lake Alluvial Fan	~160 ka	Glacial/ Interglacial Transition	Stage 6/7
Pre-Little Valley Subaerial Deposits	≥160 ka	Interpluvial	Stage 7 and older
Q/T Unconformity	> 4 Ma to 160 ka	N/A	N/A

1 Shackleton and Opdyke (1973)
2 Light and Kaufman (1997)

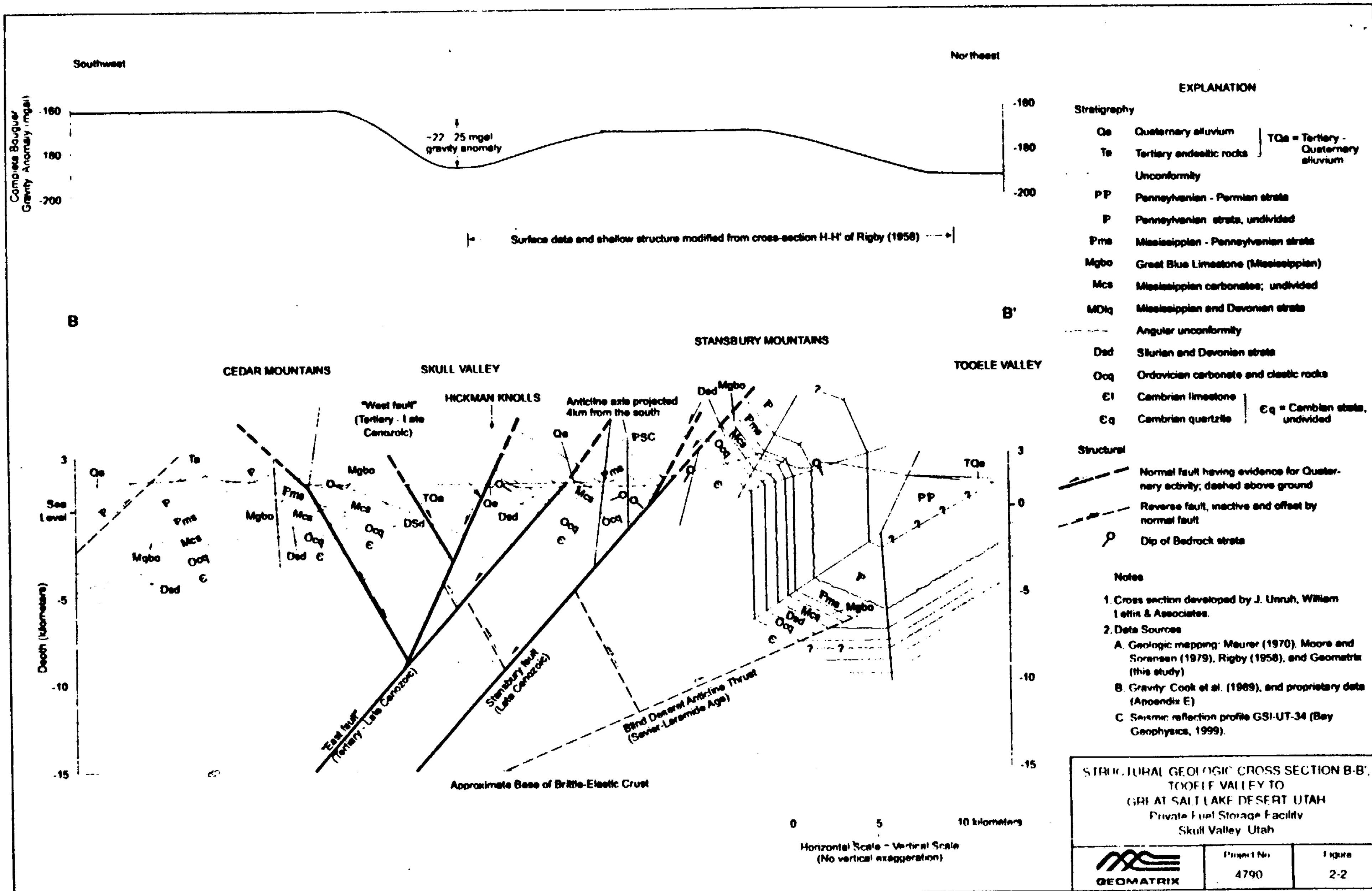

Southeast
Northwest
TP-17
TP 20
TP-3
SWEC B4
C-8
SWEC A2/TP 1
(projected)
SWEC A1
(projected)
TP-8
Post Provo regressional shoreline (erosional)
Elevation (feet)
Elevation (meters)
EXPLANATION
POST- PROVO SUBAERIAL DEPOSITS
POST- PROVO SAND RAMP
POST- PROVO EOLIAN AND PLAYA DEPOSITS
BONNEVILLE LACUSTRINE CYCLE DEPOSITS
PROVO (P) AND BONNEVILLE (B) DEEP - WATER FACIES
POST-STANSBURY TRANSGRESSIVE FACIES OVERLYING STANSBURY REGRESSIVE AND SHORELINE FACIES
STANSBURY DEEP - WATER FACIES (C=CHAROPHYTES PRESENT)
STANSBURY TRANSGRESSIVE FACIES
PRE- BONNEVILLE DEPOSITS
PROMONTORY SOIL DEVELOPED ON PRE - BONNEVILLE SUBAERIAL DEPOSITS (REWORKED EOLIAN SAND RAMP AND ALLUVIUM)
LITTLE VALLEY LACUSTRINE CYCLE DEPOSITS
PRE - LITTLE VALLEY ALLUVIUM (CHANNEL GRAVEL)
TERTIARY ROCKS
SALT LAKE GROUP
Gravel
Charophytes casts
(algal filament impressions)
Range in elevation of contact based on 5 ft spacing of samples collected from SWEC borings
Contact, solid where well constrained, dashed where less certain, queried where uncertain or no data are available
Note
Location of boreholes shown on Plate 1

RESULTS OF BEDROCK MAPPING

- Major west-dipping normal fault west of Hickman Knolls indicated by Paleozoic bedrock (Hickman Knolls) in central Skull Valley and geophysical evidence for adjacent Tertiary basin
- Major fault extending through Hickman Knolls having significant offset is unlikely - Maximum vertical offset of bedrock between the east-central and western portion of the Knolls is 15 m
- Majority of deformation consistent with brecciation of semi-consolidated material in early post-depositional environment
- Later phase of low-strain, brittle deformation expressed as north-south and east-west vertical fractures post-date earlier ductile shearing.



Southwest
Northeast
Complete Bouguer Gravity Anomaly (mgal)
150
170
190
-75 mgal gravity anomaly
Surface data and shallow structure along this reach modified from cross-section G-G' of Rigby (1958)
A
A'
CEDAR MOUNTAINS
SKULL VALLEY
STANSBURY MOUNTAINS
TOOELE VALLEY
Dip of P̶sc projected 1.5 km from south
"West fault" (Tertiary - Late Cenozoic)
"East fault" (Tertiary - Late Cenozoic)
Stansbury fault (Late Cenozoic)
Cryptic unconformity
Deseret Anticline Thrust (Sevier - Laramide Age)
Approximate Base of Brittle - Elastic Crust
Sea Level
Depth (kilometers)
3
0
-5
-10
-15
0 5 10 kilometers
Horizontal Scale = Vertical Scale (No vertical exaggeration)
EXPLANATION
Stratigraphy
Qa Quaternary alluvium
Ta Tertiary andesitic rocks
TQa = Tertiary - Quaternary alluvium
Unconformity
PP̶ Pennsylvanian - Permian strata
P̶ Pennsylvanian strata, undivided
P̶ms Mississippian - Pennsylvanian strata
Mgbo Great Blue Limestone (Mississippian)
Mcs Mississippian carbonates, undivided
MDiq Mississippian and Devonian strata
Angular unconformity
Dsd Silurian and Devonian strata
Ocq Ordovician carbonate and clastic rocks
Єl Cambrian limestone
Єq Cambrian quartzite
Єq = Cambrian strata, undivided
Structural
Normal fault having evidence for Quaternary activity; dashed above ground
Reverse fault, inactive and offset by normal fault
Dip of Bedrock strata
Notes
1 Cross section developed by J. Unruh, William Lettis & Associates.
2 Data Sources
A Geologic mapping: Maurer (1970), Moore and Sorensen (1979), Rigby (1958), and Geomatrix (this study)
B Gravity: Cook et al. (1989), and proprietary data (Appendix E)
C Seismic reflection profile GSI-UT-34 (Bay Geophysics, 1999)
STRUCTURAL GEOLOGIC CROSS SECTION A-A'
TOOELE VALLEY TO
GREAT SALT LAKE DESERT, UTAH
Private Fuel Storage Facility
Skull Valley, Utah
GEOMATRIX
Project No. 4790
Figure 2-1



Southwest
Northeast
Complete Bouguer Gravity Anomaly (mgal)
-160
-180
-200
-22 25 mgal gravity anomaly
Surface data and shallow structure modified from cross-section H-H' of Rigby (1958)
B
B'
CEDAR MOUNTAINS
SKULL VALLEY
HICKMAN KNOLLS
STANSBURY MOUNTAINS
TOOELE VALLEY
"West fault" (Tertiary - Late Cenozoic)
Anticline axis projected 4km from the south
"East fault" (Tertiary - Late Cenozoic)
Stansbury fault (Late Cenozoic)
Blind Deseret Anticline Thrust (Sevier-Laramide Age)
Approximate Base of Brittle-Elastic Crust
Sea Level
Depth (kilometers)
3
0
-5
-10
-15
Horizontal Scale = Vertical Scale (No vertical exaggeration)
0
5
10 kilometers
EXPLANATION
Stratigraphy
Qa Quaternary alluvium
Ta Tertiary andesitic rocks
TQa = Tertiary - Quaternary alluvium
Unconformity
PP Pennsylvanian - Permian strata
P Pennsylvanian strata, undivided
Pms Mississippian - Pennsylvanian strata
Mgbo Great Blue Limestone (Mississippian)
Mcs Mississippian carbonates; undivided
MDlq Mississippian and Devonian strata
Angular unconformity
Dsd Silurian and Devonian strata
Ocq Ordovician carbonate and clastic rocks
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C. Seismic reflection profile GSI-UT-34 (Bay Geophysics, 1999).
STRUCTURAL GEOLOGIC CROSS SECTION B-B', TOOELE VALLEY TO GREAT SALT LAKE DESERT, UTAH
Private Fuel Storage Facility
Skull Valley, Utah
GEOMATRIX
Project No. 4790
Figure 2-2

STANSBURY FAULT ZONE

- **Distance from proposed PFSF:** 9 km
- **Geometry:** Normal fault, west-dipping – includes main trace and secondary northwest-trending splays
- **Slip Rate:** 0.3 to 0.5 mm/yr
- **Recency and Recurrence:** 2 events post-18 ± 2 ka; most recent event- early to middle Holocene
- **Average Single Event Displacement:** 2 –3 m (preferred)

EAST FAULT

- **Distance from proposed PFSF:** 0.9 km
- **Geometry:** Normal fault, west-dipping
- **Slip Rate:** 0.05 to 0.45 mm/yr
- **Recency:** Late Pleistocene (post-28 ka, possibly post-12 ka)

WEST FAULT

- **Distance from proposed PFSF:** 2 km
- **Geometry:** Normal fault, west-dipping
- **Slip Rate:** 0.01 to 0.1 mm/yr
- **Recency:** Post-20 ka

DISTRIBUTED FAULTS

FAULT	Recency	Slip Rate (mm/yr)
D	Post-28 ka	0.01 - 0.08
F	Post-28 ka	0.01– 0.04
C	28 – 160 ka	0.001– 0.02

PROBABILISTIC SEISMIC HAZARD ANALYSIS (PSHA) APPROACH

Kevin Coppersmith

Geomatrix Consultants

Attachment 4

SAR DESIGN BASIS GROUND MOTIONS

- Consistent with Part 72.102 and 10 CFR Part 100 for nuclear power plants
- MCE on capable sources at closest approach to site; controlling source is largest ground motions and determines SSE ground motions
- SAR Design Basis Ground Motions: 0.67g

PROBABILISTIC ANALYSIS APPROACH

- Does not incorporate frequency of earthquake occurrence or uncertainties in location, size, or ground motions
- Part 100 has been revised (Part 100.23) to allow for probabilistic methodologies
- Part 72 being revised (SECY-98-126) for dry cask storage installations.

PROBABILISTIC SEISMIC HAZARD ANALYSES

- Probabilistic seismic hazard analysis: vibratory ground motions
- Probabilistic fault displacement hazard analysis: fault displacements at the PFSF site

PROBABILITY LEVEL OF INTEREST

- **PSHA Hazard Curves:** Express the probability (or annual frequency) of exceeding levels of motion
- **Probability level:** Expresses the degree of conservatism in design
- **Risk-Informed Graded Approach:** Takes into account the *consequences* of the possible failure of system in establishing hazard probability level

PROBABILITY LEVEL OF INTEREST (cont'd)

- **Risk-informed graded approach endorsed by NRC:**
  - Evaluation of the request for exemption to Part 72.102(f)(1) Seismic Design Requirement for Three Mile Island Unit 2 Independent Spent Fuel Storage Installation (SECY-98-071)
  - Rulemaking Plan for revision to Part 72 (SECY-98-126).

PROBABILITY LEVEL OF INTEREST (cont'd)

NRC Rulemaking Plan (SECY-98-126):

"NRC staff believed that a major seismic event at an ISFSI storing spent fuel in dry casks or canisters would most likely have minor radiological consequences compared with a major seismic event at an NPP, spent fuel pool, or single massive storage structure."

- Recommended probabilistic approach
- Probability levels appropriate to dry cask storage system (shorter return period)

PROBABILITY LEVEL OF INTEREST (cont'd)

- **TMI-2 ISFSI exemption to Part 72.102**
  - Approved use of probabilistic analysis
  - Approved 2,000-year return period
  - DOE Standard 1020
    - PC-3 Facilities – 2,000-year return period
  - 10 CFR Part 60 Design Basis Event
    - < 1mSv (100 mrem) – 1,000-year return period

PROBABILITY LEVEL OF INTEREST (cont'd)

- **NRC Evaluation of the request for TMI-2 Exemption (SECY-98-071):**
  - "Dry spent fuel storage facilities such as the TMI-2 ISFSI are PC 3 and must have a design earthquake equal to the mean ground motion with a 2,000-year return period. Considering the minor radiological consequences from a canister failure, and the lack of a credible mechanism to cause a failure, the staff finds that the DOE approach of using the **2,000-year return period** mean ground motion as the design earthquake for dry storage facilities is **adequately conservative.**"

PROBABILITY LEVEL FOR PFSF

- Risk-informed graded approach leads to selection of 2,000 year (5×10^{-4} per year) probability level as adequately conservative
- 2,000-year fault displacement also appropriate
  - Consequences due to fault displacement are the same as those due to vibratory ground motions

