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SUMMARY OF U.S. NUCLEAR REGULATORY COMMISSION AND U.S. DEPARTMENT OF ENERGY TECHNICAL EXCHANGE ON SEISMIC HAZARDS ASSESSMENT

On November 17, 1993, representatives of the Nuclear Regulatory Commission, U.S. Department of Energy (DOE), State of Nevada Nuclear Waste Project Office, and Nye and Clark Counties, Nevada, participated in a technical exchange on seismic hazards assessment. The purpose of the technical exchange was to discuss the contents of a DOE topical report on the assessment of seismic hazards at Yucca Mountain, Nevada. Attendees also heard a presentation on DOE's plans for addressing NRC Site Characterization Analysis open items related to the technical exchange topic. The technical exchange agenda is included as Attachment 1 and the list of attendees is Attachment 2 to this summary. Copies of presenters' handouts are Attachment 3. Technical presenters representing DOE included staff from DOE's Yucca Mountain Project Office, the U.S. Geological Survey, Geomatrix Consultants, Lawrence Livermore National Laboratory, and the Civilian Radioactive Waste Management System Management and Operating Contractor (M&O).

DOE presentations focused on discussions of elements of the proposed seismic hazards methodology, including the technical data to support seismic hazard analyses, seismic source characterization for the Yucca Mountain site, and the use and suitability of the proposed methodology for performance assessment and seismic design. During the presentations, all attendees were provided an opportunity for questions. Both the State of Nevada and NRC had closing comments on the technical exchange and the proposed seismic hazards assessment methodology. The State commented that:

1) There appeared to have been little significant progress in the area of seismic hazards assessment at Yucca Mountain in the last 10 years. The methodology as presented provided no methods specific to the unique problems in assessing seismic hazards encountered at Yucca Mountain.
2) The State's main concerns were not specifically addressed in the technical exchange presentation. None of the methods proposed have been previously tested in a licensing hearing. The topic of seismic hazard assessment could draw intervenors who will use a deterministic approach and a methodology that focuses on a probabilistic approach could result in licensing delays.
3) Presentations should have also provided discussion on how the deterministic approach is linked with the proposed probabilistic approach.
4) Discussions should have included how the near field will be considered in the proposed approach. This discussion was requested of DOE during the agenda setting.

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5) Is the accelerated seismic program really accelerated? There is a concern that seismic hazard activities are not fully funded.
6) Interested parties should consider a paper by Tom Hanks (USGS) on "Probabilistic Seismic Hazard Analysis: A Beginner's Guide" and an article by Ellis Krinitsky titled, "The Hazard in Using Probabilistic Seismic Hazard Analysis" (November 1993, Civil Engineering). The articles discuss the negatives of a probabilistic approach.

Closing comments by the NRC were:
1) The NRC is pleased that the use of the 10,000 year cumulative slip earthquake (CSE) concept has been discontinued. It believes that the discontinuation of the CSE concept is a step forward.
2) It is suggested that DOE reconsider its list of applicable 10 CFR Part 60 regulatory requirements. For example,
3) The seismic hazards assessment methodology or the subsequent topical reports (Steps 2 and 3 of the series) needs to address fault avoidance.
4) The use of the term "performance goals" in the presentations was unclear. It is suggested that DOE use a different term to avoid confusion with the same term in the Site Characterization Plan. Also, how do the performance goals in the proposed methodology related to the performance allocation process?
5) Excavation of the exploratory studies facility (ESF) will be proceeding throughout fiscal years 1995 and 1996. The design inputs (Step 3) report is not proposed until FY96. What will DOE be doing relative to ESF seismic design until the Step 3 report is completed?
6) In the seismic hazard assessment methodology report (Step 1) DOE should provide a discussion of the three seismic hazard topical reports and how the three reports are linked and their purpose.
7) The scheduling of activities related to DOE's accelerated seismic program is unclear given current delays in the gathering of geophysical data and the up-grading of the seismic network.
8) Discussions related to the near field were missing from the technical exchange and there was little data on depth attenuation. DOE needs to consider a full range of seismic events given that a large number of smaller events may impact the waste package and waste isolation.
9) The report would benefit from some discussion of the limitations of the methodology proposed.

Charlotte Abrams 12/2/95

Charlotte Abrams, Sr. Proj. Mgr.
Repository Licensing and Quality
Division of High-Level Waste
Management
Office of Nuclear Material
Safety and Safeguards
U.S. Nuclear Regulatory Commission

Christon E. Ei 11/30/95

Christian Einberg
Regulatory Integration Branch
Office of Civilian Radioactive
Waste Management
U.S. Department of Energy

Attachment 1

AGENDA
DOE-NRC TECHNICAL EXCHANGE ON SEISMIC HAZARDS ASSESSMENT

8:00	Opening Remarks	DOE, NRC, State, Affected Parties
8:10	Introduction	DOE (Sullivan-YMP)
8:20	Discussion of Proposed Methodology o Scope and Purpose of Topical Report o Overview of Methodology	DOE (Quittmeyer-M&O)
	Discussion of Elements of Proposed Methodology	
8:40	Site Characterization Data	DOE (Whitney-USGS)
9:15	Recent Practice in Seismic Hazard Assessment	DOE (Kevin Coppersmith, GeoMatrix)
9:50	Source Characterization	DOE (David Schwartz-USGS)
10:20	BREAK	
	Discussion of Elements of Proposed Methodology (continued)	
10:35	Ground Motion Estimation	DOE (Paul Somerville-M&O)
11:05	Hazard Calculation and Treatment of Uncertainty	DOE (Jean Savy-LLNL)
11:50	LUNCH	
	Discussion of Elements of Proposed Methodology (continued)	
1:15	Fault Displacement Hazard	DOE (Coppersmith, GeoMatrix)
1:45	Use of Methodology by PA/Design	DOE (Quazi Hossain-LLNL)
2:15	Summary	DOE (Statton-M&O)
2:45	Open Discussion	All
3:15	SCA Open Items	DOE (Fenster-M&O)
3:45	BREAK/CAUCUS	
4:00	State of Nevada Comments	State
4:15	Other Affected Party Comments	Affected Parties
4:30	NRC Comments	NRC
4:45	Closing Remarks	DOE, NRC, State, Affected Parties
5:00	ADJOURN	

NOTE: Each topic on the agenda includes time allotted for discussion.

Attachment 2

Nov. 17, 1993

DOE/NRC Technical Exchange
Seismic Hazards Assessment
Sign-In Log

PRINT NAME	SIGNATURE	ORGANIZATION	PHONE NO.
Steven E. LaRoy	Steven E. LaRoy	CRWMS M&O/Duke	702-794-7836
John S. TRAPP	John S. Trapp	NRC-NMSS/HLWM	504-2609 (301)
HAROLD E. LEFEVRE	Harold E. Lefevre	NRC-NMSS/HLWM	504-3464(301
J. CARL STEPP	J. Carl Stepp	WCC	512-338-1798
Stan Echols	Stan Echols	Winston & Strawn	202 371-5777
Paul Somerville	Paul Somerville	WCC	818 449 7650
Roseanne Perman	Roseanne C Perman	Geomatrix	415 434-9400
E. J. TIESENHAUSEN	E. J. Tiesenhausen	CLARK COUNTY	702 455-5775
Mal Murphy	M. R. Murphy	Nye County	26 753-6001
Mike Lugo	M. Lugo	M&O/TRW	(702) 794-7830
Paul W. Pomeroy	Paul W. Pomeroy	ACNW/NRC	(914) 339-1715
Quazi Hossain	Q. Hossain	LLNL/DOE	(510) 423-2289
JAMES PARK	James Park	NRC/NMSS/HLWM	(301) 504-2592
JIM YORK	Jim York	Weston	202-646-6650
Asadul H. Chowdhury	Asadul H. Chowdhury	CNWRA	(210) 522-5151
Bansad Jagannath	Bansad Jagannath	NRC	301-504 2593
LINDA DESELL	Linda Desell	DOE/RW	202-586-1462
SUSAN JONES	Susan Jones	DOE/YMP	702-794-7613
Steve McDuffie	Stephen McDuffie	NRC	301-504-3460
John Whitney	John W. Whitney	USGS	303 236-1078

Nov. 17, 1993

DOE/NRC Technical Exchange
Seismic Hazards Assessment
Sign-In Log

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Keith McConnell	Keith D. McConnell	NRC	301 504 2532
Lynn Deering		NRC	301 492-4737
Jean Younker	Jean Younker	~~DOE~~ (RW) NWTRB	702 794 7657
Tom Hanks	T Hanks	USGS	415-329-5634
Renner B. Hofman Jr	Renner B. Hofman Jr	CNWRA	210 522 5308
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CARL JOHNSON	Carl Johnson	NEVADA	(702) 687-3744
DAVID TILLSON	David Tillson	NEVADA	(801) 363-4093
Richard McMullen	Richard McMullen	US NRC	301 492 3806
MYSORE NATARAJA	M Nataraja	USNRC	~~301-492-3340~~ 301-504-3459
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MICHAEL A. BAUSER	Michael A. Bauser	EEI/UWASTE	202 955-6669
Ray Wallace	Raymond Wallace	USGS/HQ	(202) 586-1244
Sean Kennedy		OCRWM	202 586 9274
John P. Roberts	John P. Roberts	DOE/RW	202 586 9896

Nov. 17, 1993

DOE/NRC Technical Exchange
Seismic Hazards Assessment
Sign-In Log

PRINT NAME	SIGNATURE	ORGANIZATION	PHONE NO.
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APRIL GIL	April Gil	DOE/YMP	(702) 794-7622
LESTER BERKOWITZ	Lester Berkowitz	M&O/TRW	(202) 488 8309
John L. Russell	John L. Russell	CNWRA	(703) 979-9129
Thomas Buchsteot	Thomas Buchsteot	DOE/YMP	(702) 794-7590

DOE-NRC TECHNICAL EXCHANGE ON SEISMIC HAZARDS ASSESSMENT

SEISMIC HAZARDS ASSESSMENT METHODOLOGY TOPICAL REPORT

J. TIMOTHY SULLIVAN
U.S. DEPARTMENT OF ENERGY

INTRODUCTION

- DOE TO PRESENT THE FIRST OF SEVERAL TOPICAL REPORTS ON SEISMIC HAZARD EVALUATION AT YUCCA MOUNTAIN
- THESE TOPICAL REPORTS SHOULD:
  - CLARIFY THE DOE APPROACH TO SEISMIC HAZARD EVALUATION
  - PROVIDE A BASIS FOR RESOLVING DOE-NRC OPEN ITEMS
  - ELICIT NRC ACCEPTANCE OF THE DOE APPROACH
- PRESUBMITTAL BRIEFINGS SHOULD PROVIDE A FORUM FOR DISCUSSION AND CLARIFICATION OF DOE'S POSITION

STATUS - TOPICAL REPORT

- WORKING GROUP WAS CONVENED DURING FY93 AND DEVELOPED DRAFT TOPICAL REPORT
- TODAY'S BRIEFING DESCRIBES THE CONTENTS OF THIS DOE TOPICAL REPORT AND PROVIDES AN OPPORTUNITY FOR DISCUSSION AND RESPONSES
- DOE WILL CONSIDER COMMENTS FROM TODAY'S BRIEFING THEN SUBMIT TOPICAL REPORT TO NRC IN EARLY 1994

CONTENTS - TOPICAL REPORT

- DOE PROPOSES USE OF PROBABILISTIC METHODOLOGY TO ASSESS SEISMIC HAZARDS AT YUCCA MOUNTAIN
  - METHODOLOGY ENCOMPASSES THE TRADITIONAL DETERMINISTIC APPROACH
- THIS SEISMIC TOPICAL REPORT PROVIDES THE OVERALL FRAME WORK FOR SEISMIC HAZARD ASSESSMENT. STUDY PLANS PROVIDE FURTHER DETAILS ON SPECIFIC ELEMENTS OF THE METHODOLOGY
- DOE IS DISCARDING CUMULATIVE-SLIP EARTHQUAKE METHODOLOGY

DESTINATION

FY 96

- PRELIMINARY HAZARD CURVES FOR PERFORMANCE ASSESSMENT
- PRELIMINARY PRECLOSURE SEISMIC DESIGN INPUTS
  - GROUND MOTION
  - DISPLACEMENT