APPLICATION OF PSHA TO PFSF SITE

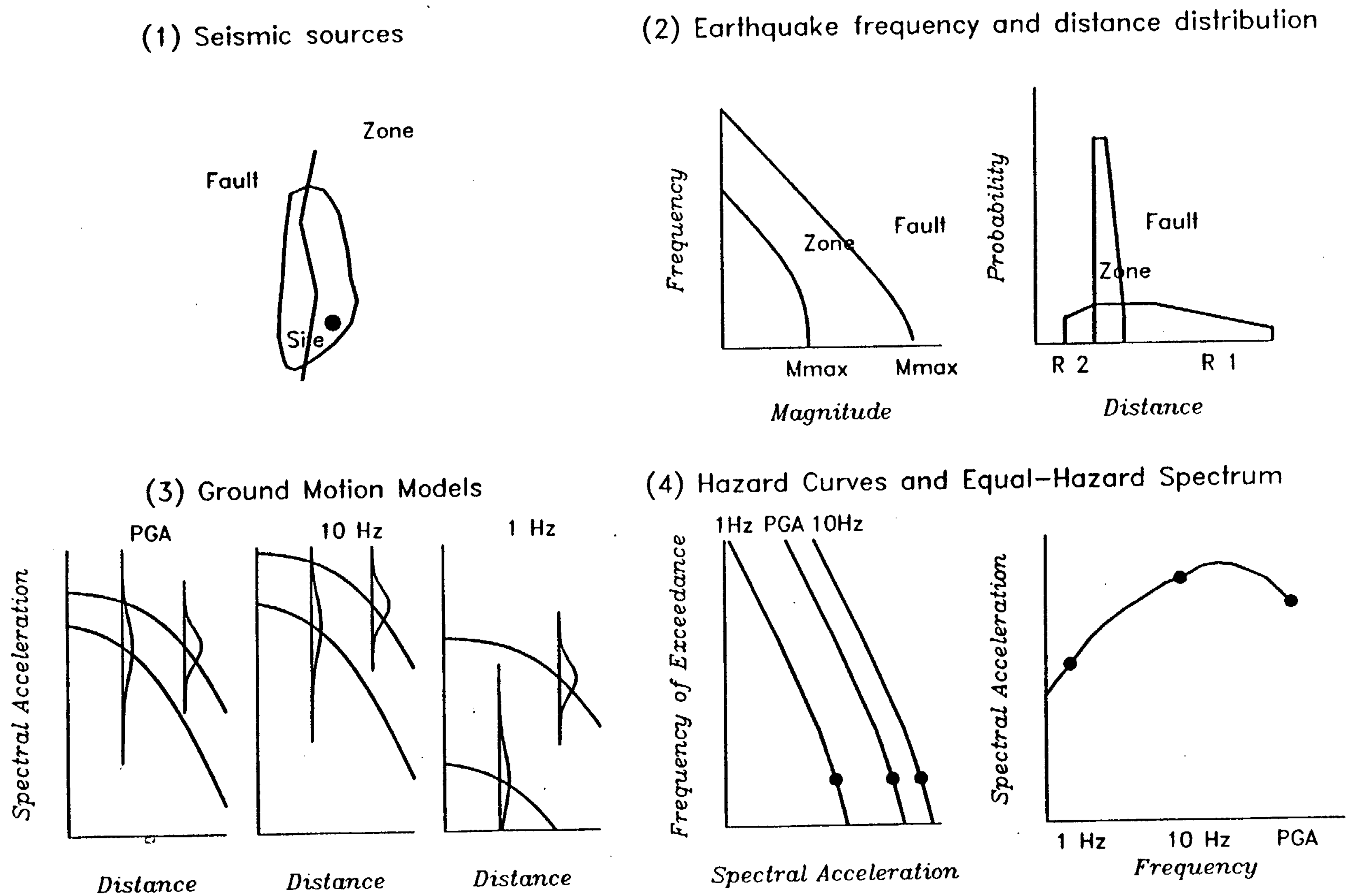
Robert Youngs

Geomatrix Consultants

Attachment 5

PSHA METHODOLOGY

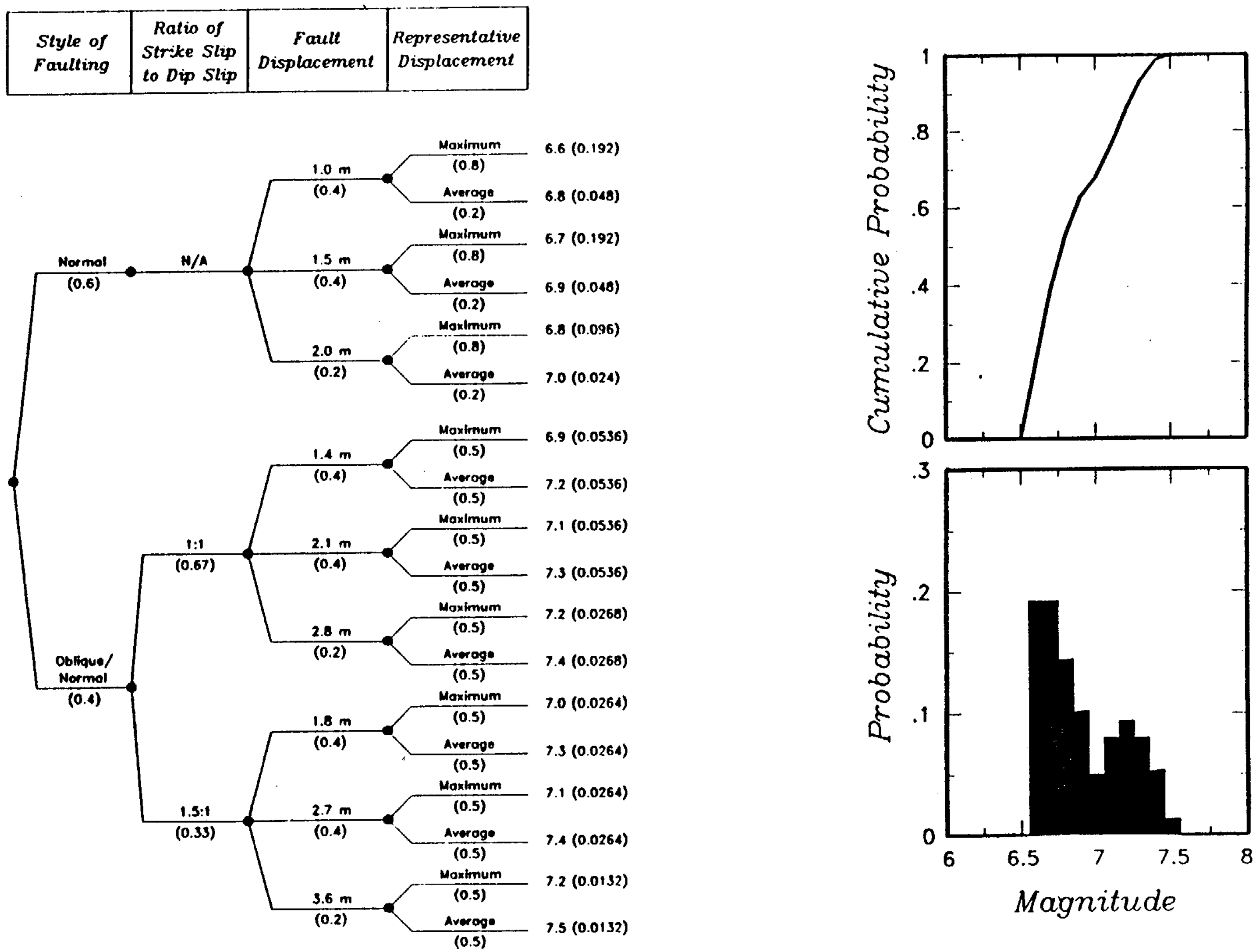
- **IDENTIFICATION OF SEISMIC SOURCES**
  - Faults
  - Areal Source Zones
- **SEISMIC SOURCE CHARACTERIZATION**
  - Frequency of Earthquake Occurrence
  - Maximum Magnitude
  - Spatial Distribution Model
- **GROUND MOTION ATTENUATION MODEL**
- **DEVELOPMENT OF HAZARD CURVES**



GEOMATRIX

SEISMIC HAZARD COMPUTATIONAL MODEL
Private Fuel Storage Facility
Skull Valley, Utah

Project No.	Figure
4790	6-1

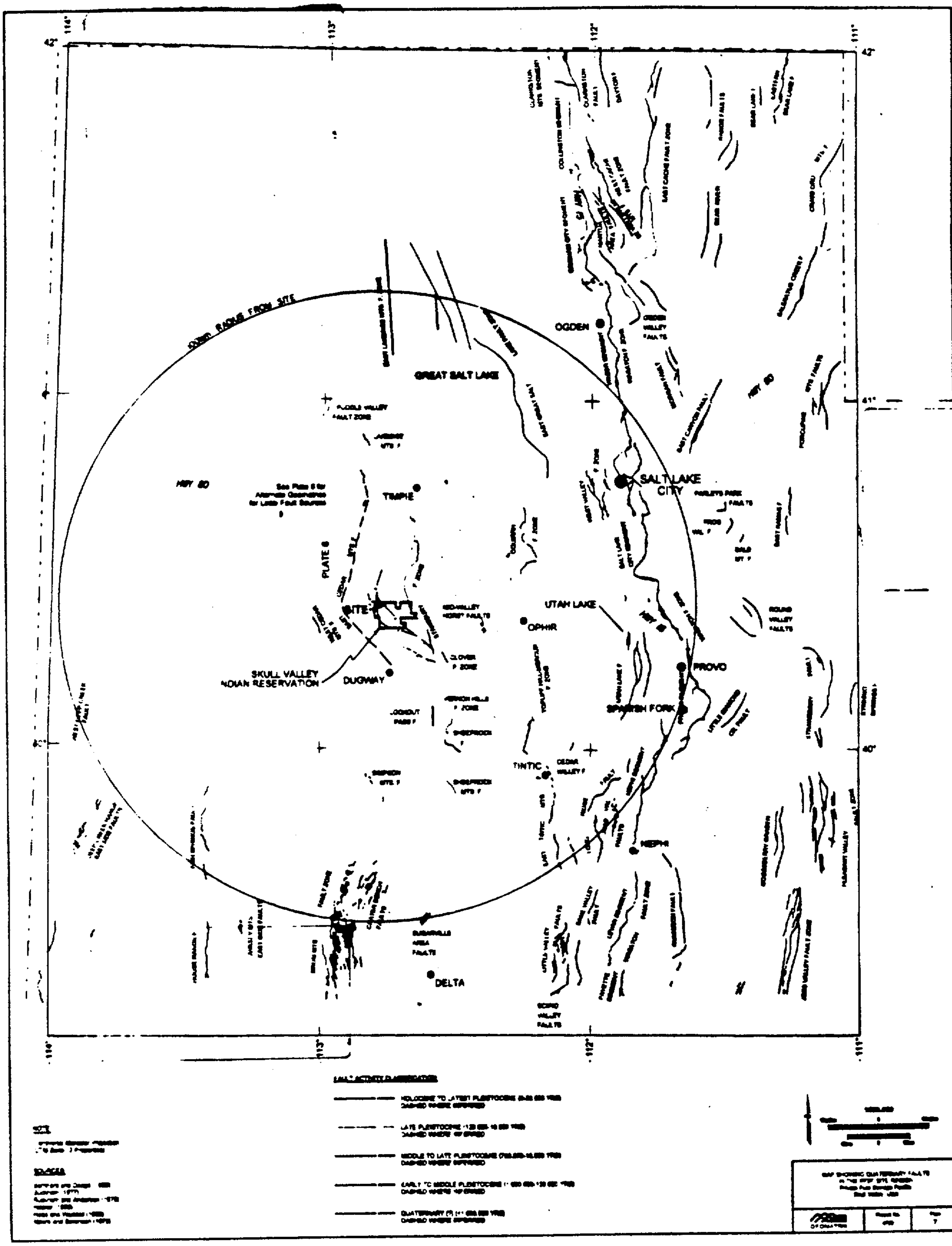


GEOMATRIX

EXAMPLE LOGIC TREE FOR ASSESSING MAGNITUDE OF PALEO EARTHQUAKES
Private Fuel Storage Facility
Skull Valley, Utah

Project No. 4790

Figure 6-2



GREAT SALT LAKE
OGDEN
SALT LAKE CITY
UTAH LAKE
PROVO
SPANISH FORK
OPHIR
TINTIC
NEPHI
DELTA
DUGWAY
SKULL VALLEY INDIAN RESERVATION
SITE
TIMPIE
PLATE 6
HWY 80
40°
41°
42°
111°
112°
113°
114°

FAULT CHARACTERIZATION PARAMETERS

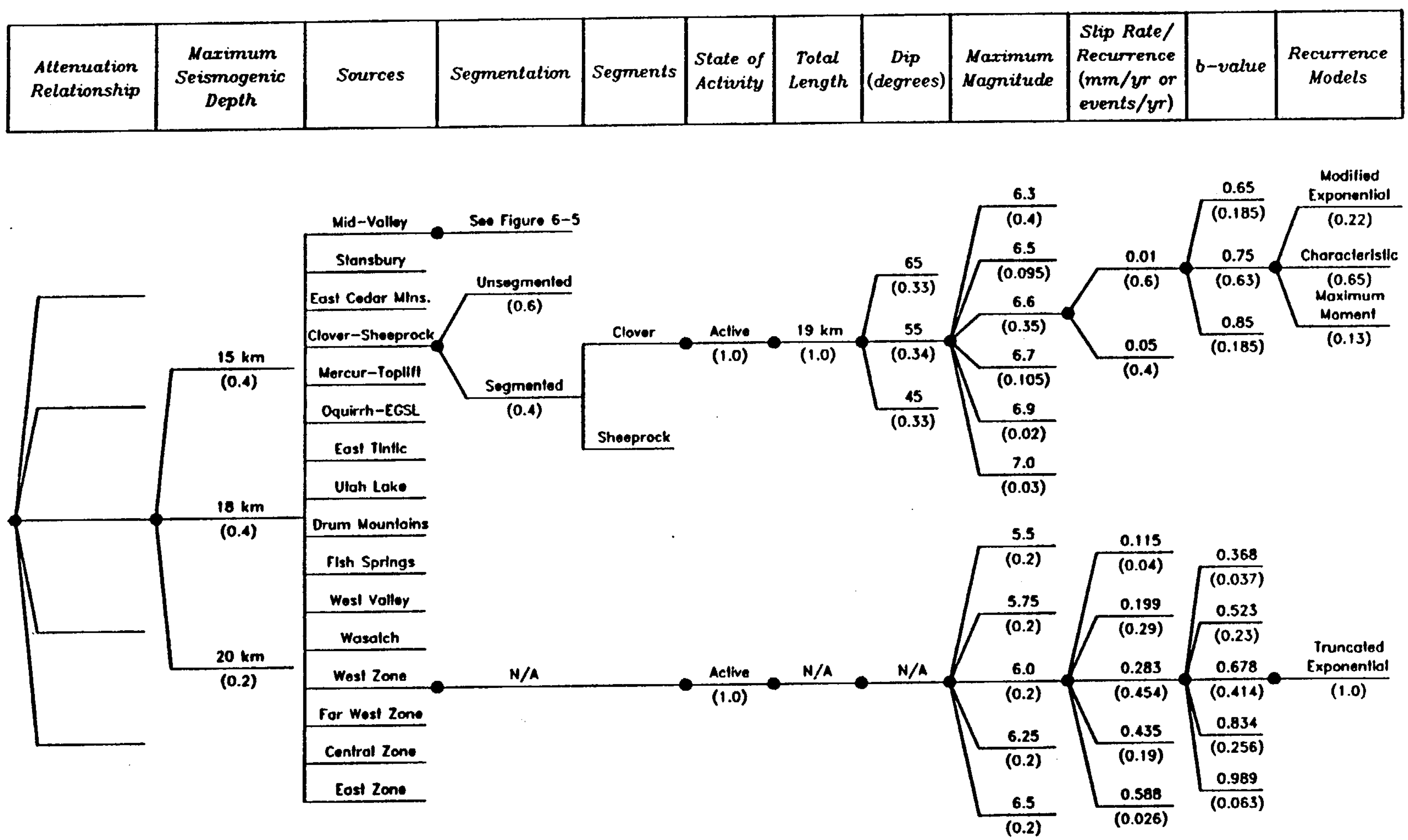
- Technique and relative weights based on Yucca Mountain Expert Panel
- Maximum magnitude assessed using six techniques
- Three recurrence models

TABLE 6-2

FAULT SOURCES-SOURCE CHARACTERIZATION PARAMETERS AND WEIGHTS

Private Fuel Storage Facility
Skull Valley, Utah

Fault	Map Designation	Probability of Activity	Total Length (km)	Downdip Geometry	Maximum Rupture Lengths (km)	Slip Rate (mm/yr) [wt]	Single Event Displacement[1] (m)	Comments
Mid-Valley Faults								
East, West, and Springline faults	EF, WF, and SpF	EF [1.0] WF [1.0] SpF [0.8]	EF 28 [1.0] SpF 18 [1.0] EF/SpF 46 [1.0] WF-Model A 23 [1.0] WF-Model B 36 [1.0]	45°W [0.33] 55°W [0.34] 65°W [0.33] In cases where the West fault is treated as an independent fault source, the dips of the East and West faults are modeled to be parallel to preclude intersections or truncations of the faults at depth.	EF 12 [0.2] 18 [0.5] 28 [0.3] SpF 18 [1.0] EF/SpF 12 [0.1] 18 [0.3] 28 [0.5] 46 [0.1] WF-Model A 12 [0.6] 23 [0.4] WF-Model B 12 [0.5] 21 [0.4] 36 [0.1]	EF 0.05 [0.1] 0.1 [0.3] 0.2 [0.4] 0.3 [0.19] 0.45 [0.01] WF 0.01 [0.2] 0.04 [0.5] 0.07 [0.2] 0.1 [0.1] EF-WF 0.05 [0.1] 0.1 [0.28] 0.2 [0.29] 0.3 [0.28] 0.45 [0.05] SpF 0.05 [0.2] 0.1 [0.2] 0.2 [0.35] 0.3 [0.2] 0.45 [0.05] EF/SpF and EF-WF/SpF Variable slip along strike		See Figure 6-4 for logic tree showing alternate mid-valley fault sources included in seismic hazard model