FY 95

- DATA ANALYSIS
- SOURCE CHARACTERIZATION
- GROUND MOTION ASSESSMENT
- PROBABILISTIC SEISMIC HAZARD ANALYSIS

PRELIMINARY DRAFT
INFORMATION ONLY

CURRENT ACTIVITIES

FY 94

- COMPLETE CRITICAL PALEOSEISMOLOGY FIELD STUDIES
- COMPLETE SEISMIC HAZARD ASSESSMENT METHODOLOGY TOPICAL REPORT #1
- DEVELOP TOPICAL REPORT #2 - DETERMINATION OF SEISMIC HAZARD LEVELS FOR PRECLOSURE DESIGN
- COMPLETE GROUND MOTION ASSESSMENT STUDY PLAN (8.3.1.17.3.3)
- COMPLETE PROBABILISTIC SEISMIC HAZARD ANALYSIS STUDY PLAN (8.3.1.17.3.6)

SUMMARY

- SEISMIC HAZARD EVALUATION TOPICAL REPORTS
  - SEISMIC HAZARD ASSESSMENT METHODOLOGY (FY94)
  - DETERMINATION OF HAZARD LEVELS (FY94-95)
  - DESIGN AND PERFORMANCE ASSESSMENT INPUTS (FY96)
- SEISMIC HAZARD ASSESSMENT METHODOLOGY TOPICAL REPORT
  - ASSESSMENT METHODOLOGY ADDRESSES BOTH VIBRATORY GROUND MOTION AND FAULT DISPLACEMENT
  - THE ASSESSMENT METHODOLOGY PROVIDES THE DOE FRAMEWORK; STUDY PLANS IMPLEMENT THE ELEMENTS OF THE METHODOLOGY
  - FORMAL SUBMITTAL OF THIS TOPICAL REPORT TO THE NRC IS ANTICIPATED IN EARLY 1994

PRELIMINARY DRAFT

INFORMATION ONLY

Civilian Radioactive Waste Management System

Management & Operating Contractor

TRW Environmental Safety Systems Inc.

DOE-NRC TECHNICAL EXCHANGE ON SEISMIC HAZARDS ASSESSMENT

OVERVIEW OF METHODOLOGY

Richard C. Quittmeyer
November 17, 1993

B&W Fuel Company
Duke Engineering & Services, Inc.
Fluor Daniel, Inc.

INTERA Inc.
JK Research Associates, Inc.
E. R. Johnson Associates, Inc.

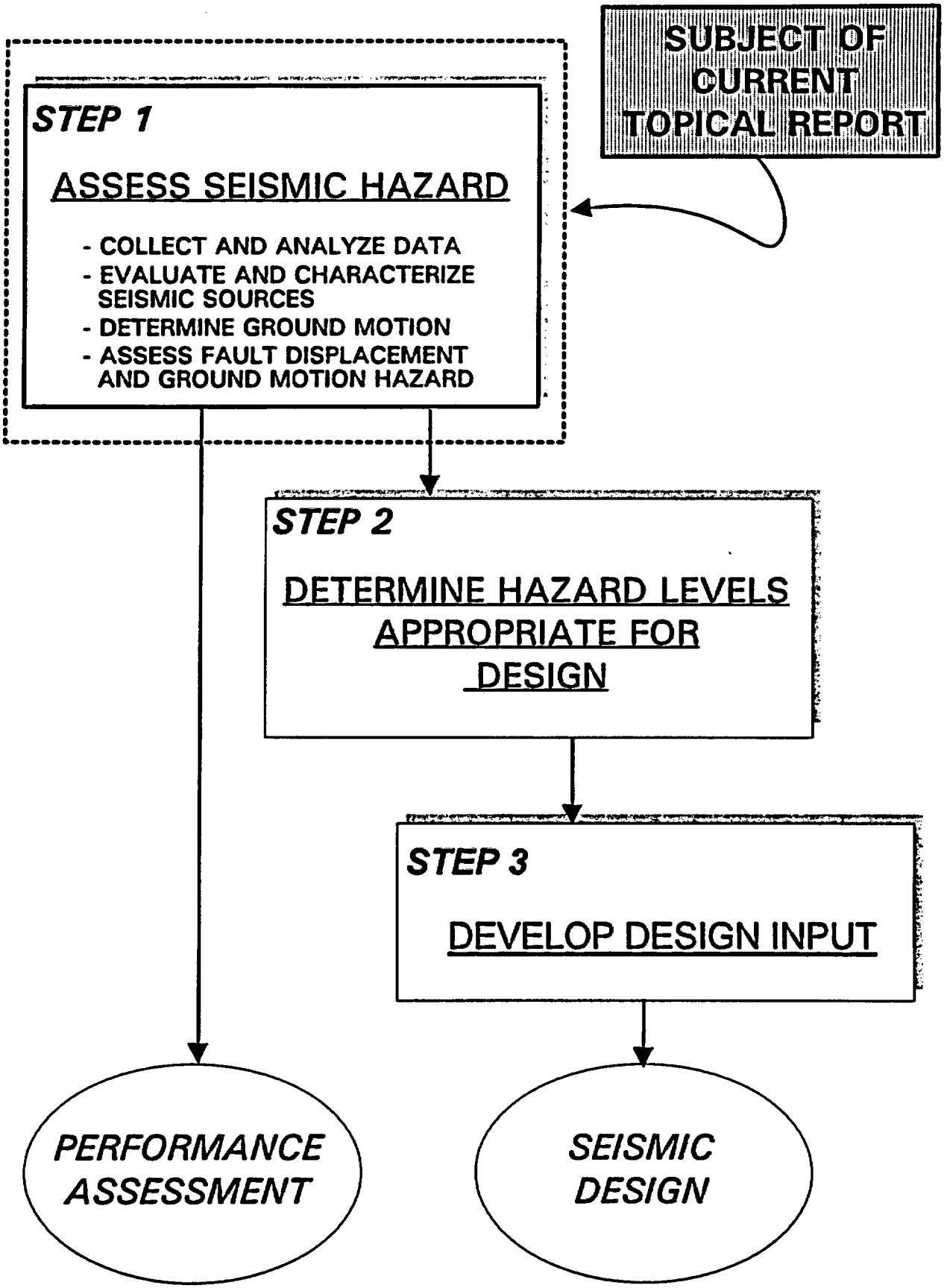
Logicon RDA
Morrison Knudsen Corporation
Woodward-Clyde Federal Services

RELATION OF TOPICAL REPORT TO THE OVERALL SEISMIC HAZARD PROGRAM

- THREE STEP PROCESS
  1 Assess fault displacement and vibratory ground motion hazards
  2 Determine hazard levels appropriate for design
  3 Develop seismic design inputs, and inputs for long-term performance assessment

- CURRENT TOPICAL REPORT ADDRESSES <u>STEP 1</u>

SEISMIC HAZARDS PROGRAM



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OVERVIEW OF METHODOLOGY

- **ASPECTS TO BE DISCUSSED**
  - Requirements, needs and guidance
  - Goals
  - Components of the methodology

REQUIREMENTS

- **REGULATORY - 10 CFR PART 60**
  - Description and assessment of features that might affect GROA design and performance [Section 60.21 (c) (1-3)]
  - Design structures, systems and components important to safety so that natural phenomena anticipated at the GROA will not interfere with necessary safety functions [Section 60.131 (b) (1)]
  - Design GROA to provide protection against radiation exposures and releases of radioactive material [Section 60.111 (a)]
  - Design GROA to provide retrievability of waste during preclosure period [Section 60.111 (b)]

REQUIREMENTS

- **REGULATORY - 10 CFR PART 60 (cont)**
  - **Adequately investigate and evaluate potentially adverse conditions [Section 60.122]**
    - » **Natural phenomena that may adversely affect groundwater flow system [60.122 (c) (3)]**
    - » **Structural deformation that may adversely affect groundwater flow system [60.122 (c) (4)]**
    - » **Structural deformation during the Quaternary Period [60.122 (c) (11)]**
    - » **Historical earthquakes that could affect the site significantly if repeated [60.122 (c) (12)]**

REQUIREMENTS

- **REGULATORY - 10 CFR PART 60 (cont)**
  - **Adequately investigate and evaluate potentially adverse conditions [Section 60.122] (continued)**
    - » **Indications that the frequency of occurrence or magnitude of earthquakes may increase [60.122 (c) (13)]**
    - » **More frequent occurrence or higher magnitude earthquakes than typical of the area in which the geologic setting is located [60.122 (c) (14)]**

REQUIREMENTS

- **OTHER NEEDS**
  - **The methodology should accommodate:**
    - » **Design and performance assessment needs**
    - » **Fault displacement and vibratory ground motion hazards**
    - » **Surface and subsurface facilities**
    - » **Preclosure and postclosure time frames**
  - **Stable, credible and broadly accepted by the technical community**

GUIDANCE

- **STAFF TECHNICAL POSITION (NUREG 1451)**
  - Identification of faults to study in detail for fault displacement and ground motion hazard assessment
  - Identification of Type I faults
    - » subject to displacement
    - » may affect the design and/or performance of structures, systems and components important to safety, containment, or waste isolation
    - » may provide significant input into models used in design or in the assessment of performance

GOALS

- **GOAL WAS TO DEVELOP A METHODOLOGY:**
  - **Based on experience**
    - » **Build on recent experience in seismic hazard assessment, including methodology development and applications reviewed and accepted by the NRC**
  - **Driven by data**
    - » **Incorporate all relevant data from site characterization program**
    - » **Expand data collection if need is indicated**
  - **Focused on issues**
    - » **Address issues specific to Yucca Mountain**

GOALS

- **GOAL WAS TO DEVELOP A METHODOLOGY: (cont)**
  - Treating randomness and uncertainty properly
    - » Specific evaluation of various sources of uncertainty (scientific and data)
  - With flexibility
    - » Ability to accommodate a variety of scientific interpretations consistent with the data
  - Including sensitivity analysis
    - » Identify important contributors to hazard
    - » Aid in defining the need for additional data

GOALS

- **GOAL WAS TO DEVELOP A METHODOLOGY: (cont)**
  - **Incorporating careful documentation**
    - » **Traceability of inputs and interpretations**
    - » **Credibility**

METHODOLOGY

- RELIES ON DATA COLLECTION AND ANALYSIS
- METHODOLOGY COMPONENTS
  - Source Evaluation and Characterization
  - Ground Motion / Attenuation Relations
  - Ground Motion Hazard Assessment
  - Fault Displacement Hazard Assessment
- BASED ON EXPERIENCE
- SUPPORTS APPLICATIONS
  - Seismic Design
  - Performance Assessment

COLLECT AND ANALYZE DATA
John Whitney

EVALUATE AND CHARACTERIZE SOURCES
David Schwartz

DETERMINE GROUND MOTION / ATTENUATION
Paul Somerville

ASSESS GROUND MOTION HAZARD
Jean Savy

ASSESS FAULT DISPLACEMENT HAZARD
Kevin Coppersmith

RELATION OF METHODOLOGY TO RECENT HAZARD ASSESSMENT EXPERIENCE
Kevin Coppersmith

RELATION OF METHODOLOGY TO THE APPLICATIONS IT MUST SERVE
Quazi Hossain

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DOE-NRC TECHNICAL EXCHANGE
ON
SEISMIC HAZARDS ASSESSMENT

SITE CHARACTERIZATION DATA

JOHN W. WHITNEY

U. S. GEOLOGICAL SURVEY

THE TECHNICAL DATA TO SUPPORT SEISMIC HAZARD ANALYSES ARE GATHERED IN A SERIES OF 12 SCIENTIFIC ACTIVITIES DESCRIBED IN THE DOE SITE CHARACTERIZATION PLAN

THESE ACTIVITES WERE DESIGNED TO ADDRESS THREE SEISMOTECTONIC ISSUES:

1. WHAT IS THE EXPECTED GROUND MOTION AT YUCCA MOUNTAIN SITE?

2. WHAT IS THE EXPECTED SURFACE DISPLACEMENT AT THE YUCCA MOUNTAIN SITE?

3. WHAT IS THE HAZARD FROM SEISMICALLY INDUCED FAILURE OF SOIL DEPOSITS

PHOTOGRAPH OF YUCCA MOUNTAIN SHOWING THE GHOST DANCE, BOW RIDGE, AND PAINTBRUSH CANYON FAULTS.