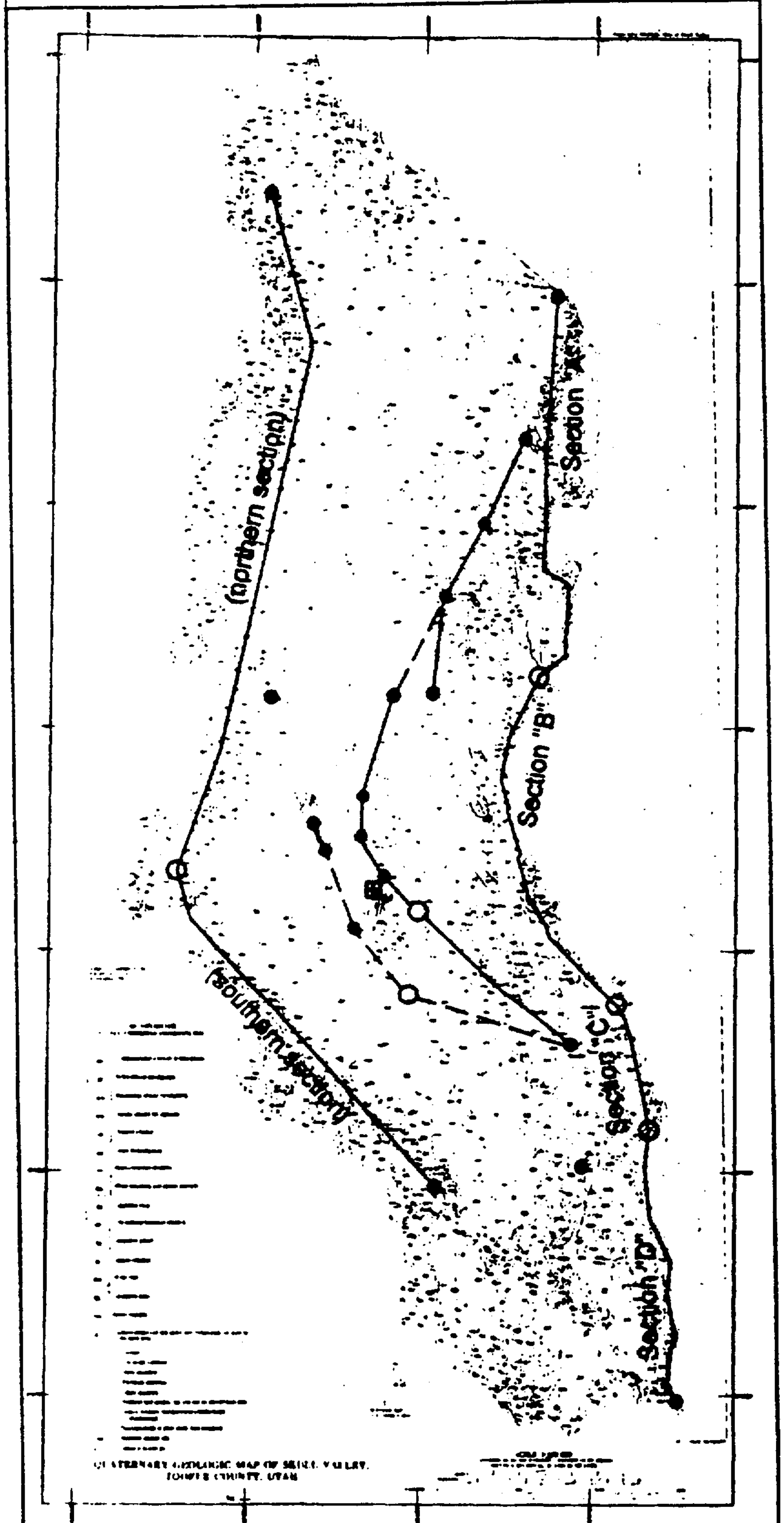
GEOMATRIX

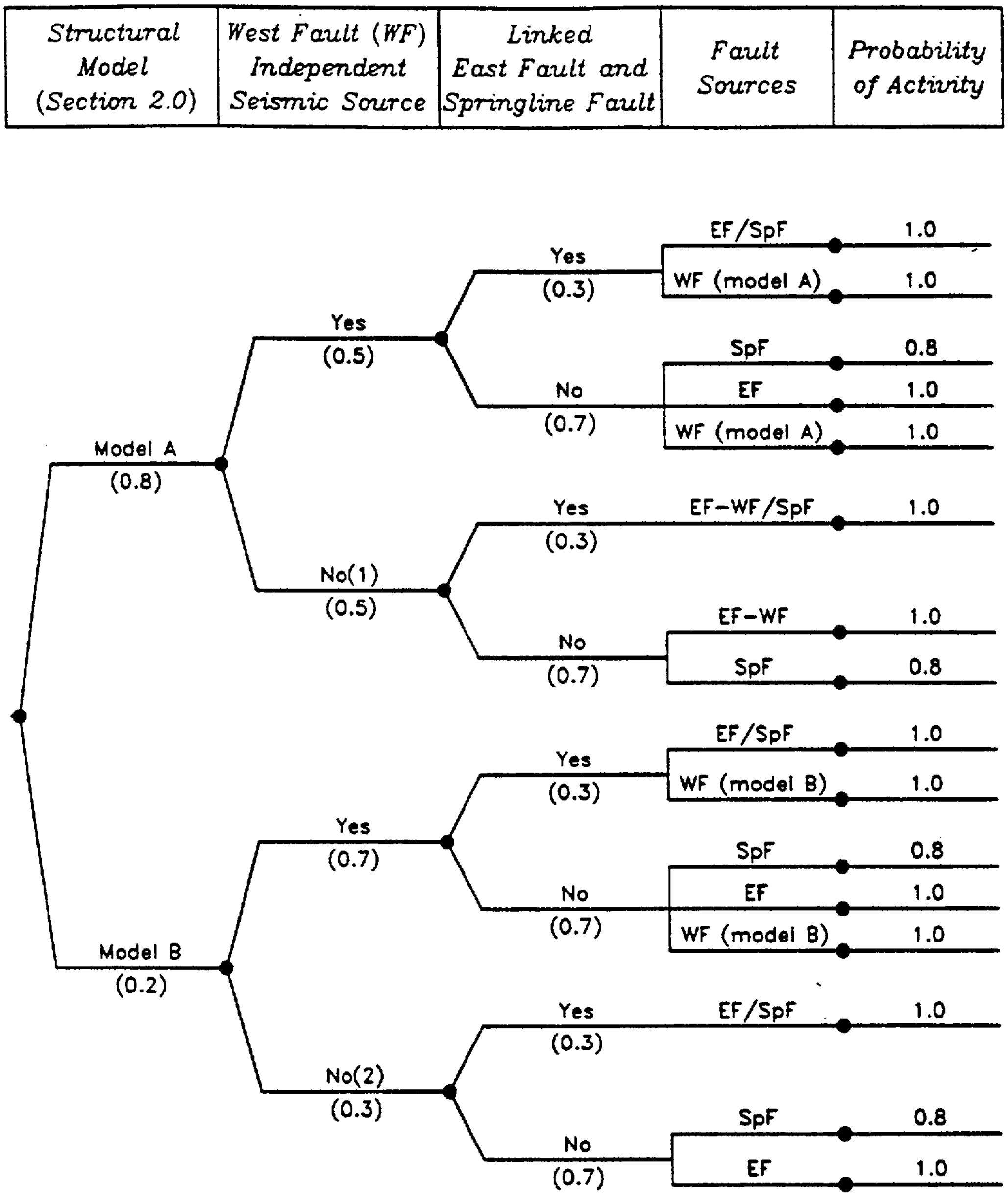
SEISMIC HAZARD MODEL LOGIC TREE
Private Fuel Storage Facility
Skull Valley, Utah

Project No. 4790

Figure 6-3

SEISMOGENIC FAULT RUPTURE SCENARIO- MODEL A





1. WF merges with EF above seismogenic depth. Slip rate estimate is based on combined slip rates indicated for both faults.
2. Deformation along WF is treated as secondary rupture in the hanging wall of EF.

GEOMATRIX

LOGIC TREE – MID-VALLEY FAULT SOURCES
Private Fuel Storage Facility
Skull Valley, Utah

Project No. 4790

Figure 6-5

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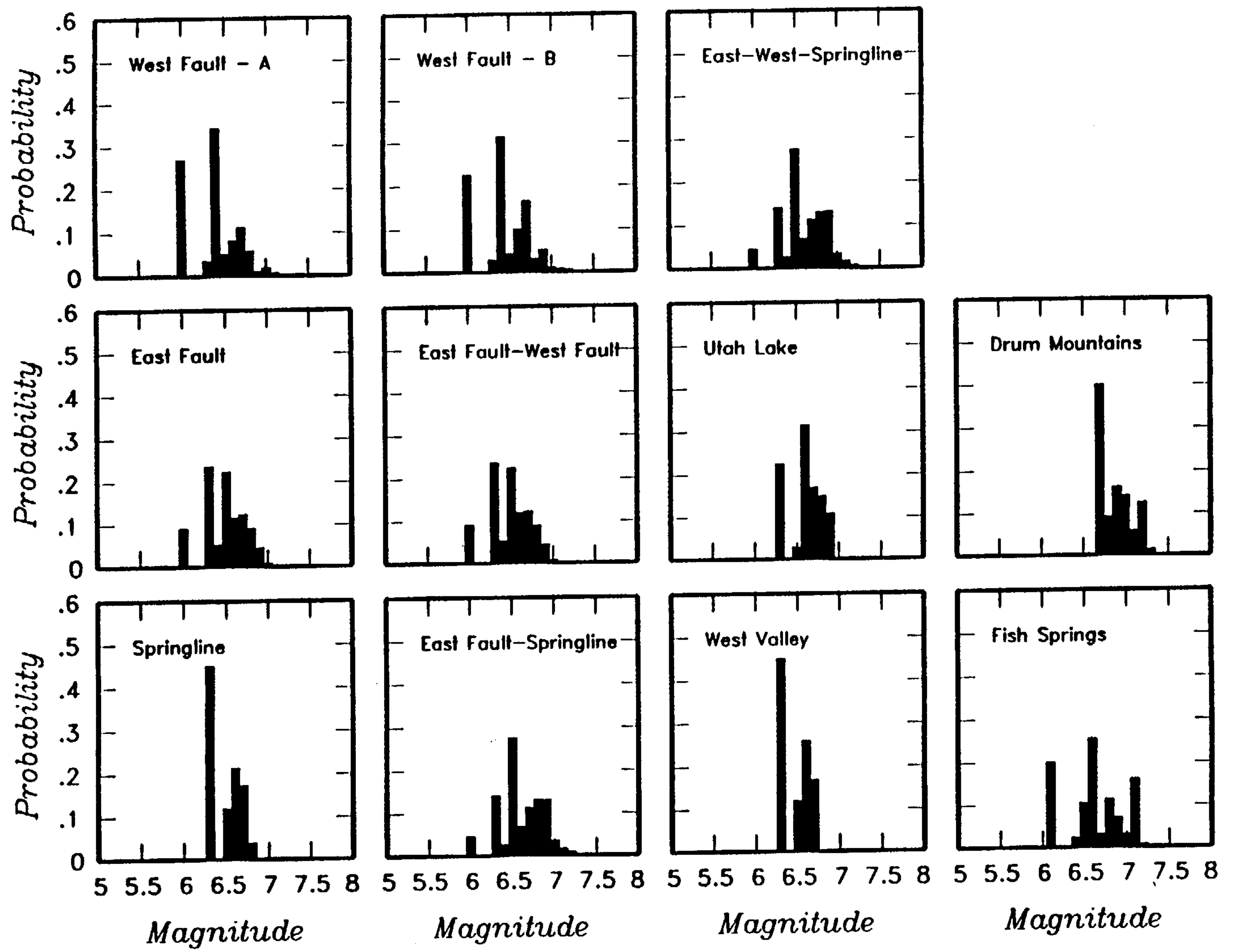
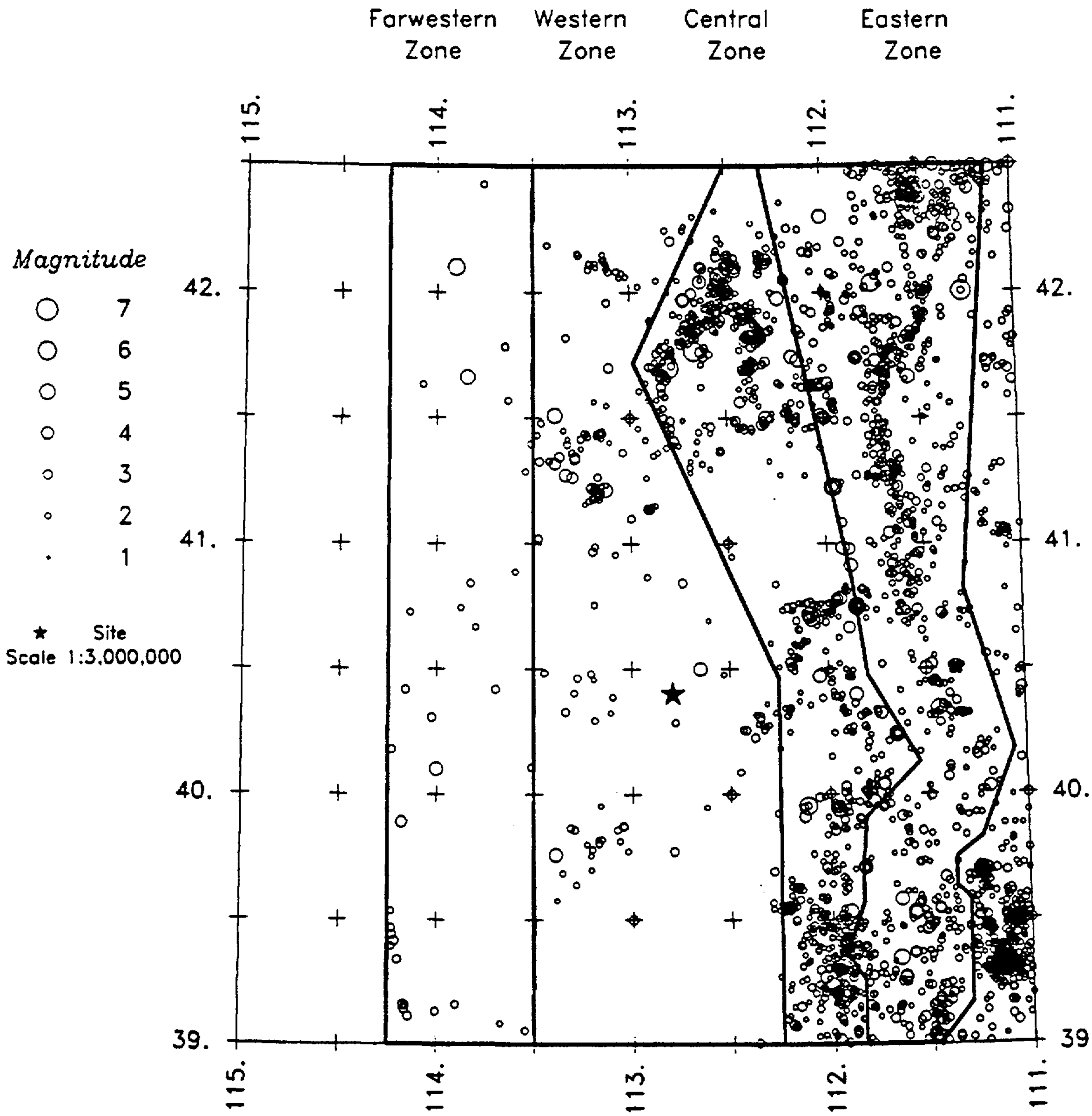
Non-GDS



GEOMATRIX

MAXIMUM MAGNITUDE DISTRIBUTIONS FOR FAULT SOURCES
Private Fuel Storage Facility
Skull Valley, Utah
(page 2 of 3)

Project No.	4790
Figure	6-6



GEOMATRIX

MAP SHOWING LOCATION OF SEISMIC SOURCE ZONES AND INDEPENDENT EARTHQUAKES RECORDED FROM 1850 TO 7/1/98
Private Fuel Storage Facility
Skull Valley, Utah

Project No. 4790

Figure 6-7

Non-GDS

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GROUND MOTION MODELS

1. Use empirical models selected by Yucca Mountain Ground Motion Expert Panel

    - Seven empirical models based primarily on California data
    - Five have companion soil site attenuation relationships

2. Modify California models for conditions in site region following procedure used for Yucca Mountain assessment

    - Modify for difference between California strike-slip and normal faulting earthquakes using Yucca Mountain adjustments
    - Modify for difference in regional attenuation (Q)
    - Modify for differences between California soil site response and Skull Valley site response.

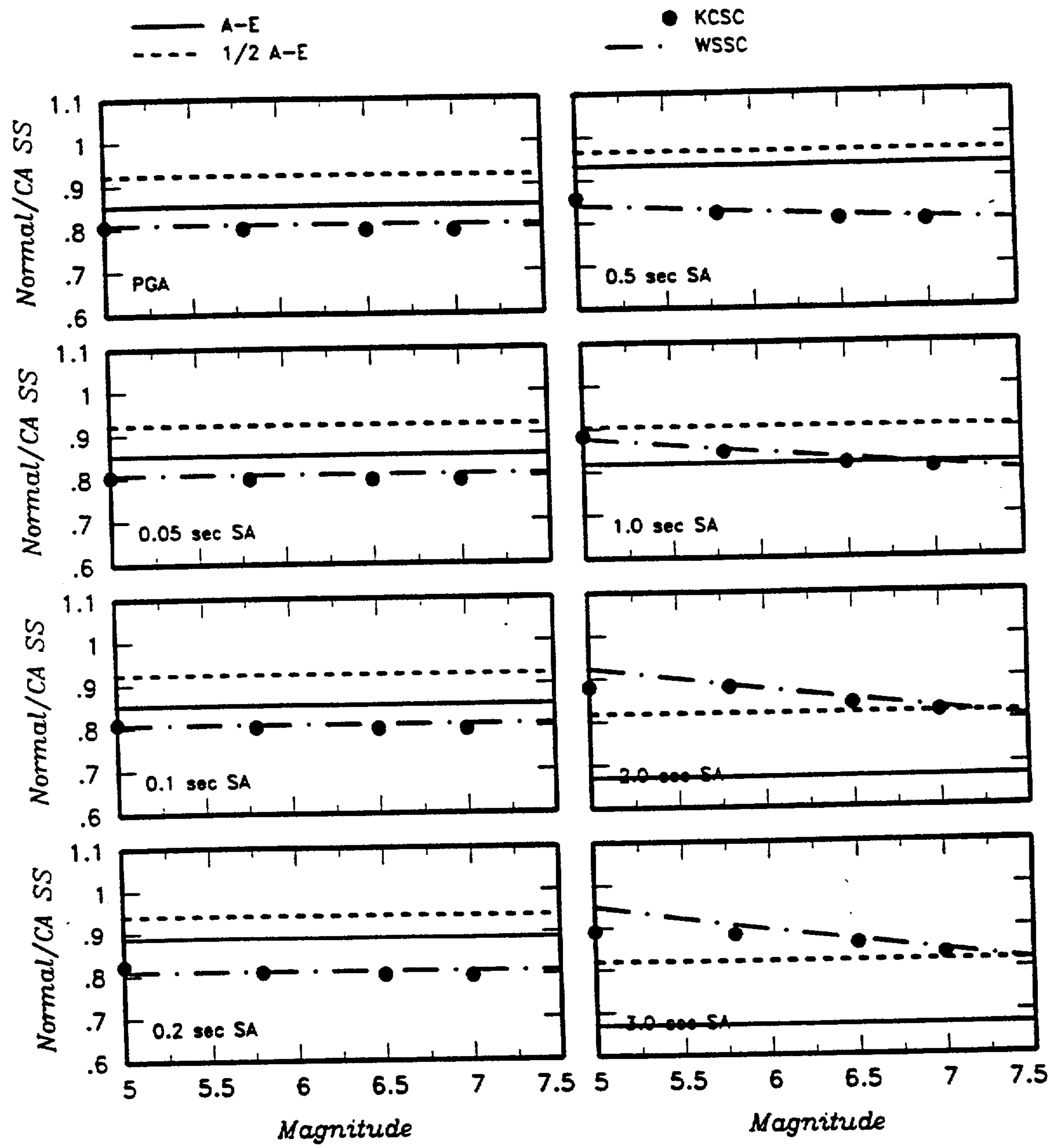
GEOMATRIX

TABLE F-1

EMPIRICAL ATTENUATION RELATIONSHIPS FOR HORIZONTAL MOTIONS AND SEISMIC SOURCE SCALING FACTORS FROM THE YUCCA MOUNTAIN GROUND MOTION EXPERT PANEL

Private Fuel Storage Facility
Skull Valley, Utah

Rock Site Attenuation Relationship	Earthquake Source Scaling Method	Average Weight Across Expert Panel	Re-normalized Weights for Companion Soil Relationships
Abrahamson and Silva (1997)	None	0	0
	A-E	0.222	0.246
	½ A-E	0.036	0.040
	KCSC	0.051	0.056
	WSSC	0.014	0.016
Boore and others (1997)	None	0.006	0.006
	A-E	0.014	0.016
	½ A-E	0.036	0.040
	KCSC	0.042	0.046
	WSSC	0.050	0.055
Campbell (1997)	None	0.006	0.006
	A-E	0.029	0.032
	½ A-E	0.036	0.040
	KCSC	0.051	0.056
	WSSC	0.036	0.040
Idriss (1991, 1997)	None	0.006	
	A-E	0.014	
	½ A-E	0	
	KCSC	0.051	
	WSSC	0.021	
Sadigh and others (1997)	None	0.006	0.006
	A-E	0.029	0.032
	½ A-E	0.036	0.040
	KCSC	0.051	0.056
	WSSC	0.021	0.024
Spudich and others (1997)	None	0.115	0.128
	KCSC	0.018	0.020
Sabetta and Pugliese (1996)	None	0.006	

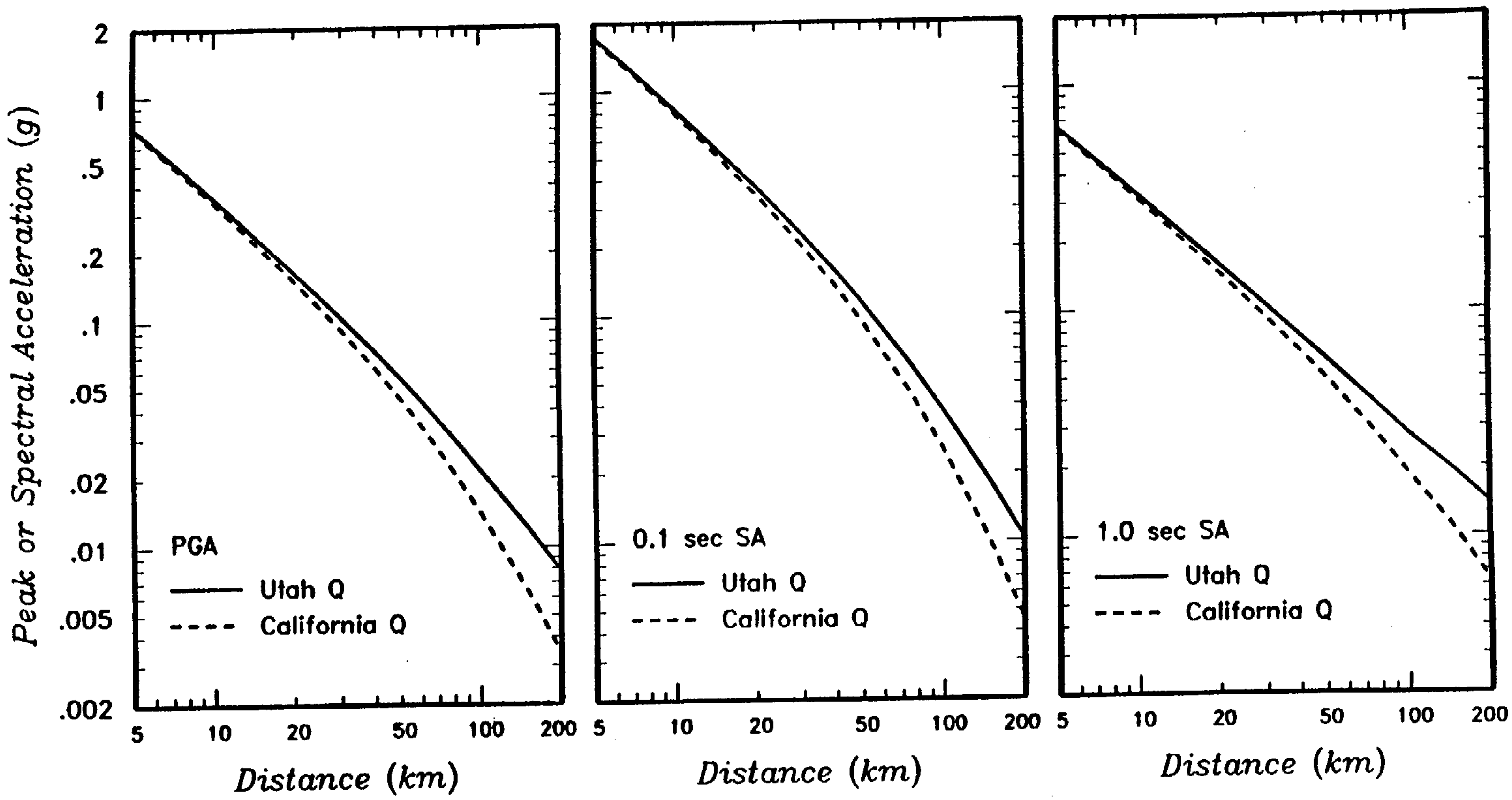


GEOMATRIX

SCALING RELATIONSHIPS DEVELOPED FOR THE YUCCA MOUNTAIN PROJECT (CRWMS M&O, 1998) FOR TRANSLATING HORIZONTAL GROUND MOTIONS FROM CALIFORNIA STRIKE-SLIP EARTHQUAKES TO EXTENSIONAL TECTONICS NORMAL FAULTING EARTHQUAKE MOTIONS.