A STRONG EMPHASIS IS PLACED ON OBTAINING ACCURATE BEHAVIORAL CHARACTERISTICS OF FAULTS IN THE YUCCA MOUNTAIN AREA

SITE CHARACTERIZATION APPROACHES

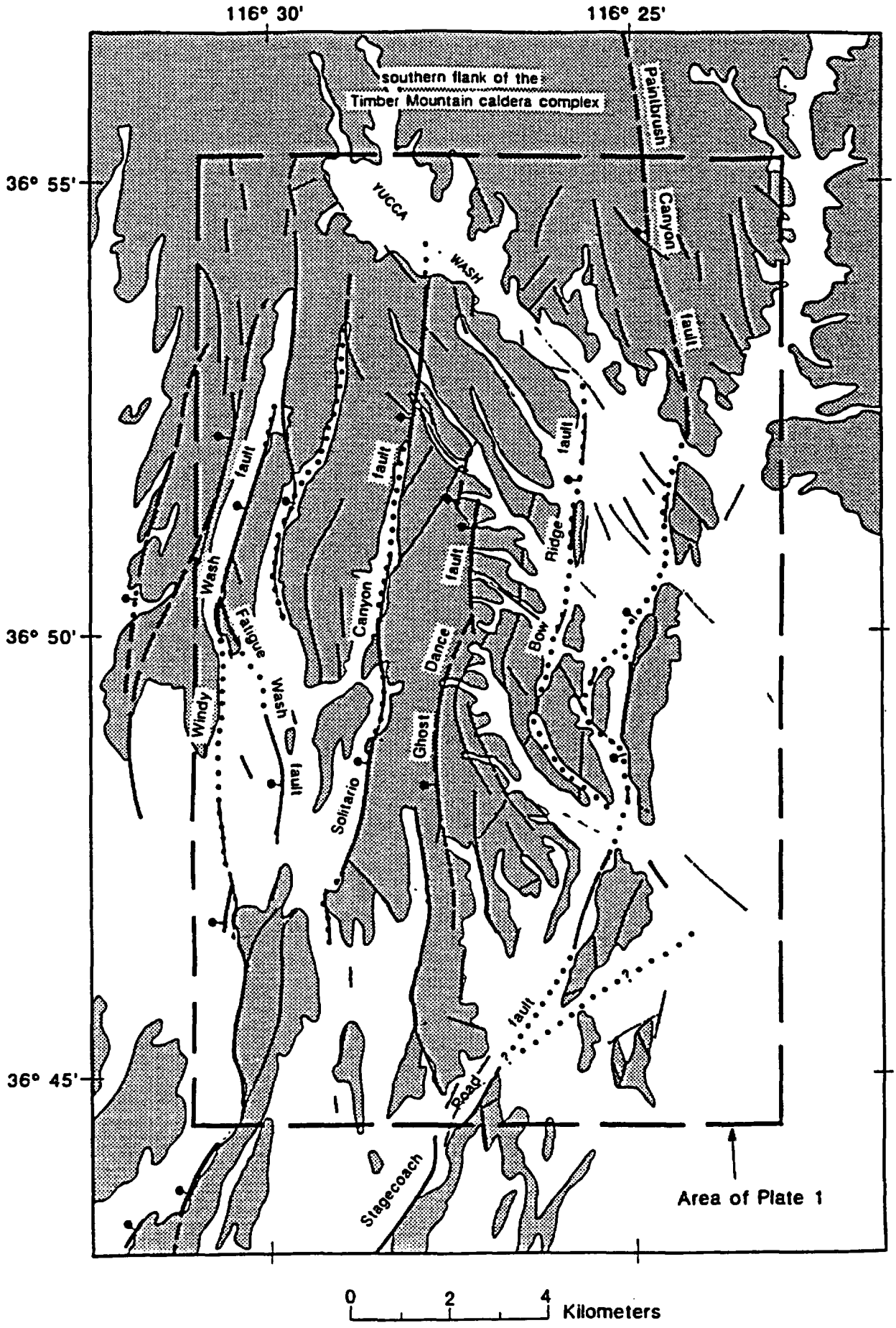
1. BUILDING BLOCKS OF BASIC GEOLOGY AND GEOPHYSICS
   - GEOLOGIC MAPPING
   - STRATIGRAPHY AND CHRONOLOGY
   - GRAVITY AND AEROMAGNETIC SURVEYS
   - SEISMIC REFLECTION AND REFRACTION DATA
   -SEISMICITY DATA

2. LEVEL OF DETAIL DECREASES AWAY FROM YUCCA MOUNTAIN
   - SCALE OF MAPPING
   - DENSITY OF FAULT TRENCHES
   - DENSITY OF GEOPHYSICAL SURVEYS
   - 100KM RADIUS TECTONICS STUDY AREA

3. TECTONIC ANALYSES AND MODELS
   - BEHAVIOR OF INDIVIDUAL STRUCTURES
   - CONSTRAINTS OF FIELD RELATIONSHIPS
   - INTEGRATION OF MULTIPLE DATA SETS
   - FORMULATION AND TESTING OF MODELS

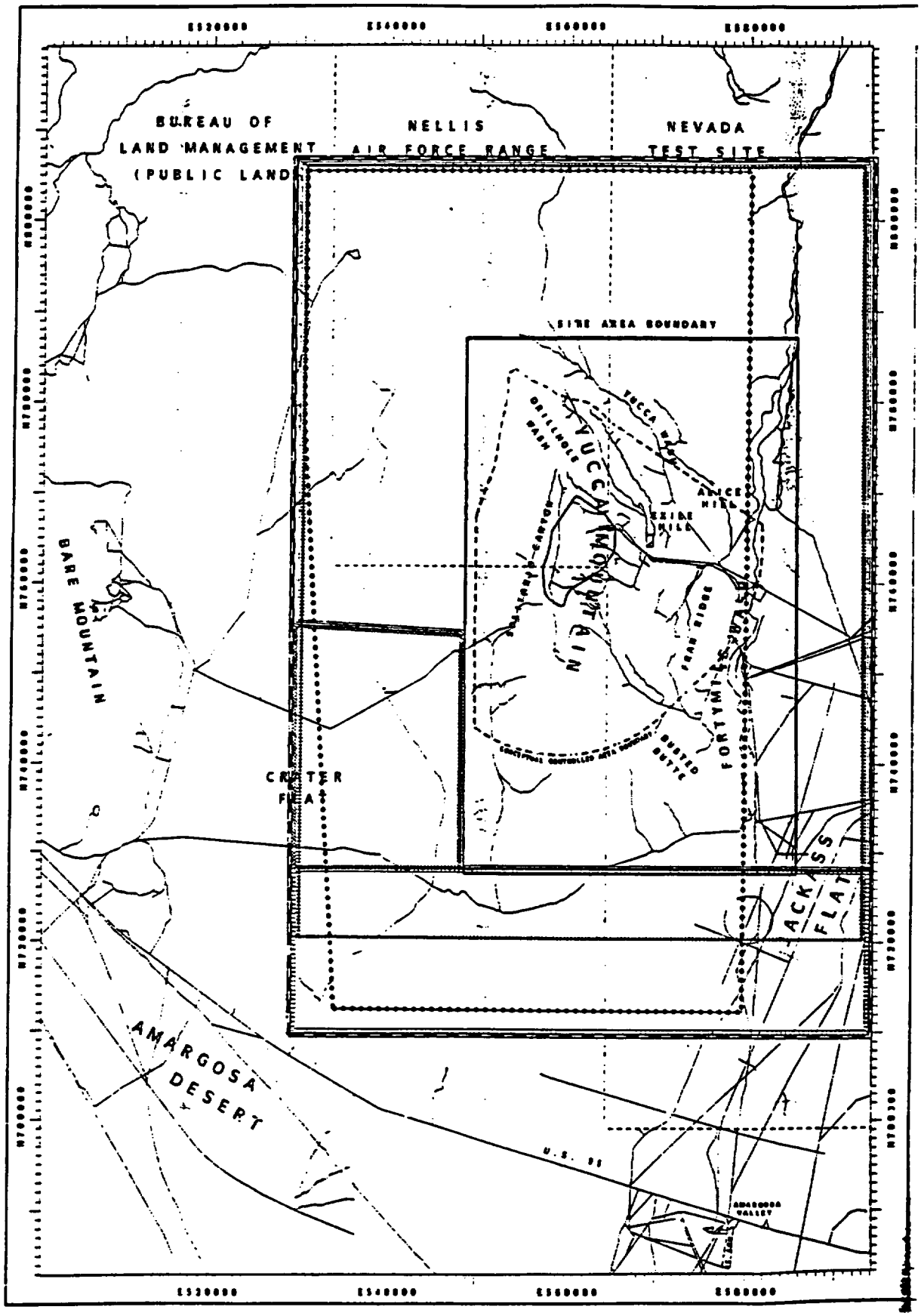
4. FEEDBACK APPROACH
   - TESTING ALTERNATIVE MODELS
   - REVISE GEOLOGICAL AND GEOPHYSICAL ACTIVITIES
   - REVISE OR FORMULATE NEW MODELS

PRINCIPAL FAULTS IN THE YUCCA MOUNTAIN SITE AREA



PRELIMINARY PREDECISIONAL DRAFT MATERIAL

INDEX OF AEROMAGNETIC SURVEYS IN THE YUCCA MOUNTAIN SITE AREA



Data Being Developed to Characterize Seismic Sources

Historical seismicity maps and cross-sections

Quaternary fault maps, literature reviews, and reconnaissance investigations

Detailed paleoseismic investigations of local Quaternary faults

Fault segmentation models

Focal mechanisms, hypocenter distributions, and historical earthquake data

Heat-flow, magnetic, and gravity anomaly maps

Seismic reflection and refraction investigations and borehole logs

Detachment fault maps, ages, and geometric interpretations

Geodetic leveling, trilateration, and global-positioning satellite (GPS) surveys

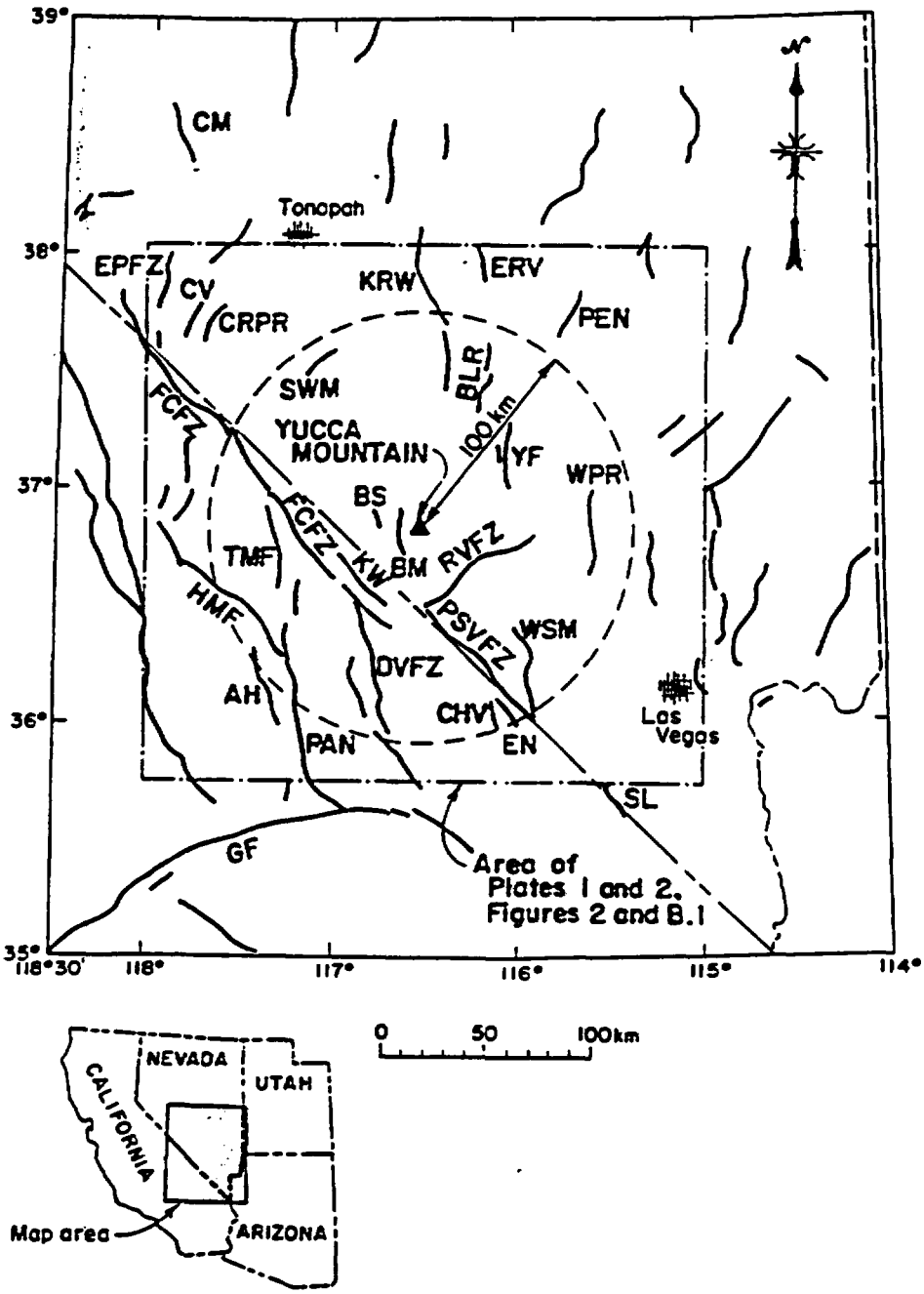
Crustal stress measurements

Fault kinematic indicators such as the orientations of slickensides and fault striae

Tectonic geomorphology investigations for evidence of deformation or stability

Tectonic models of local and regional structures

Empirical correlations between rupture dimensions and moment magnitude



Major known and suspected Quaternary faults in southern Nevada and southeastern California in the regional surrounding Yucca Mountain.