Project No. 4790

Figure F-1

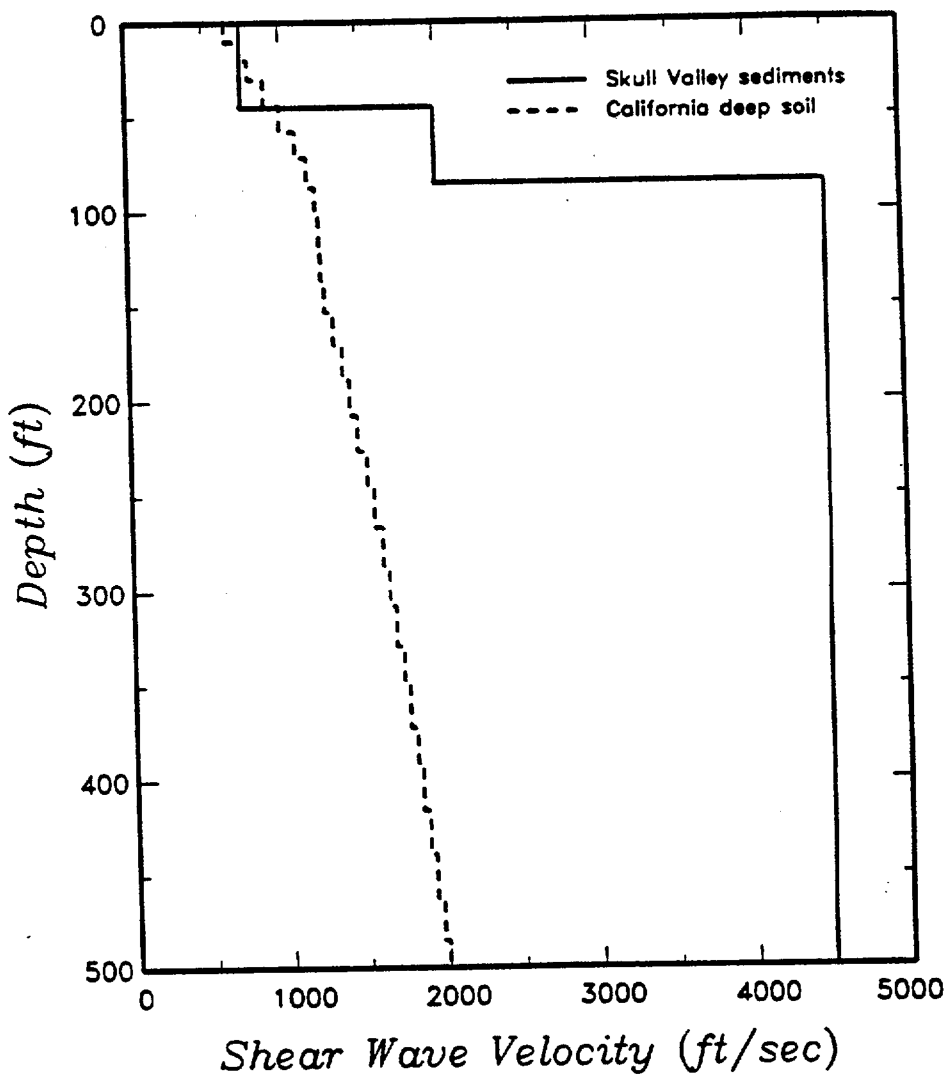


GEOMATRIX

ATTENUATION OF GROUND MOTION COMPUTED USING THE STOCHASTIC GROUND MOTION MODEL WITH $Q = 150f^{0.6}$ FOR CALIFORNIA AND $Q = 500f^{0.2}$ FOR UTAH.

Project No. 4790

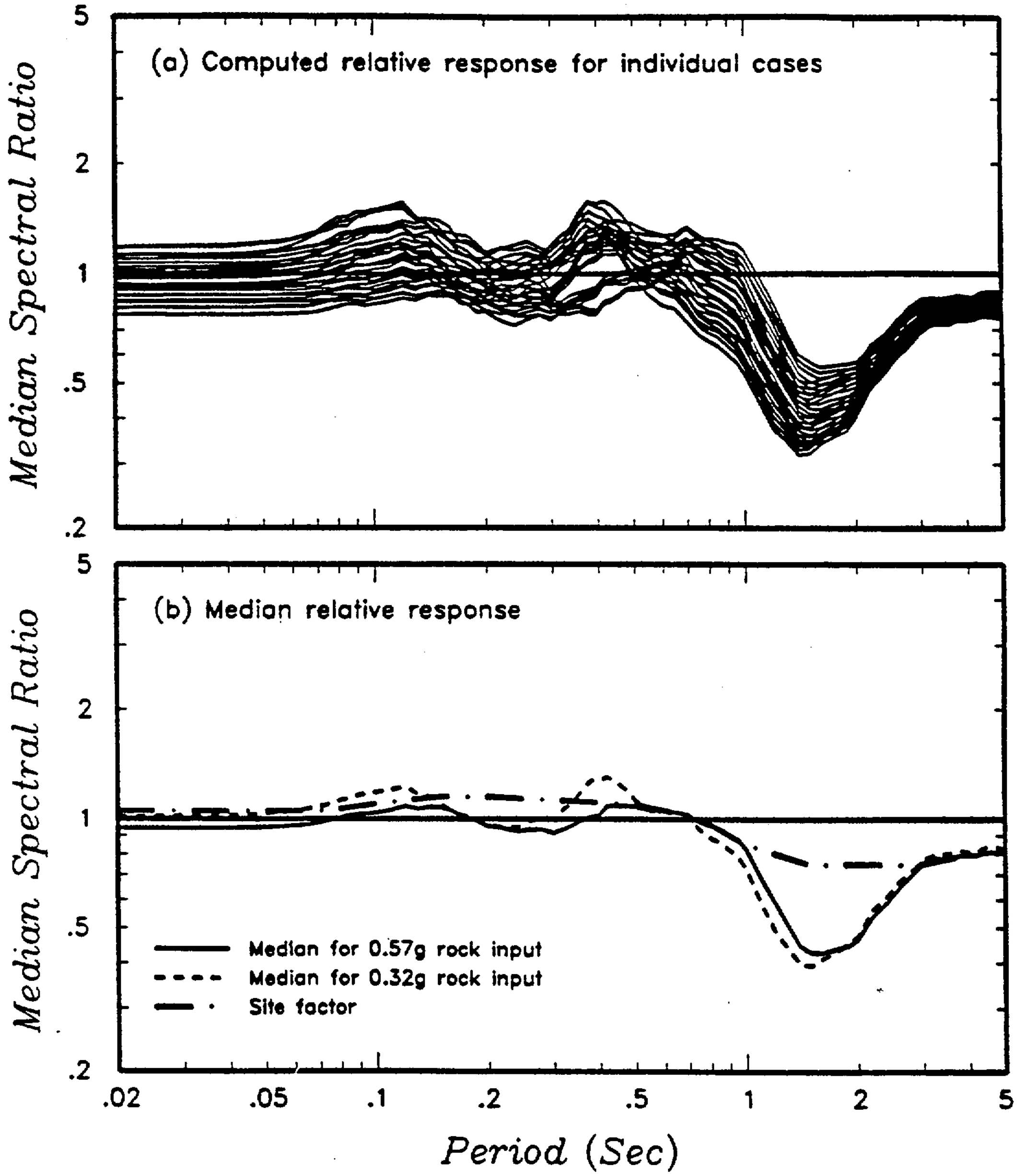
Figure F-3



GEOMATRIX

COMPARISON OF THE SHEAR WAVE VELOCITY PROFILE FOR THE SKULL VALLEY SEDIMENTS USING THE MIDPOINT OF THE VELOCITY RANGE FOR THE SALT LAKE GROUP TO THE GENERIC CALIFORNIA DEEP SOIL PROFILE DEVELOPED BY SILVA AND OTHERS (1998).

Project No.	4790
Figure	F-4

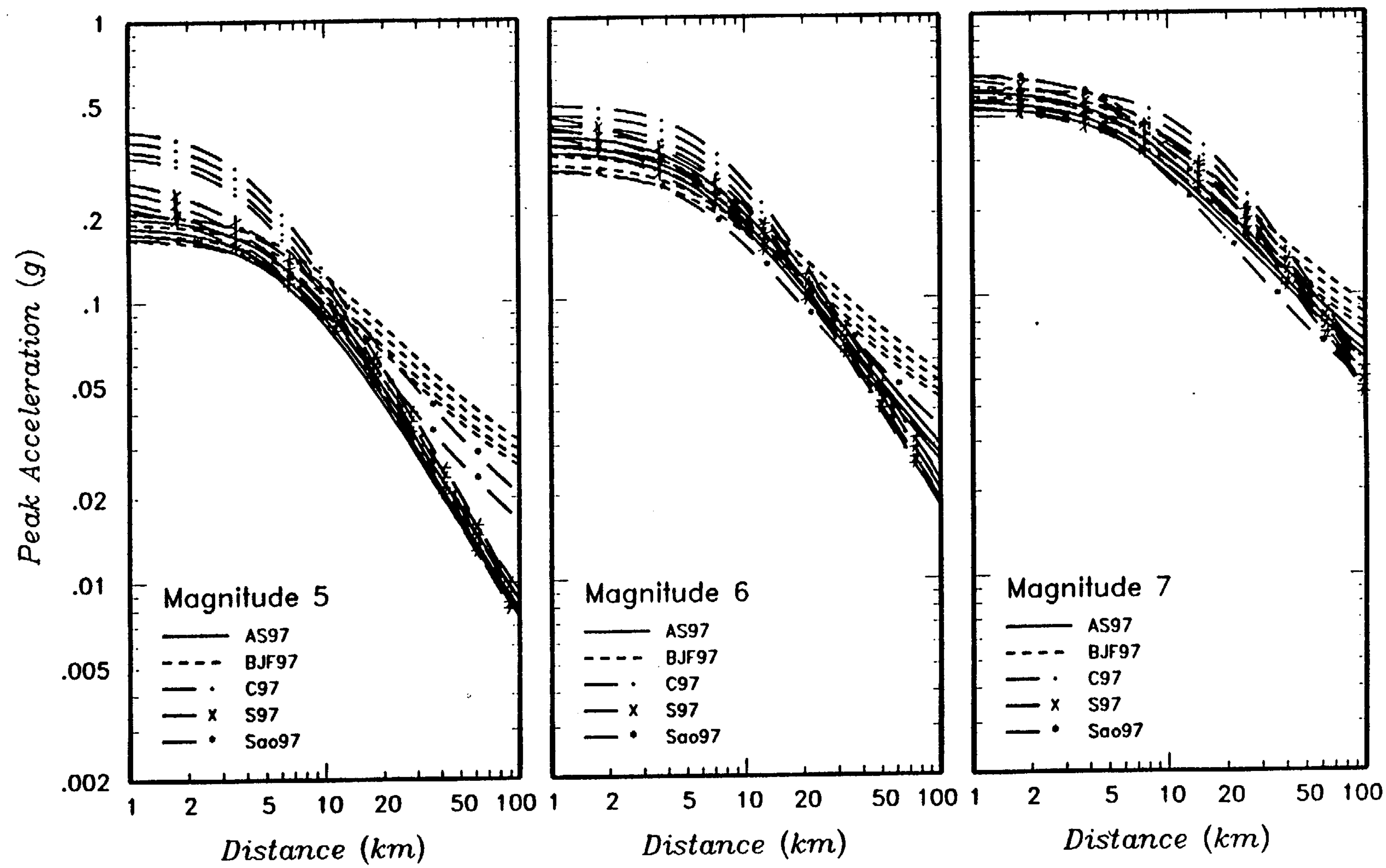


GEOMATRIX

SUMMARY OF RELATIVE RESPONSE ANALYSES. (A) MEDIAN RELATIVE RESPONSE CURVES FROM PREVIOUS CASES (VARIATIONS IN SEDIMENT VELOCITY, SOIL MODULUS AND DAMPING CURVES, κ, AND INPUT ROCK MOTION LEVEL). (B) MEDIAN RELATIVE RESPONSE FOR ALL CASES FOR INPUT ROCK MOTIONS SCALED TO 0.32 G (M 7 EARTHQUAKE) AND 0.57G (M 6.5 EARTHQUAKE). ALSO SHOWN IS AVERAGE SITE CORRECTION FACTOR USED TO ADJUST CALIFORNIA DEEP SOIL EMPIRICAL ATTENUATION RELATIONSHIPS TO SOIL CONDITIONS AT THE SKULL VALLEY SITE.

Project No. 4790

Figure F-16

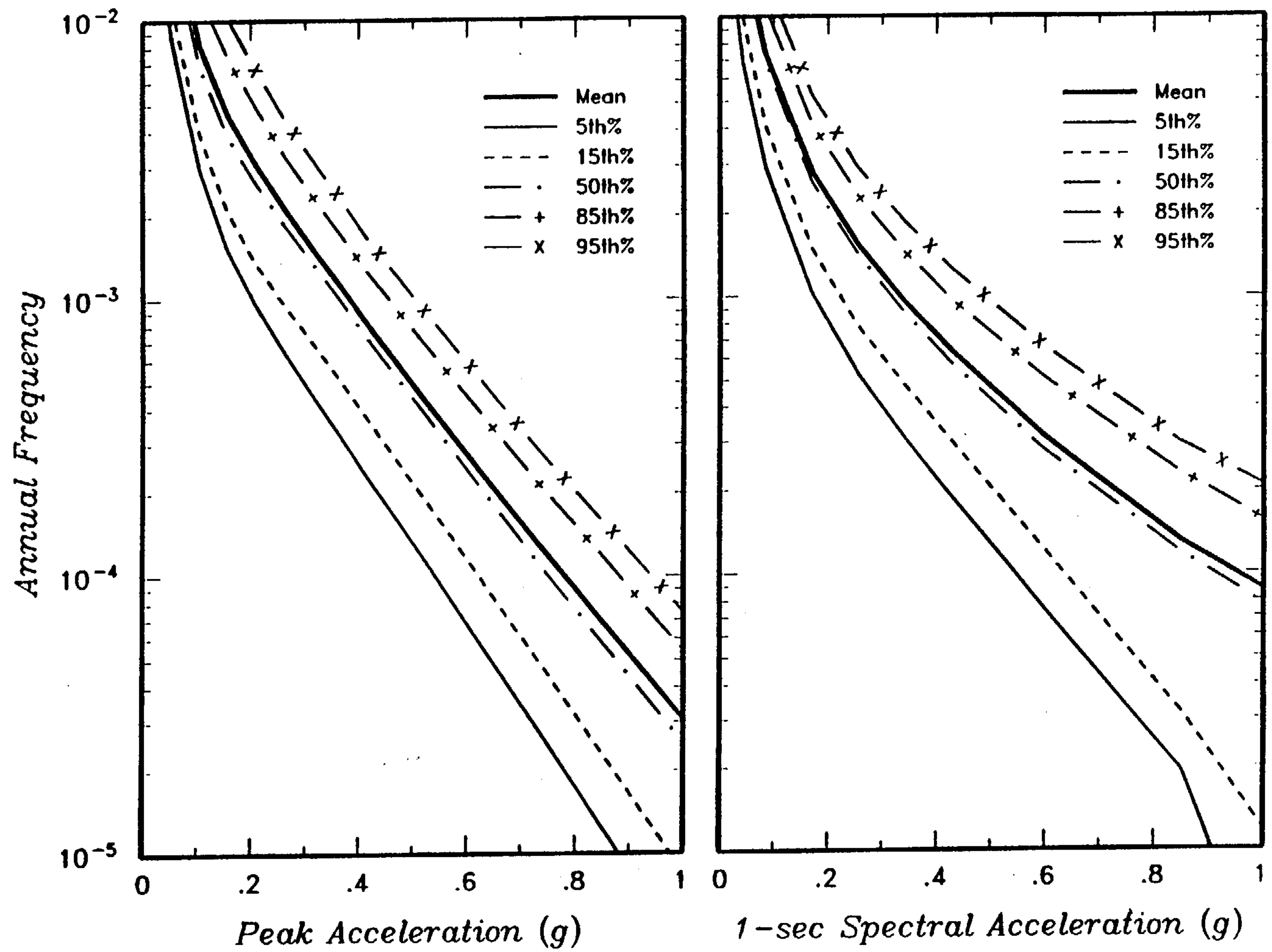


GEOMATRIX

COMPARISON OF HORIZONTAL MOTION ATTENUATION RELATIONSHIPS USED IN THE HAZARD ANALYSIS.
Private Fuel Storage Facility
Skull Valley, Utah
(Page 1 of 2)

Project No. 4790

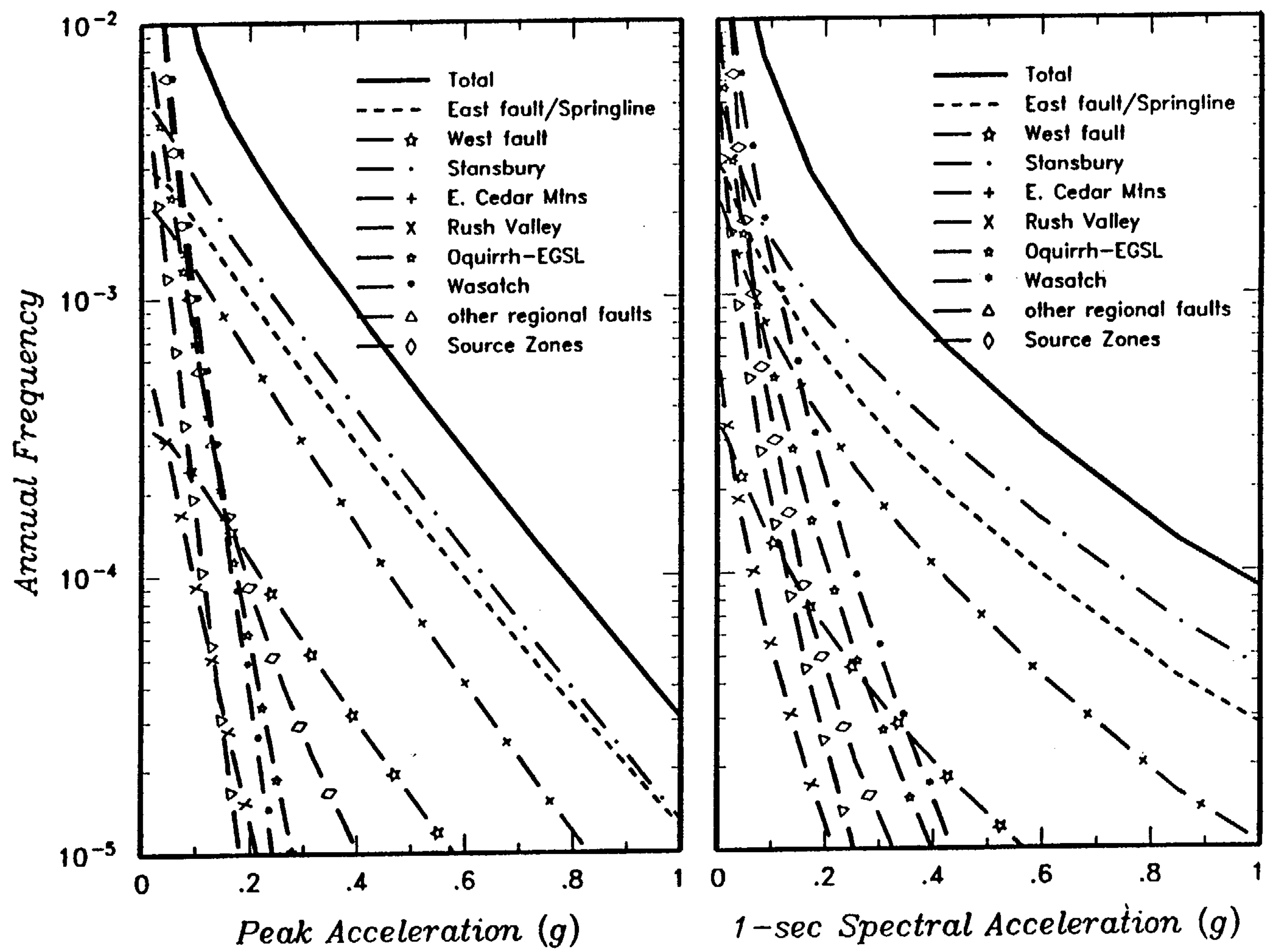
Figure 6-9



GEOMATRIX

COMPUTED TOTAL MEAN AND 5TH- TO 95TH-PERCENTILE HORIZONTAL MOTION HAZARD CURVES FOR THE CTB SITE.
Private Fuel Storage Facility
Skull Valley, Utah

Project No.	Figure
4790	6-11

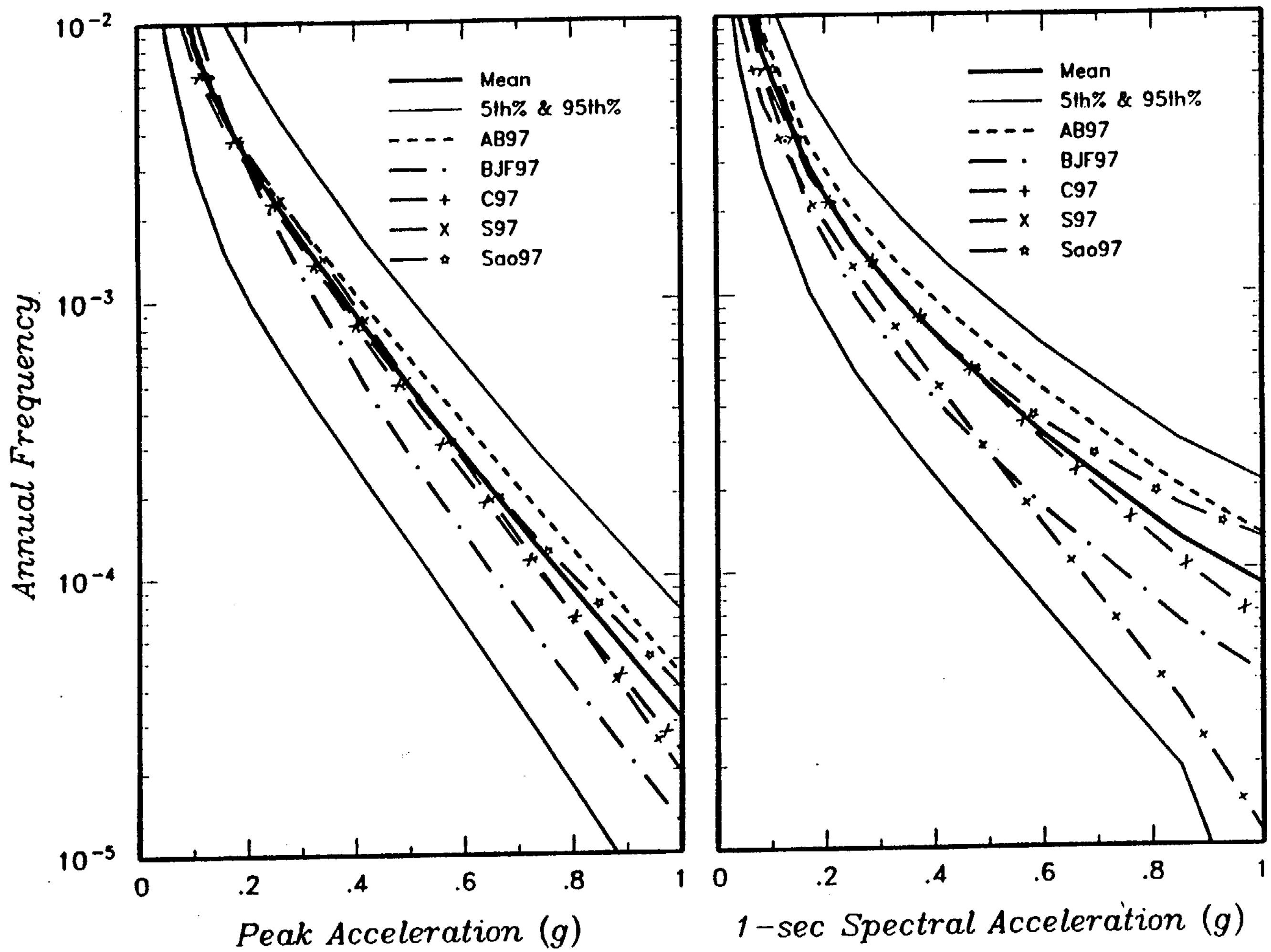


GEOMATRIX

CONTRIBUTIONS OF INDIVIDUAL SOURCES TO TOTAL MEAN HAZARD FOR HORIZONTAL MOTION AT THE CTB SITE.
Private Fuel Storage Facility
Skull Valley, Utah

Project No. 4790

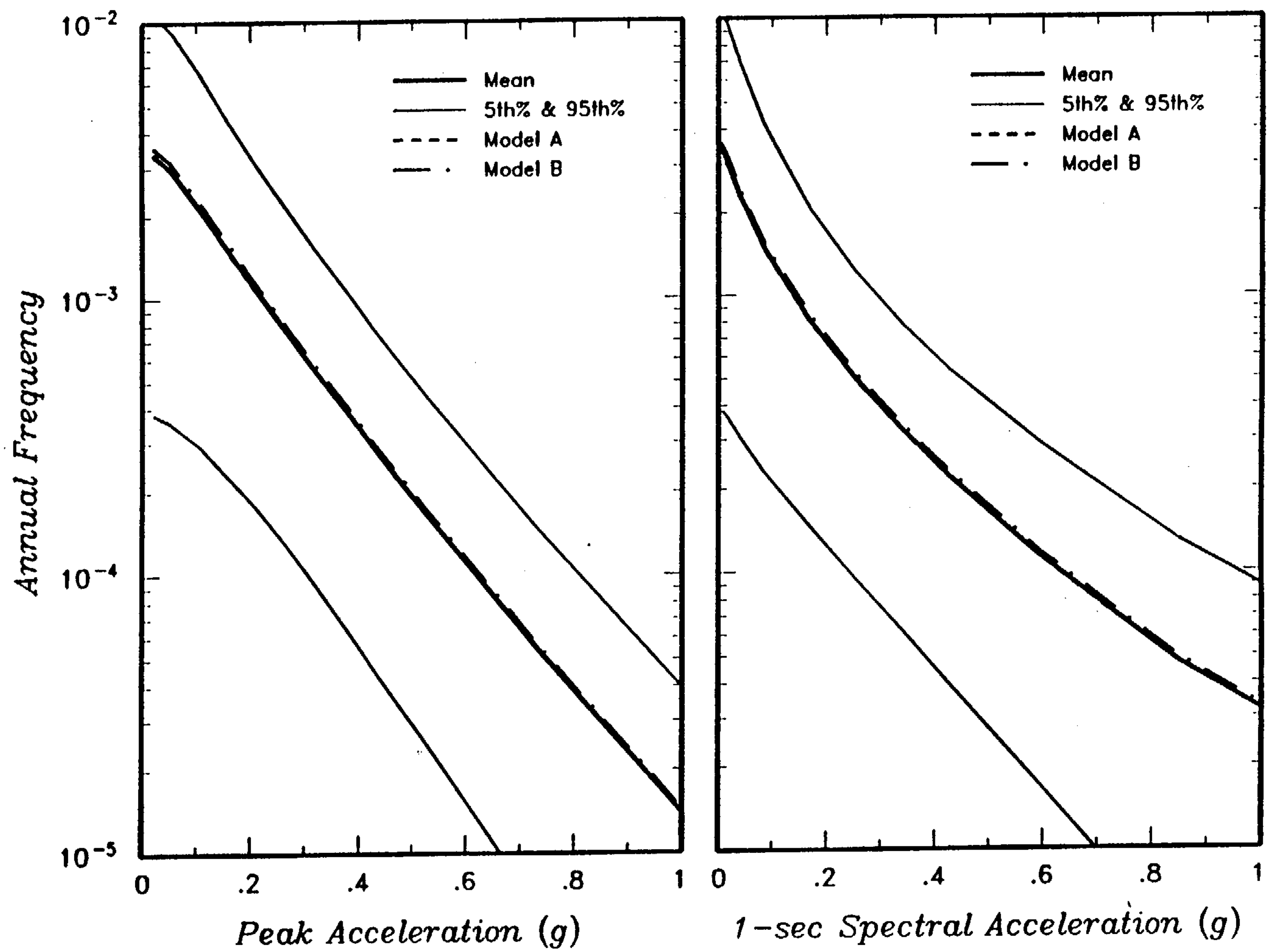
Figure 6-12



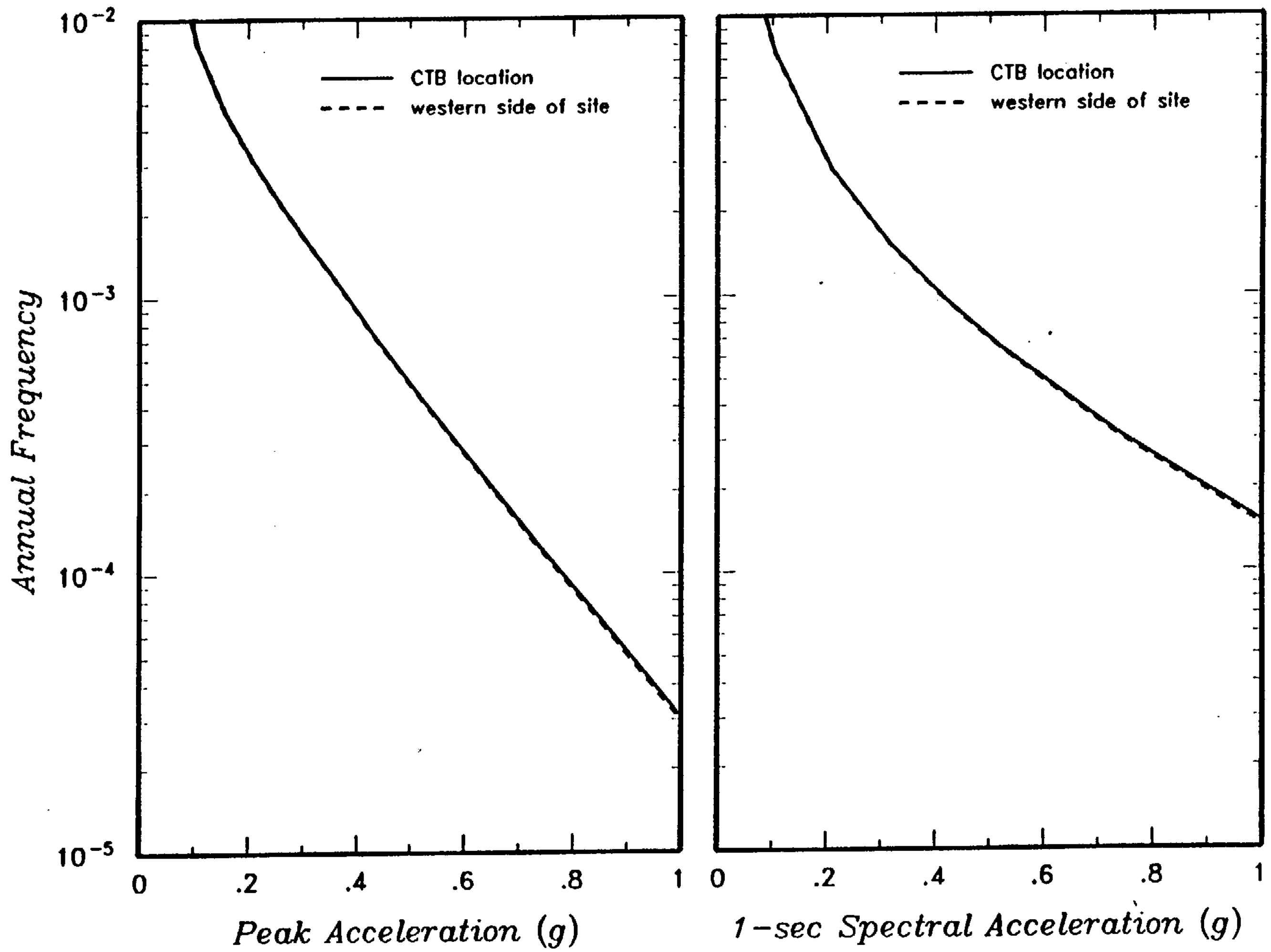
GEOMATRIX

EFFECT OF CHOICE OF ATTENUATION RELATIONSHIP ON MEAN HAZARD FOR HORIZONTAL MOTION AT THE CTB SITE.
Private Fuel Storage Facility
Skull Valley, Utah

Project No.	4790
Figure	6-14



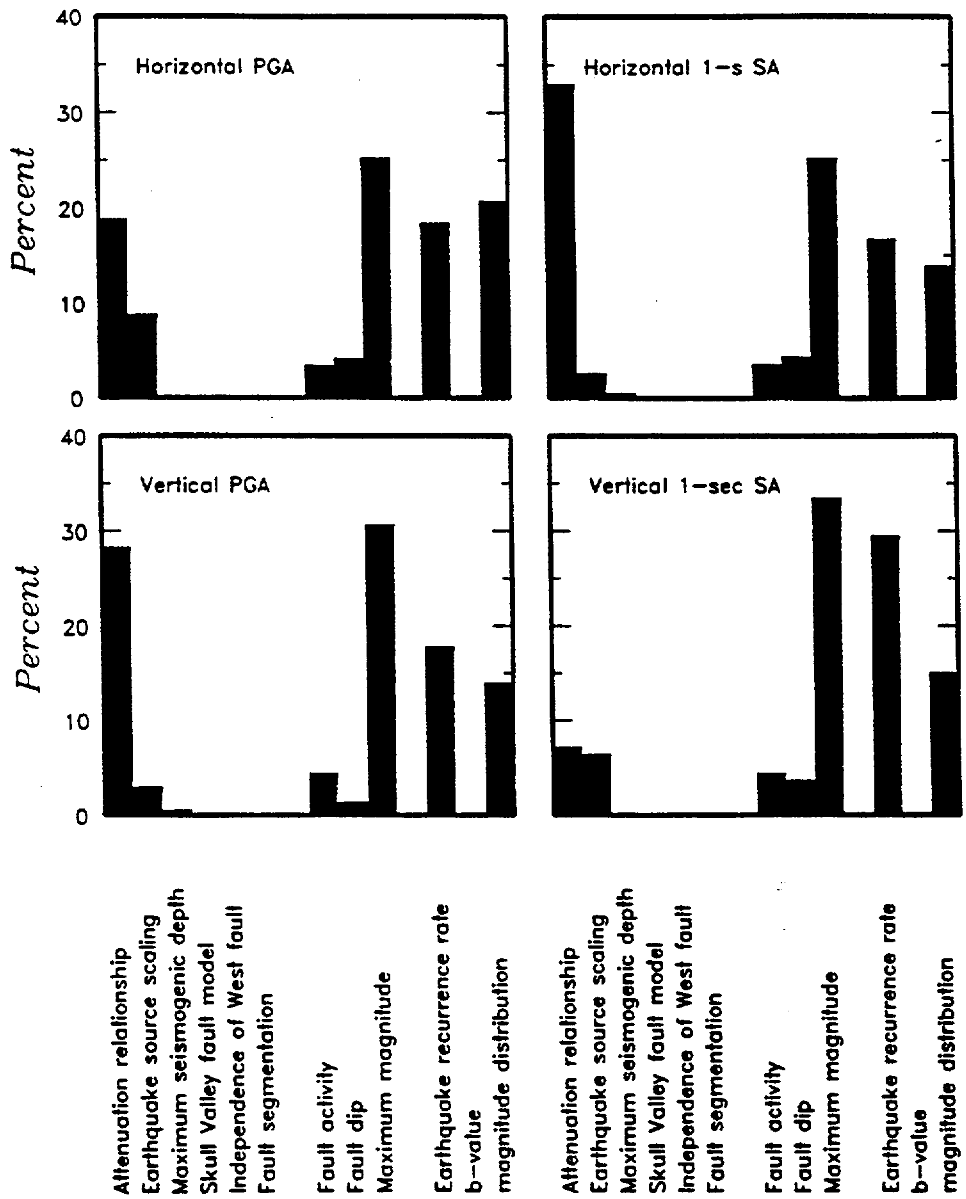
GEOMATRIX	EFFECT OF ALTERNATIVE MODELS FOR THE SKULL VALLEY FAULTS ON MEAN HAZARD FOR HORIZONTAL MOTION FROM THESE FAULTS AT THE CTB SITE. Private Fuel Storage Facility Skull Valley, Utah	Project No. 4790 Figure **6-15**