PRELIMINARY FAULT PARAMETERS FOR KNOWN OR SUSPECTED QUATERNARY FAULTS WITHIN 100 KM OF YUCCA MOUNTAIN

Fault Name	Total Length (km)	Closest Approach to ESF (km)	Style of Faulting	Slip Rate (mm/yr)	Recurrence Interval (ka)
Bare Mountain fault zone	10-16	14	Normal Right Oblique	0.01-0.15	20-100
Mine Mountain fault zone	13-20	17	Normal Left Oblique	(0.0001-0.001)	(100-2000)
Cane Spring fault zone	15-27	24	Normal Left Oblique	(0.0001-0.001)	(100-2000)
Rock Valley fault zone	19-65	27	Left Oblique Normal	0.003-0.02	30-150
Ash Meadows fault zone	48-60	34	Normal Oblique?	0.005-0.02	20-100
Yucca fault zone	22-35	38	Normal Right Oblique	0.008-0.02	20-130
Carpetbag fault system	17-35	41	Normal Oblique?	(0.0001-0.001)	(500-1000)
Keane Wonder fault zone	25-29	45	Normal Left Oblique	(0.01-0.1)	(20-100)
Furnace Creek fault zone	190	52	Right Lateral	(2.0-4.0)	(1-5)
Death Valley fault zone	75	57	Normal Right Oblique	(2.0-4.0)	(1-4)
West Springs Mountain fault zone	60	57	Normal Right Lateral	0.06-0.1	(20-100)
Pahrump-Stewart Valley fault system	70	70	Right Oblique Normal	(0.01-0.1)	(20-100)
Panamint Valley fault zone	80	97	Right Lateral Normal	1.5-3.5	1-4

PALEOSEISMIC STUDIES AT YUCCA MOUNTAIN

TRENCHING STUDIES: EMPHASIS ON SLIP RATES, RECURRENCE INTERVALS, DISPLACEMENTS PER EVENT, AND KINEMATIC DATA
41 TRENCHES HAVE BEEN EXCAVATED IN THE YUCCA MTN SITE AREA

- 30 TRENCHES DISPLAY EVIDENCE OF QUATERNARY MOVEMENT ON 8 DIFFERENT FAULTS

- 11 TRENCHES EXCAVATED ACROSS SUSPECTED FAULTS OR LINEAMENTS SHOW NO EVIDENCE OF FAULTING

- 6-7 NEW TRENCHES PLANNED IN FY 94: EMPHASIS ON COMPLETING STUDIES ON SOLITARIO CANYON, PAINTBRUSH CANYON, BOW RIDGE, STAGECOACH RD, ROCK VALLEY AND BARE MOUNTAIN FAULTS