GEOMATRIX

COMPARISON OF TOTAL MEAN HAZARD FOR HORIZONTAL MOTION AT THE CTB LOCATION AND WESTERN SIDE OF SITE AREA.
Private Fuel Storage Facility
Skull Valley, Utah

Project No.	4790
Figure	6-18

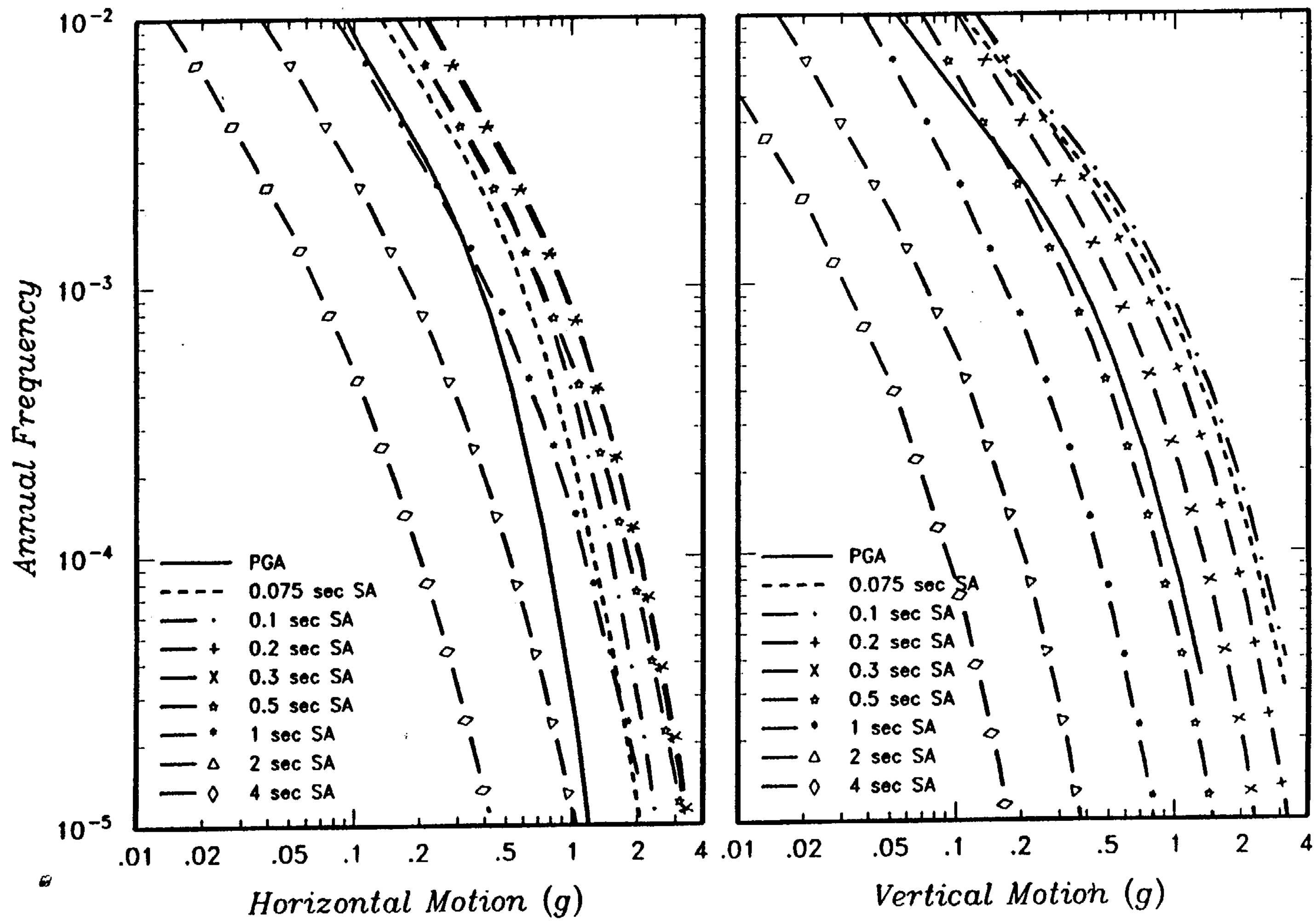


GEOMATRIX

RELATIVE CONTRIBUTION OF THE UNCERTAINTY IN THE COMPONENTS OF THE SEISMIC HAZARD MODEL TO THE TOTAL UNCERTAINTY IN THE HAZARD AT THE CTB SITE.
Private Fuel Storage Facility
Skull Valley, Utah

Project No. 4790

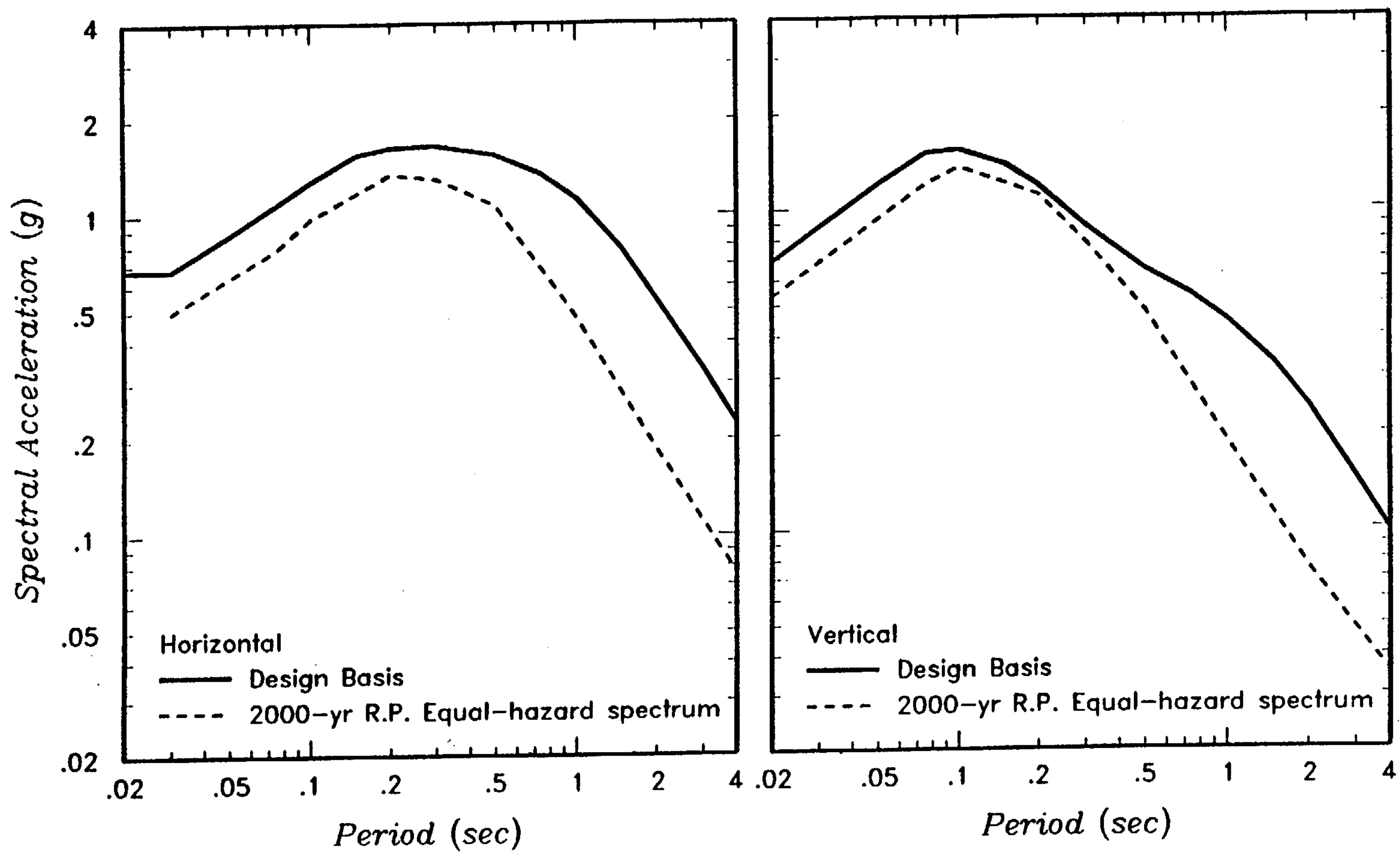
Figure 6-22



GEOMATRIX

MEAN SEISMIC HAZARD CURVES FOR HORIZONTAL AND VERTICAL MOTIONS FOR THE CTB SITE.
Private Fuel Storage Facility
Skull Valley, Utah

Project No.	4790
Figure	6-23



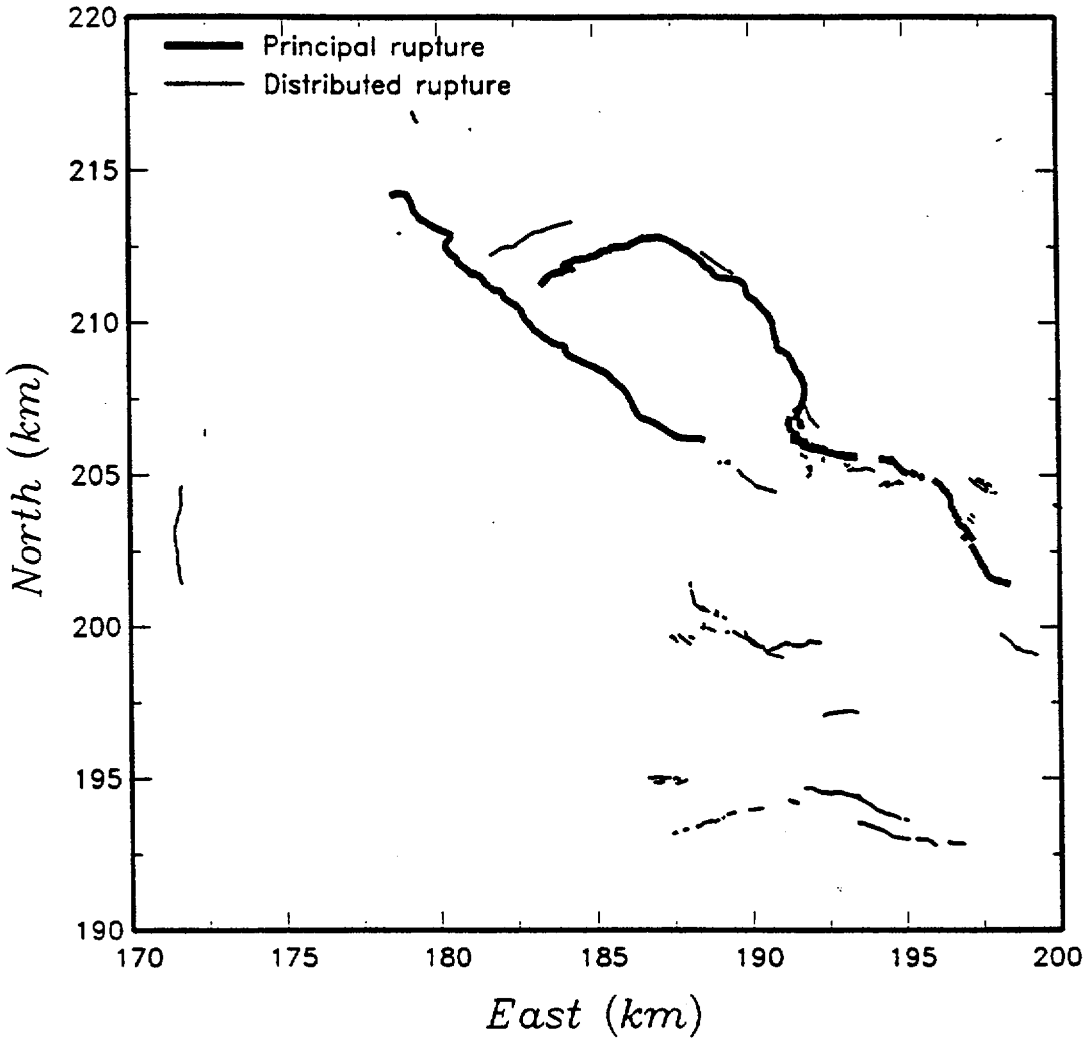
GEOMATRIX

COMPARISON OF 2,000-YEAR RETURN PERIOD EQUAL-HAZARD SPECTRA WITH THE DESIGN BASIS RESPONSE SPECTRA.
Private Fuel Storage Facility
Skull Valley, Utah

Project No. 4790

Figure 6-24

PROBABILISTIC FAULT DISPLACEMENT ANALYSIS



GEOMATRIX

EXAMPLE OF PRINCIPAL AND DISTRIBUTED RUPTURE (1959 HEBGEN LAKE MONTANA **M** 7.4 EARTHQUAKE).
Private Fuel Storage Facility
Skull Valley, Utah

Project No.
4790

Figure
7-1

Probabilistic Seismic Hazard Analysis (PSHA)
(Cornell, 1968, 1971)

Assumption of Poisson process for earthquake occurrence leads to probability of ground motion parameter Z exceeding level z in time t

$$\mathbf{P}(Z > z|t) = 1 - e^{-\nu(z)\cdot t}$$

where $\nu(z)$ is the annual frequency of events in which Z exceeds z

$$\mathbf{P}(Z > z|t) \leq \nu(z) \cdot t$$

regardless of the probability model assumed for earthquake occurrence, provided $\nu(z)$ is the proper average over time t.

For $t = 1$ year and $\nu(z) < 0.1$, $P(Z > z) \approx \nu(z)$.

For PSHA:

$$\nu(z) = \sum_i \sum_j \lambda(e_{ij}) \cdot P(Z > z | e_{ij})$$

$\lambda(e_{ij})$ Frequency of event (earthquake) of size *j* on source *i*.

Defined by identifying sources of earthquakes and specifying the earthquake recurrence relationship for each source

$P(Z>z | e_{ij})$ Conditional probability that event (earthquake) of size *j* on source *i* will produce ground motion parameter *Z* in excess of level *z*.

Defined by specifying the spatial distribution of earthquakes on each source and a ground motion attenuation relationship (distribution of *Z* as a function of size, distance, etc.).

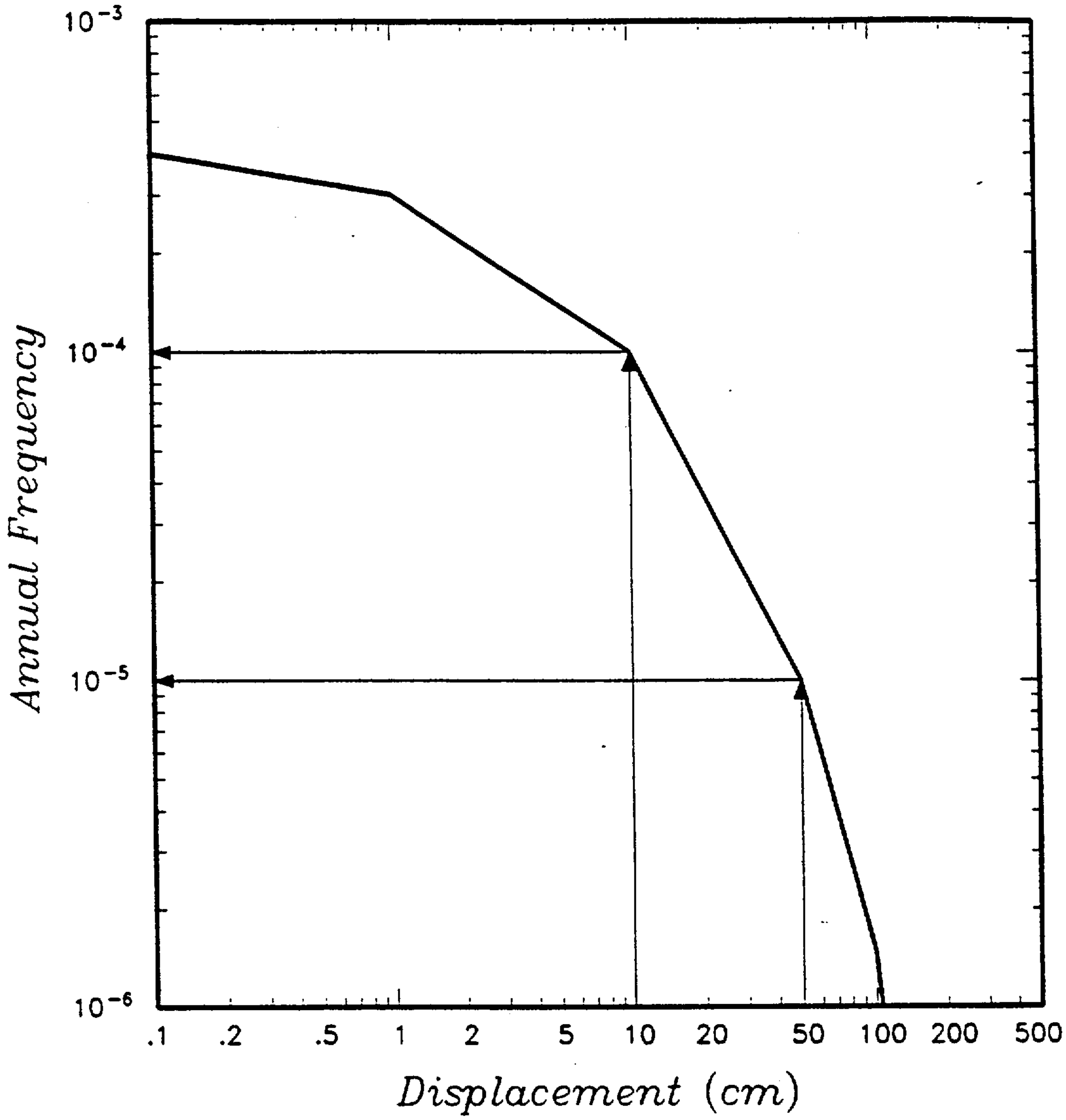
DISPLACEMENT HAZARD

Hazard Definition

Frequency at which *single event* displacement, D, exceeds some specified value, d.

$$\boldsymbol{\nu}(d) = \boldsymbol{\lambda}(E_D) \cdot \mathbf{P}(D > d | E_D)$$

$\lambda(E_D)$	frequency of displacement events
$\mathbf{P}(D>d \mid E_D)$	conditional probability that the displacement in a single displacement event will exceed level d



GEOMATRIX

EXAMPLE DISPLACEMENT HAZARD CURVE.
Private Fuel Storage Facility
Skull Valley, Utah

Project No. 4790

Figure 7-2

ESTIMATION OF DISPLACEMENT EVENT FREQUENCY

"Displacement Approach"

Estimation of frequency from data at point of interest

- Recurrence interval data for surface rupturing events
- Slip Rate, *SR*, data together with an estimate of the average slip in rupturing events, $\overline{D}$

$$\lambda(E_D) = SR / \overline{D}$$

"Earthquake Approach"

Estimation of frequency from frequency of events (earthquakes) in the region and the likelihood that each will cause slip at the point of interest.

$$\lambda(E_D) = \sum_i \sum_j \lambda(e_{ij}) \cdot \mathrm{P}(\mathrm{slip} \mid e_{ij})$$

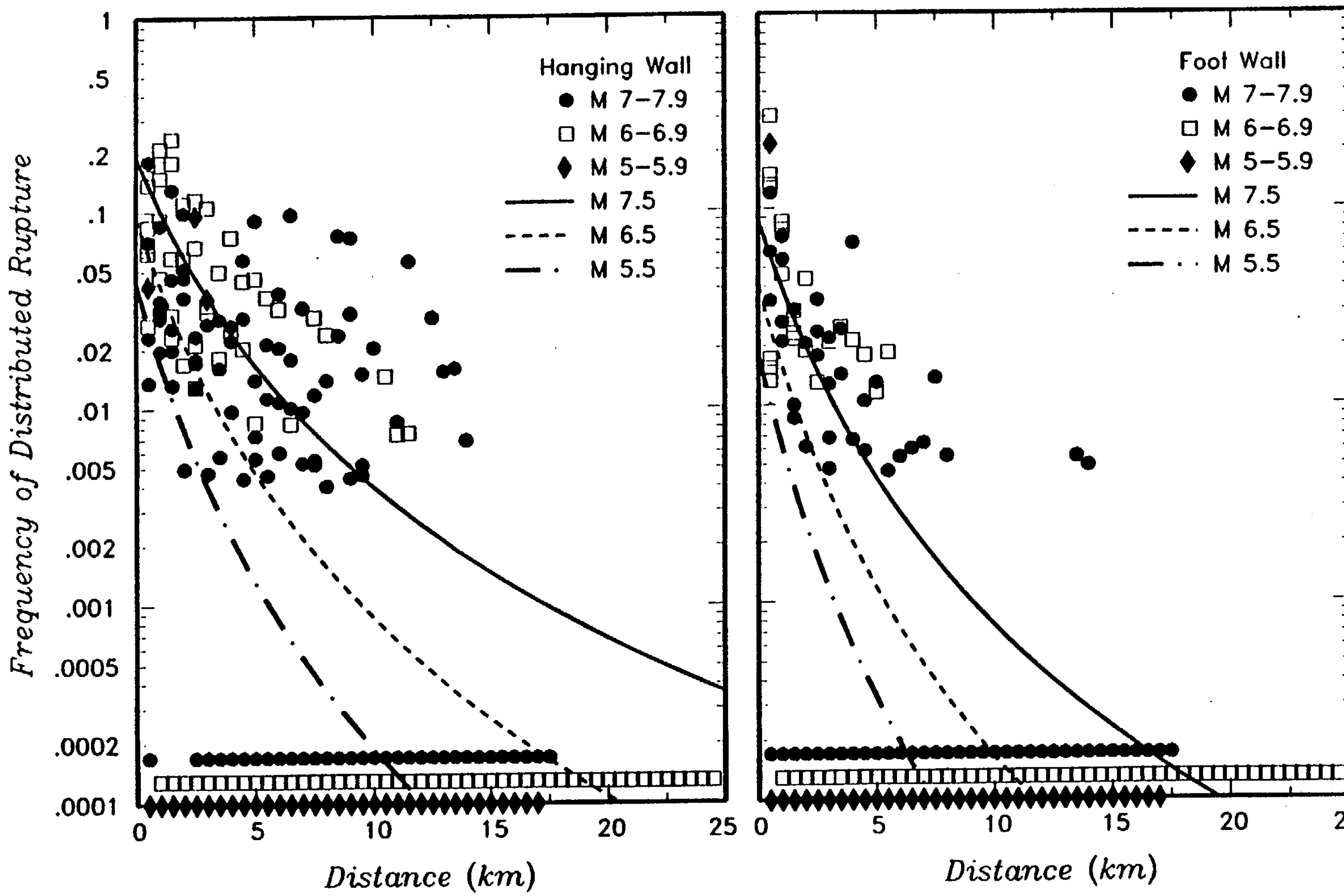
ESTIMATION OF DISPLACEMENT EVENT FREQUENCY USING EARTHQUAKE APPROACH

Distributed Faulting

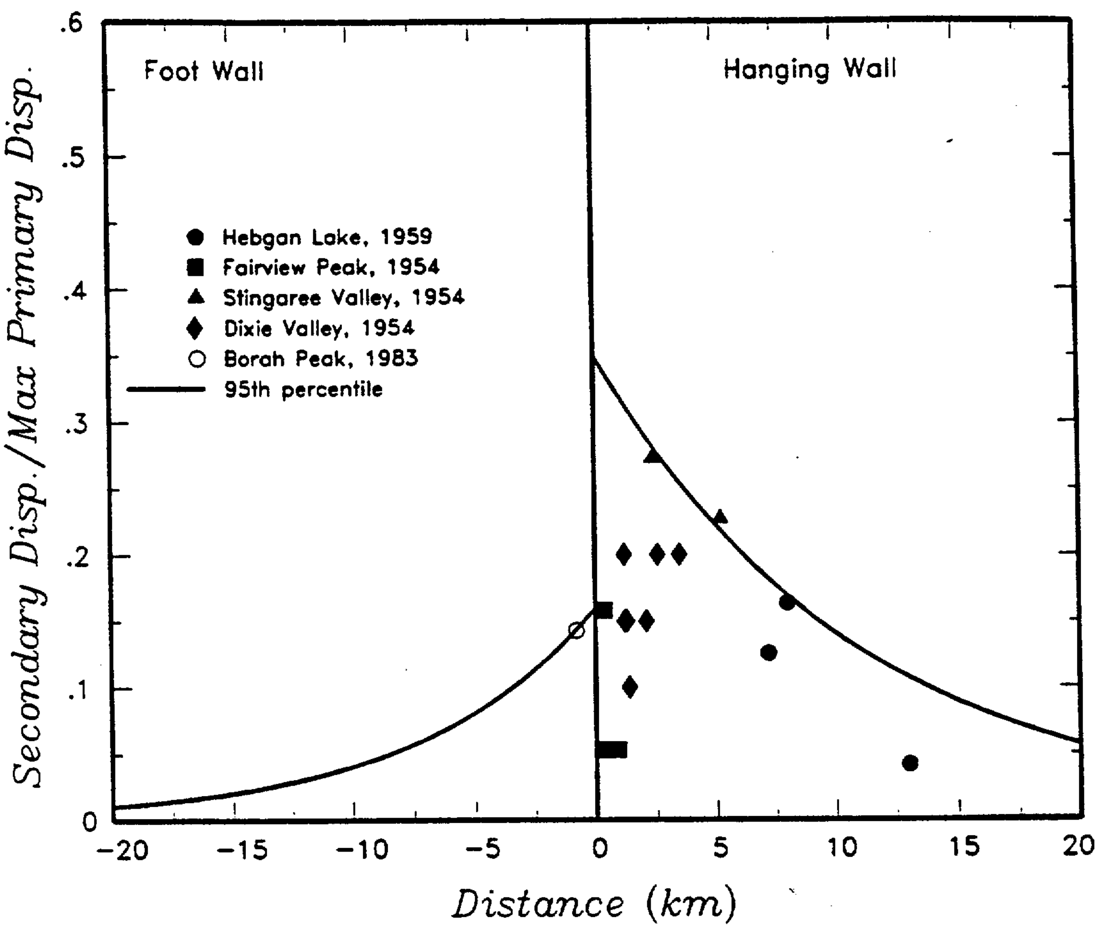
- Analysis of historical surface ruptures

$$\mathbf{P}(\text{Slip} \mid \text{Event on } j) = \frac{e^{-f(m,r,h)}}{1 + e^{-f(m,r,h)}}$$

where h is 1 for hanging wall deformation and 0 for foot wall deformation



GEOMATRIX	PROBABILITY OF OCCURRENCE OF DISTRIBUTED FAULTING AS A FUNCTION OF EARTHQUAKE MAGNITUDE AND DISTANCE TO PRINCIPAL RUPTURE. Private Fuel Storage Facility Skull Valley, Utah	Project No. 4790 Figure 7-3



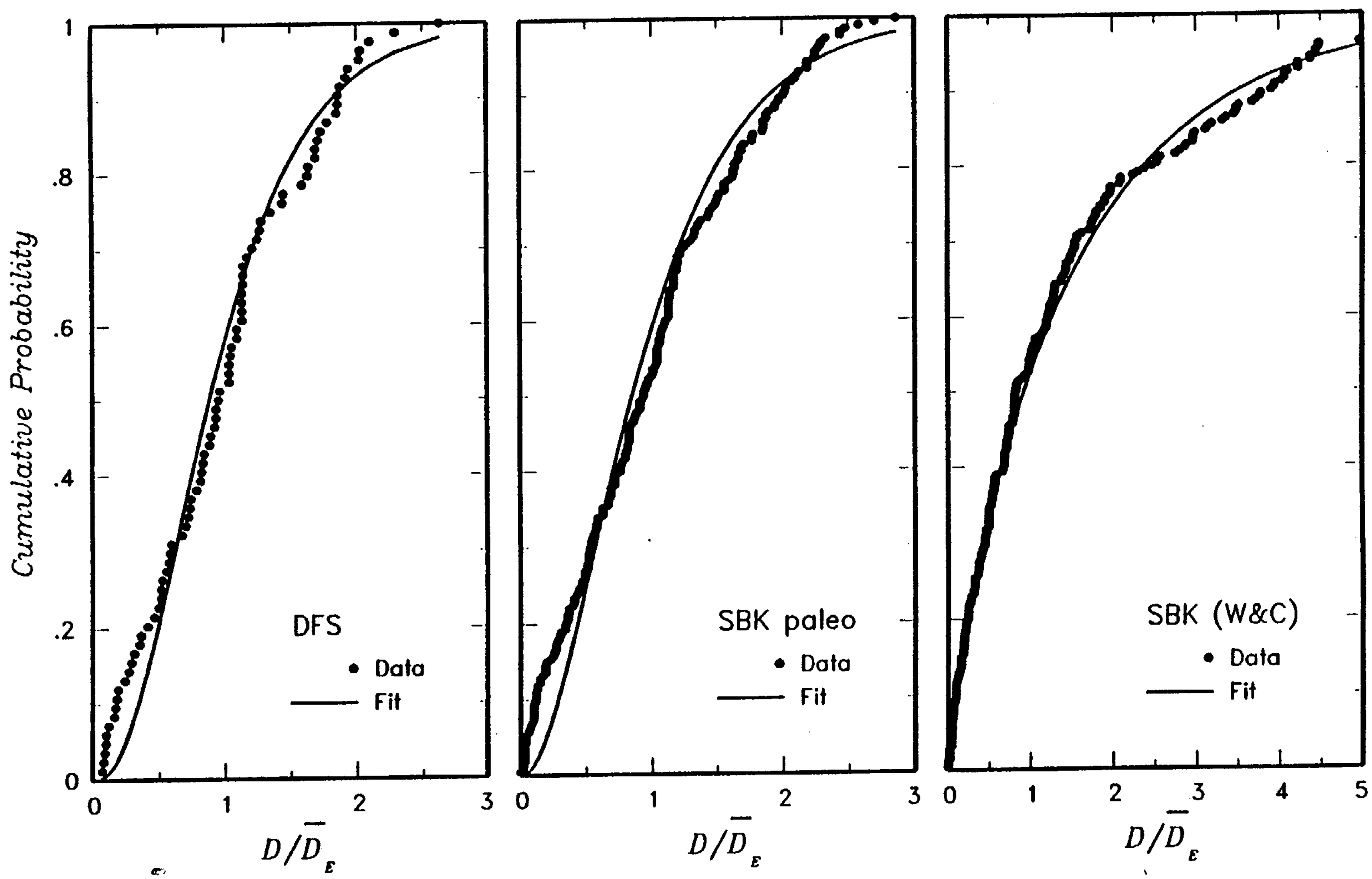
from CRWMS M&O (1998)

GEOMATRIX

CURVE DEFINING THE 95TH PERCENTILE OF THE DISTRIBUTION OF DISPLACEMENT ON A DISTRIBUTED RUPTURE AS A FRACTION OF THE MAXIMUM DISPLACEMENT ON THE PRINCIPAL RUPTURE.
Private Fuel Storage Facility
Skull Valley, Utah

Project No. 4790

Figure 7-4



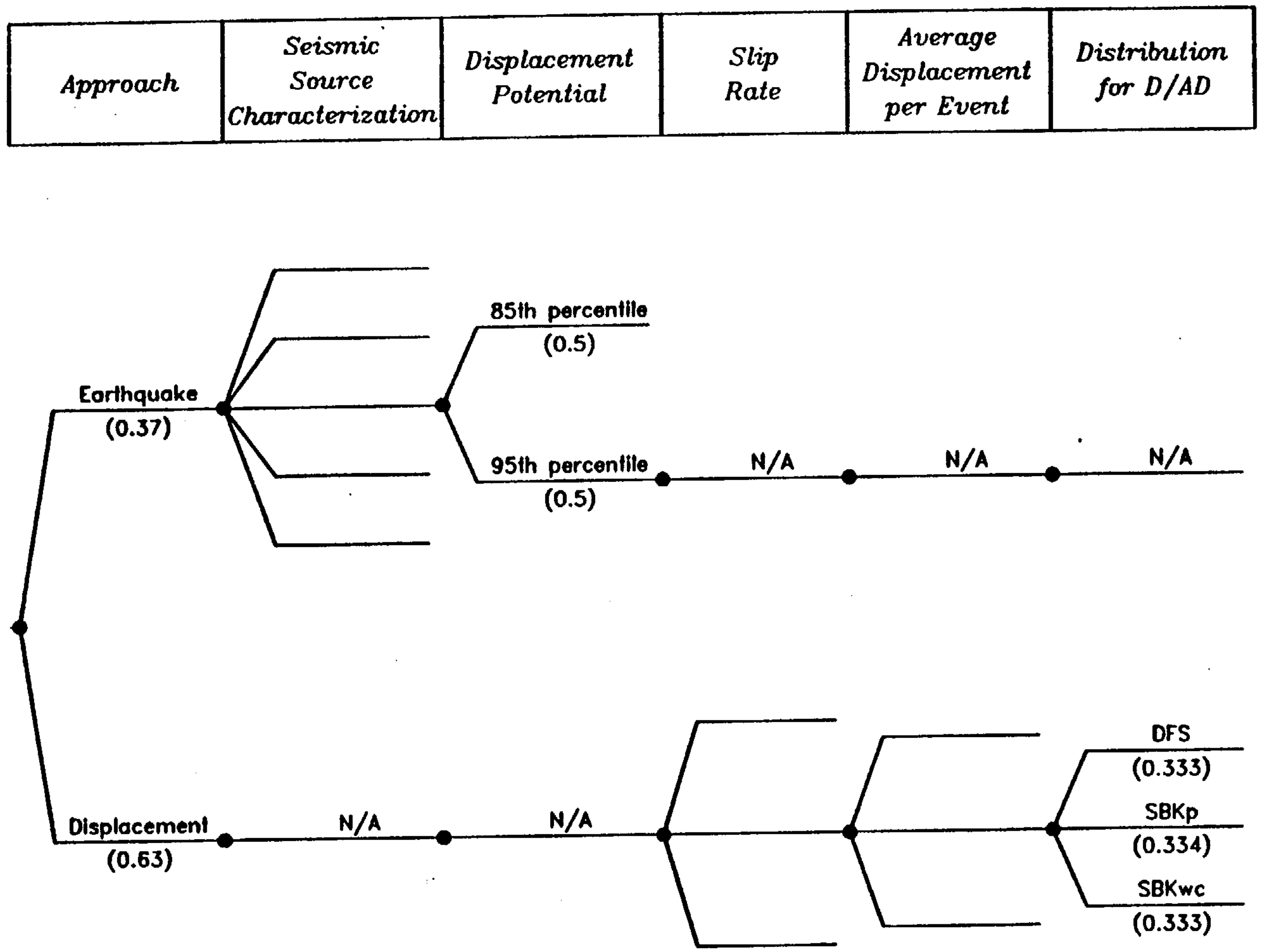
from CRWMS M&O (1998)

GEOMATRIX

ALTERNATIVE DISTRIBUTIONS FOR THE RATIO $D/\bar{D}_E$ USED IN THE DISPLACEMENT APPROACH.

Private Fuel Storage Facility
Skull Valley, Utah

Project No.	4790
Figure	7-5

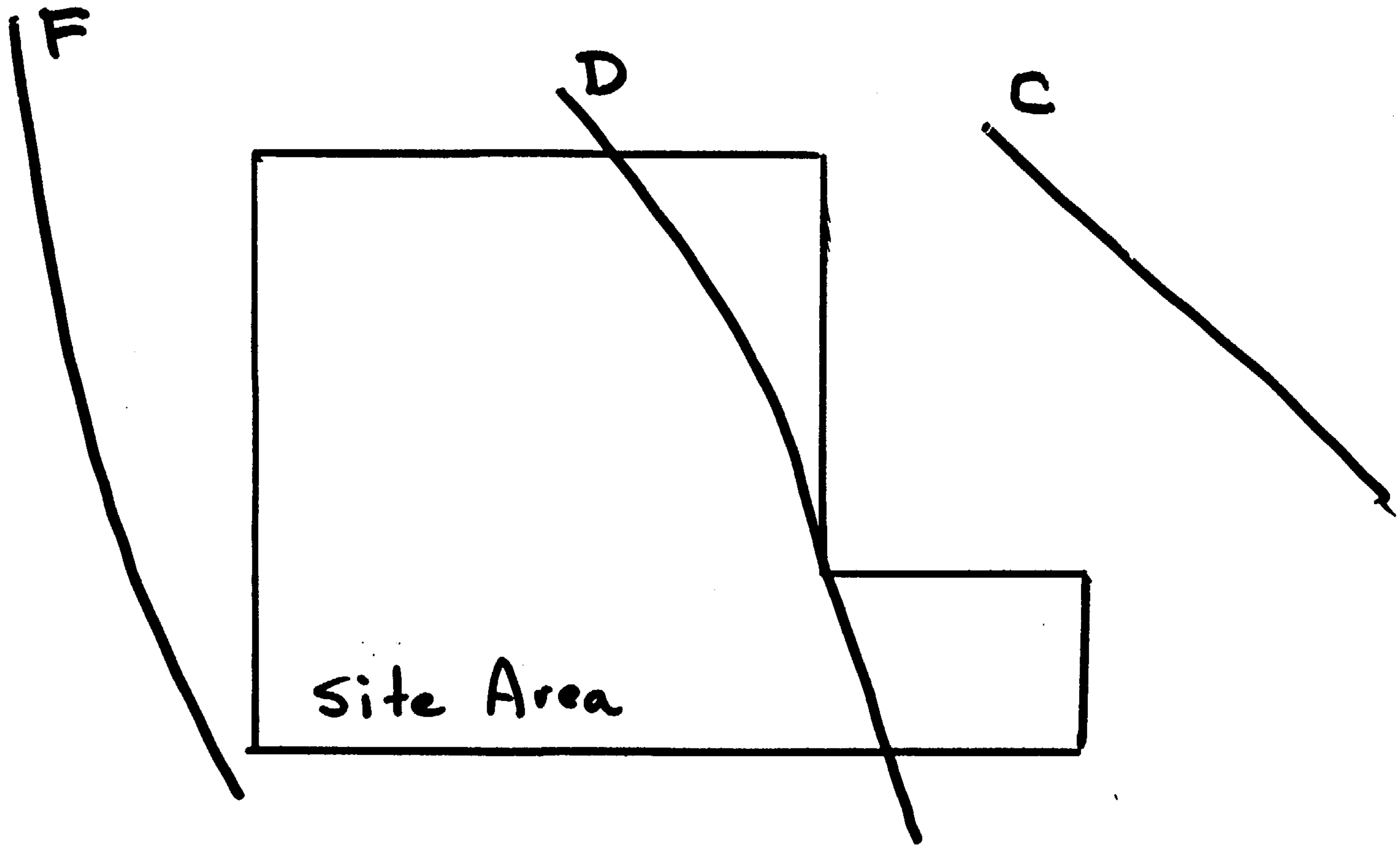


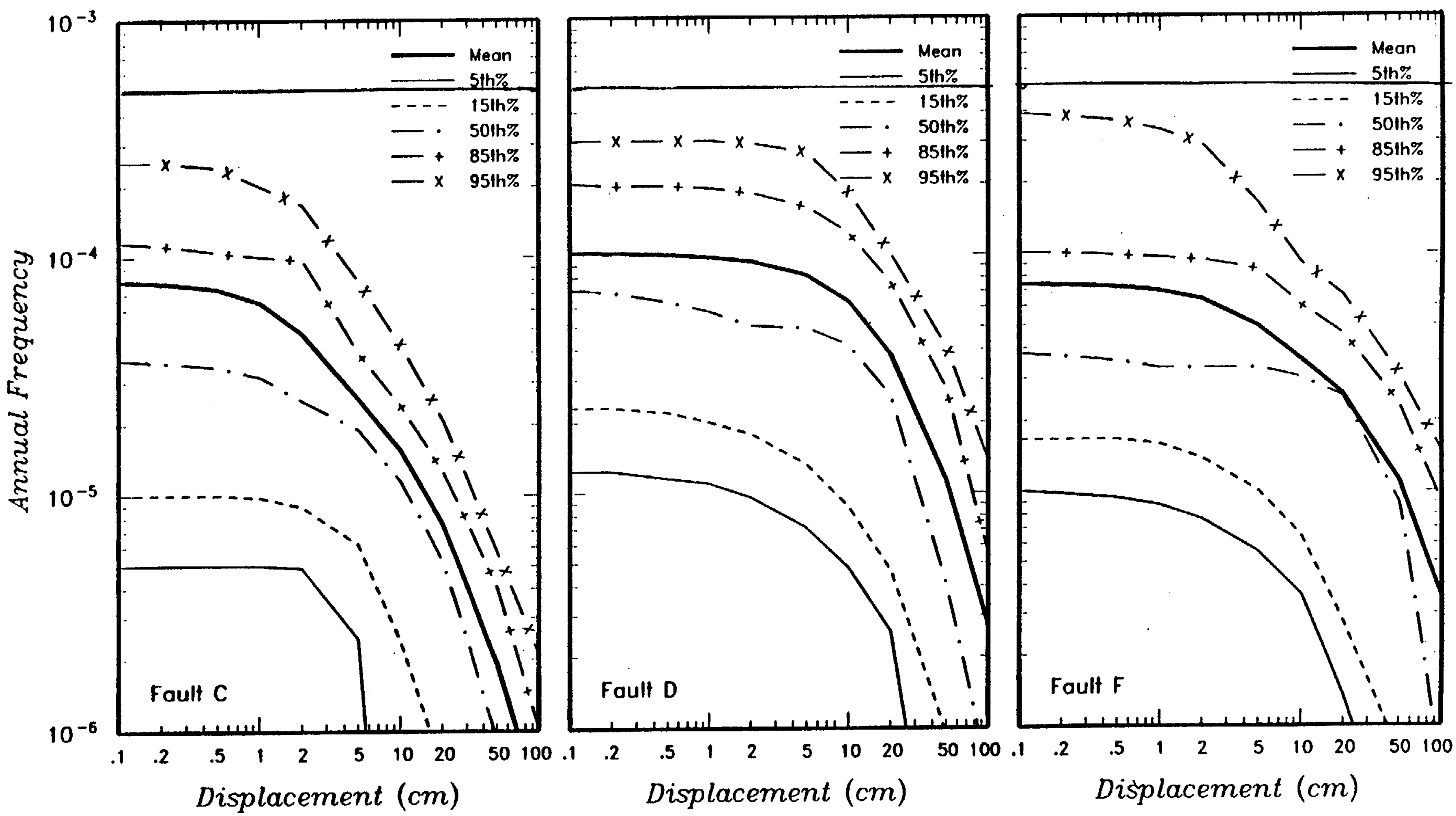
GEOMATRIX

LOGIC TREE FOR PROBABILISTIC DISPLACEMENT HAZARD CHARACTERIZATION.
Private Fuel Storage Facility
Skull Valley, Utah

Project No. 4790

Figure 7-6

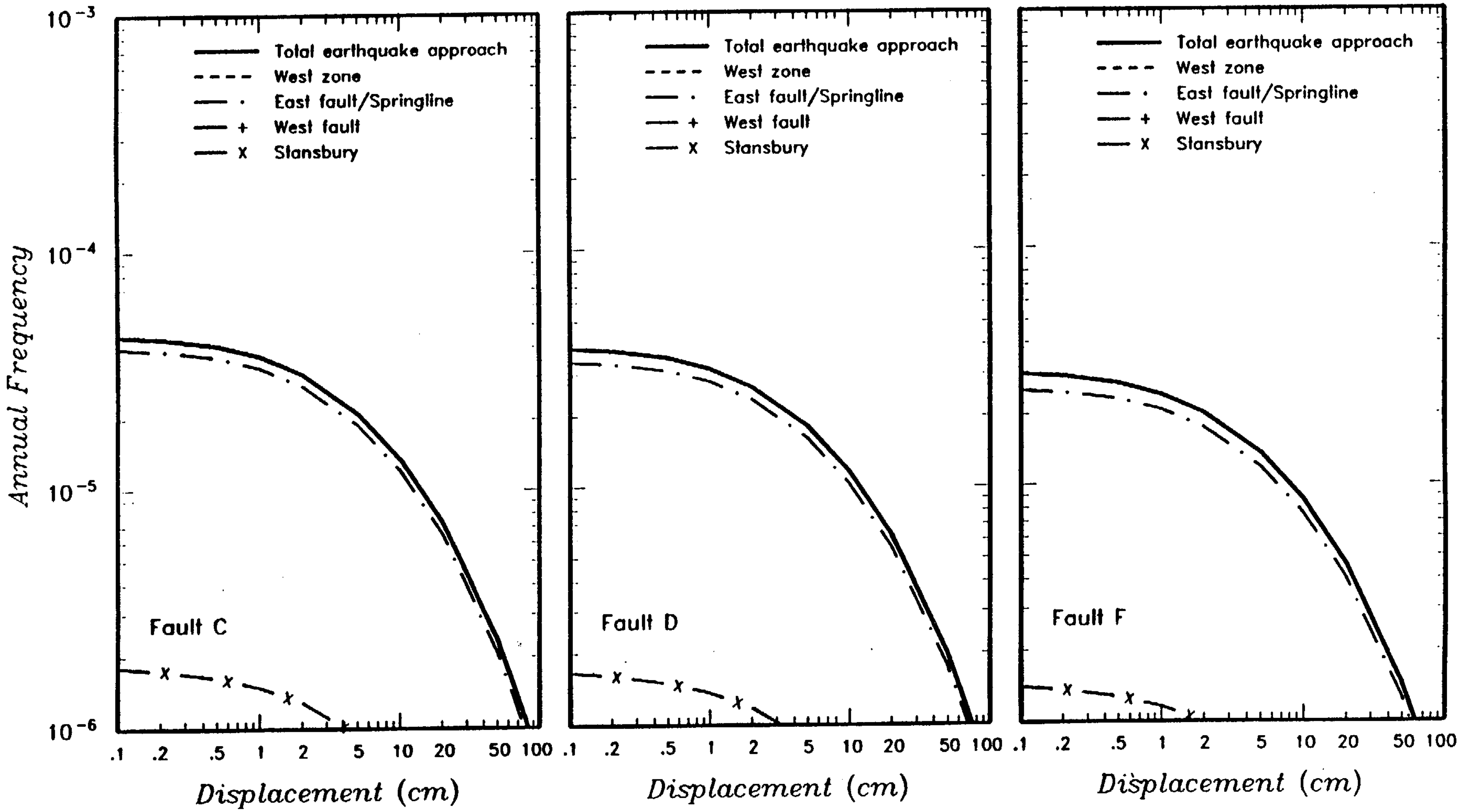

F
D
C
Site Area



GEOMATRIX

COMPUTED TOTAL MEAN AND 5TH- TO 95TH-PERCENTILE DISPLACEMENT HAZARD CURVES.
Private Fuel Storage Facility
Skull Valley, Utah

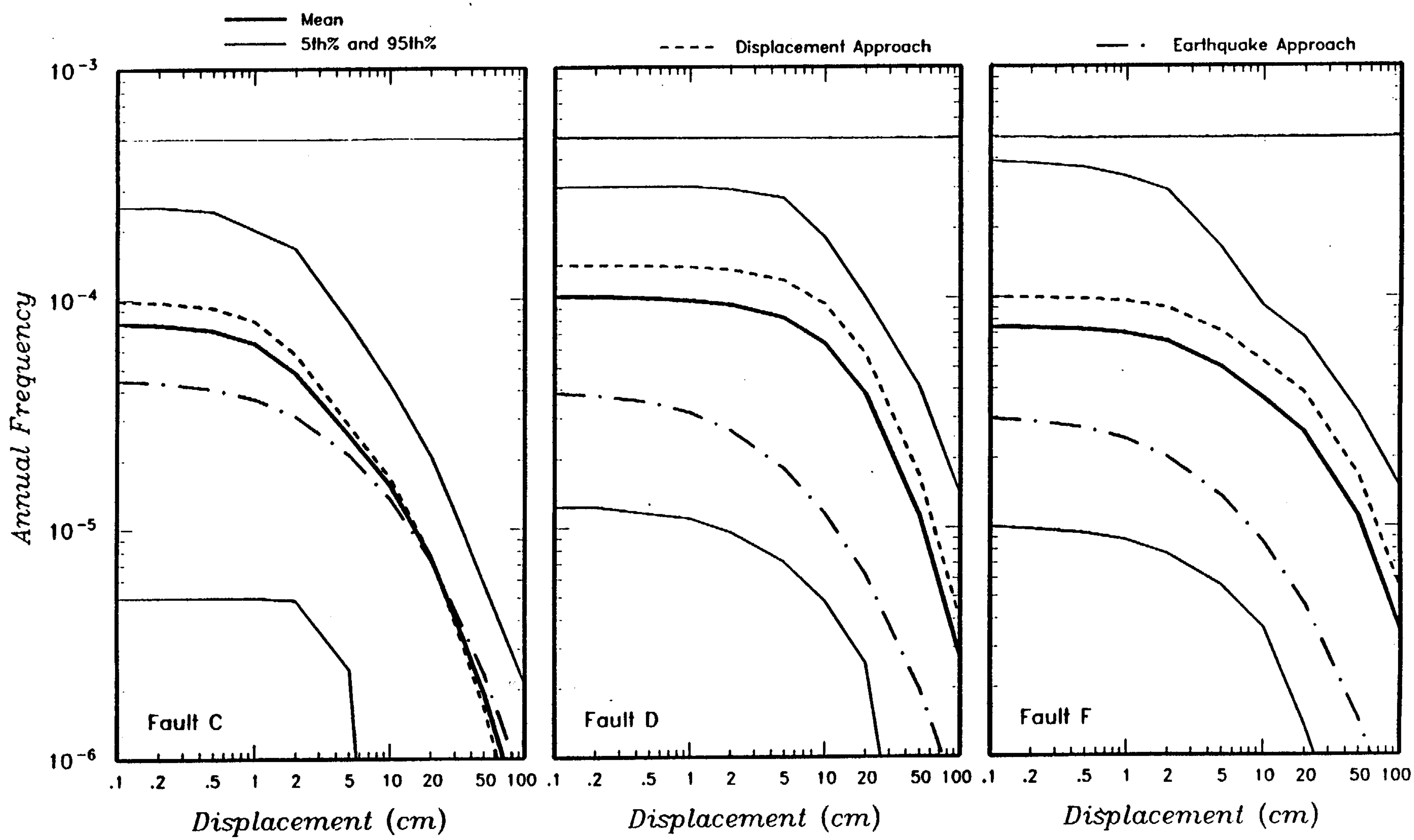
Project No.	4790
Figure	7-7



GEOMATRIX

CONTRIBUTIONS OF INDIVIDUAL SOURCES TO TOTAL MEAN HAZARD FOR THE EARTHQUAKE APPROACH.
Private Fuel Storage Facility
Skull Valley, Utah

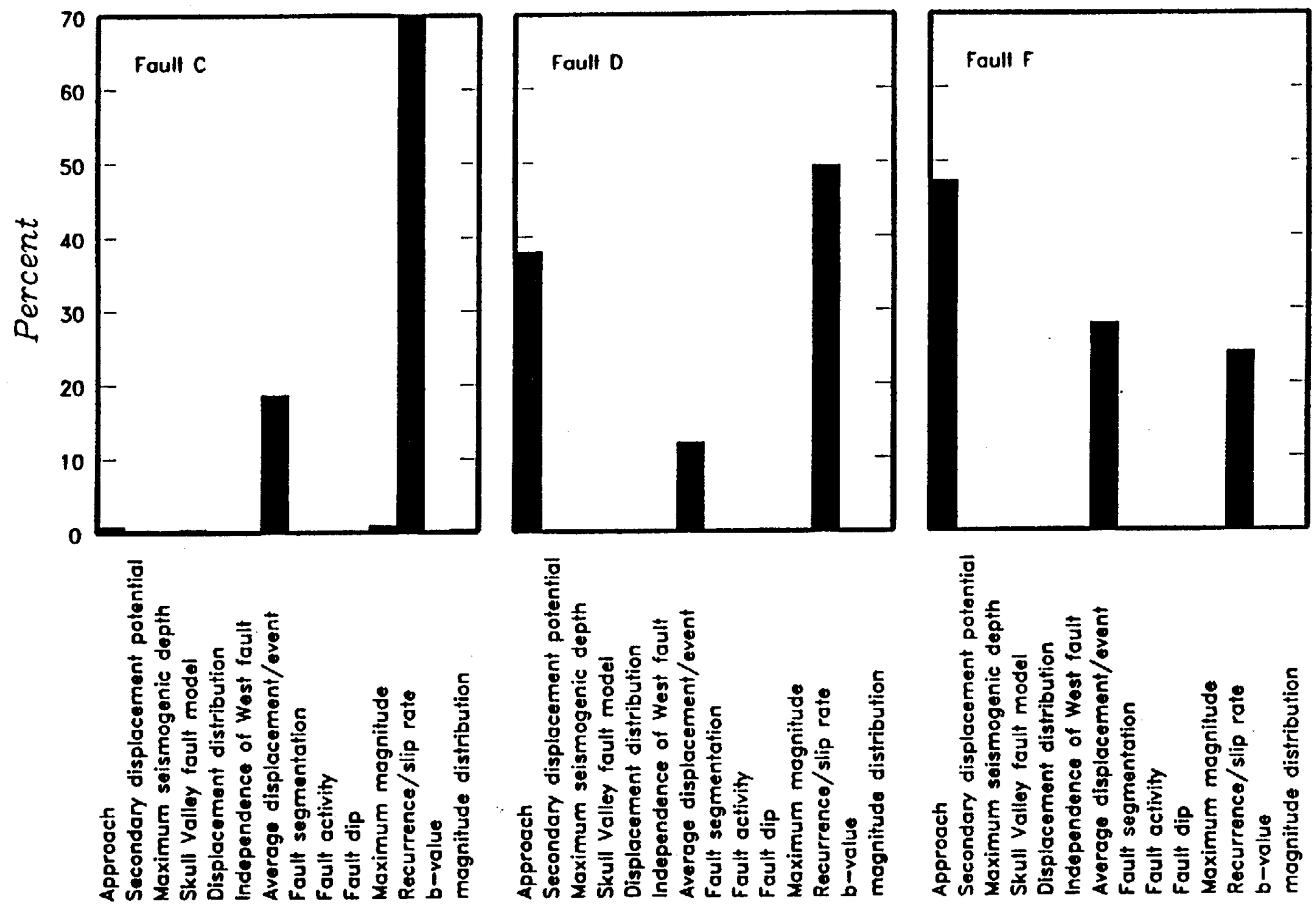
Project No.	4790
Figure	7-8



GEOMATRIX

EFFECT OF APPROACH ON MEAN DISPLACEMENT HAZARD.
Private Fuel Storage Facility
Skull Valley, Utah

Project No.	4790
Figure	7-9



GEO TRIX

RELATIVE CONTRIBUTION OF THE UNCERTAINTY IN THE COMPONENTS OF THE DISPLACEMENT HAZARD MODEL TO THE TOTAL UNCERTAINTY IN THE HAZARD.
Private F Storage Facility
Sl lley, Utah

Project No. 4790

Figure 7-10

Private Fuel Storage

cc:

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Private Fuel Storage, L.L.C.
P. O. Box C4010
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The Honorable Michael O. Leavitt
Governor of Utah
Salt Lake City, UT 84114-0601

The Honorable Leon D. Bear, Chairman
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