- ASSESS PALEOSEISMIC HISTORY OF GHOST DANCE FAULT

SHALLOW SEISMIC REFLECTION STUDIES

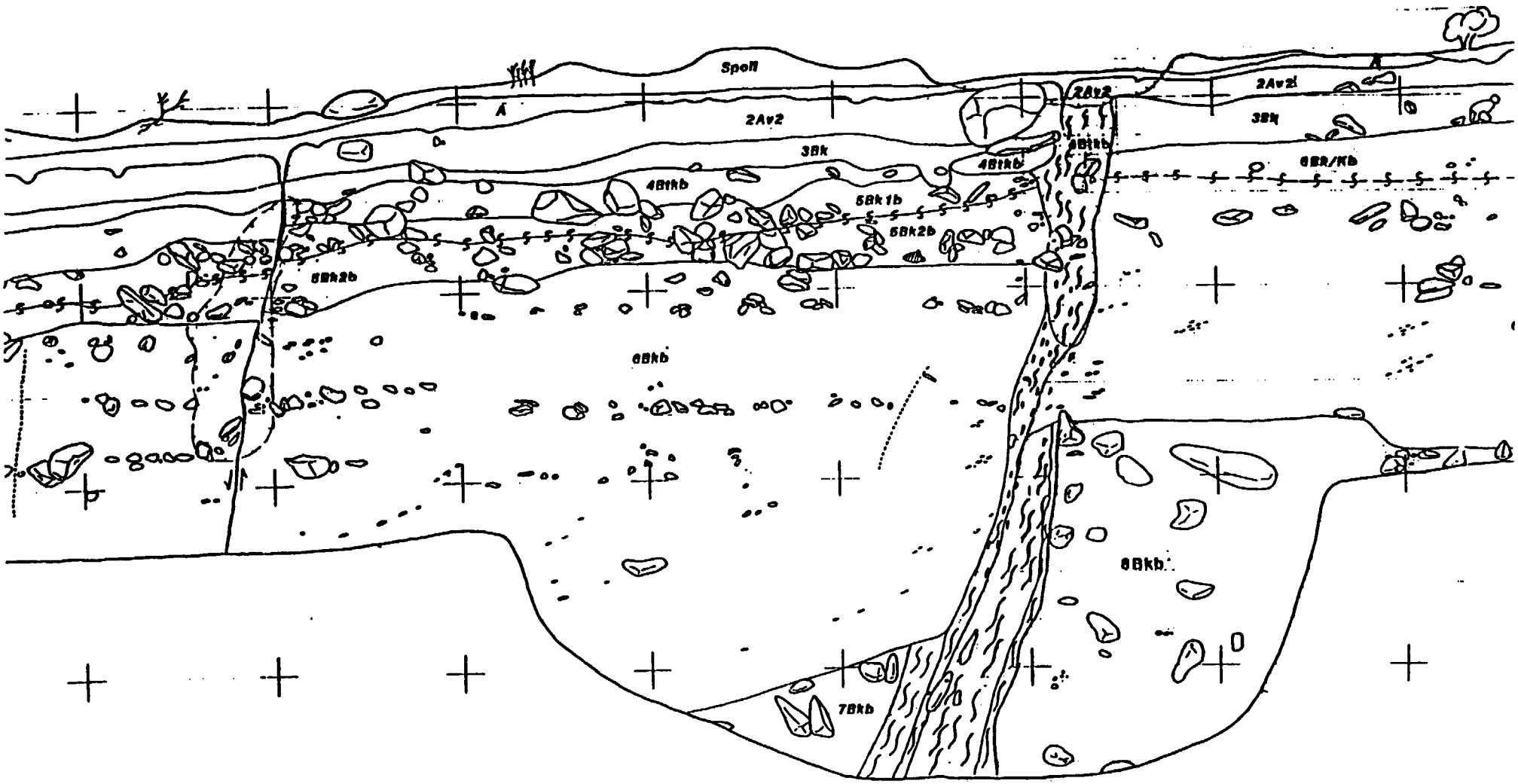
- 3.7M YEARS OF OFFSET ALONG WINDY WASH FAULT

SHALLOW DRILLING AND ESF FAULT STUDIES

PHOTOGRAPH OF WESTERN CRATER FLAT AND YUCCA MOUNTAIN SHOWING THE FATIGUE WASH AND SOLITARIO CANYON FAULTS

PHOTOGRAPH OF TYPICAL TRENCH EXCAVATION. TRENCH STUDIES ARE USED TO GATHER PALEOSEISMIC DATA ON INDIVIDUAL FAULT STRANDS.

A PORTION OF PRELIMINARY TRENCH LOG CF-3N ON THE WINDY WASH FAULT



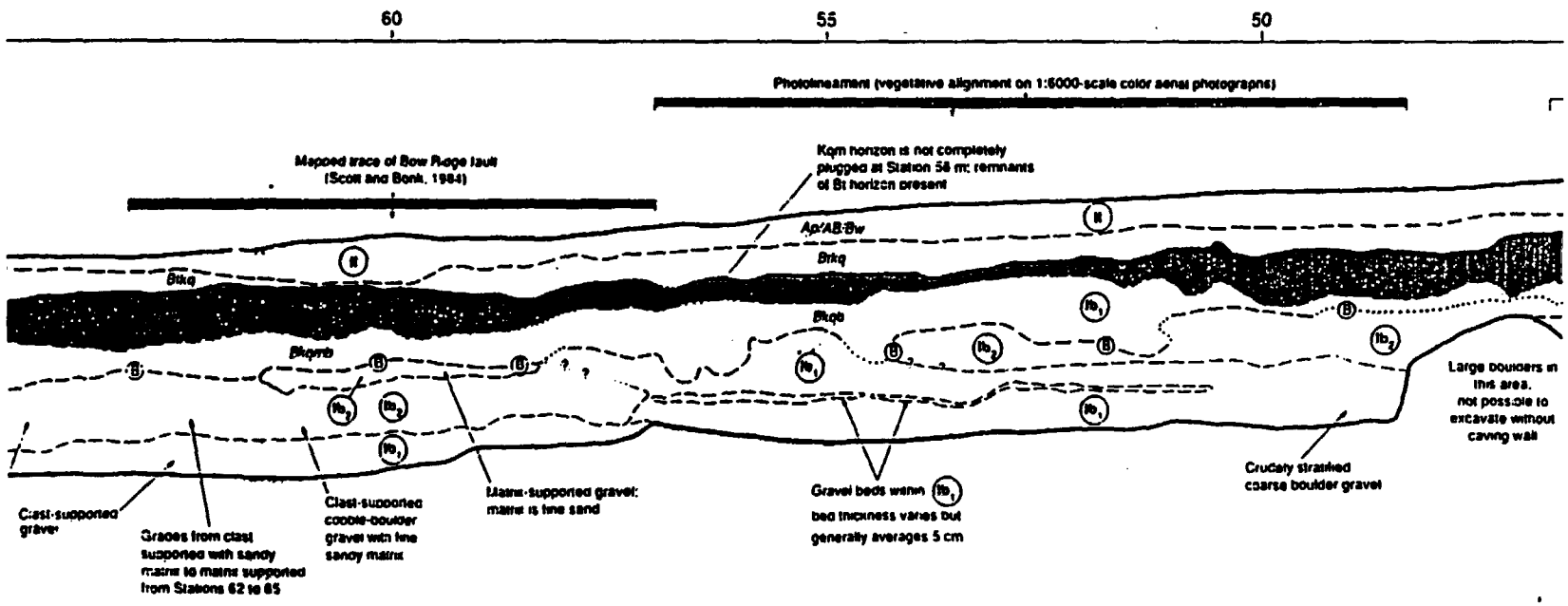
PRELIMINARY PREDECISIONAL DRAFT MATERIAL

PRELIMINARY FAULT PARAMETERS FOR KNOWN FAULTS IN THE YUCCA MOUNTAIN SITE AREA

Fault Name	Total Length (km)	Closest Approach to ESF (km) North Portal	Style of Faulting	Slip Rate (mm/yr)	Recurrence Interval (ka)
Bow Ridge fault zone	4-10	0.3	Normal Left Oblique	0.0005-0.002	50-100
Paintbrush Canyon fault zone	20-26	1.5	Normal Left Oblique	0.006-0.04	20-100
Ghost Dance fault zone	3-9	3	Normal Oblique?	(0.0001-0.001)	(200-5000)
Solitario Canyon fault zone	13-22	4	Normal Left Oblique	0.001-0.02	20-100
Fatigue Wash fault zone	10-16	5	Normal Left Oblique	0.005-0.002	40-100
Windy Wash fault zone	14-24	6	Normal Left Oblique	0.005-(0.03)	40-100
Stagecoach fault zone	6-10	11	Normal Left Oblique	0.006-0.02	20-100
Crater Flat fault zone	3-9	12	Normal Left Oblique?	(0.001-0.01)	(40-200)

PHOTOGRAPH OF MIDWAY VALLEY SHOWING EXPLORATORY TRENCH ACROSS THE PROPOSED SURFACE FACILITIES SITE

Central Part of Trench TR-A/BR-3 (South Wall, Part B)



Data Used to Assess Ground Motions

Surface and underground recordings of earthquakes and nuclear explosions

Ground motion records on both rock and alluvial sites with flat to steep topography

High-gain, portable, and broadband records in analog and digital formats

Empirical ground motion attenuation relations based on strong motion recordings

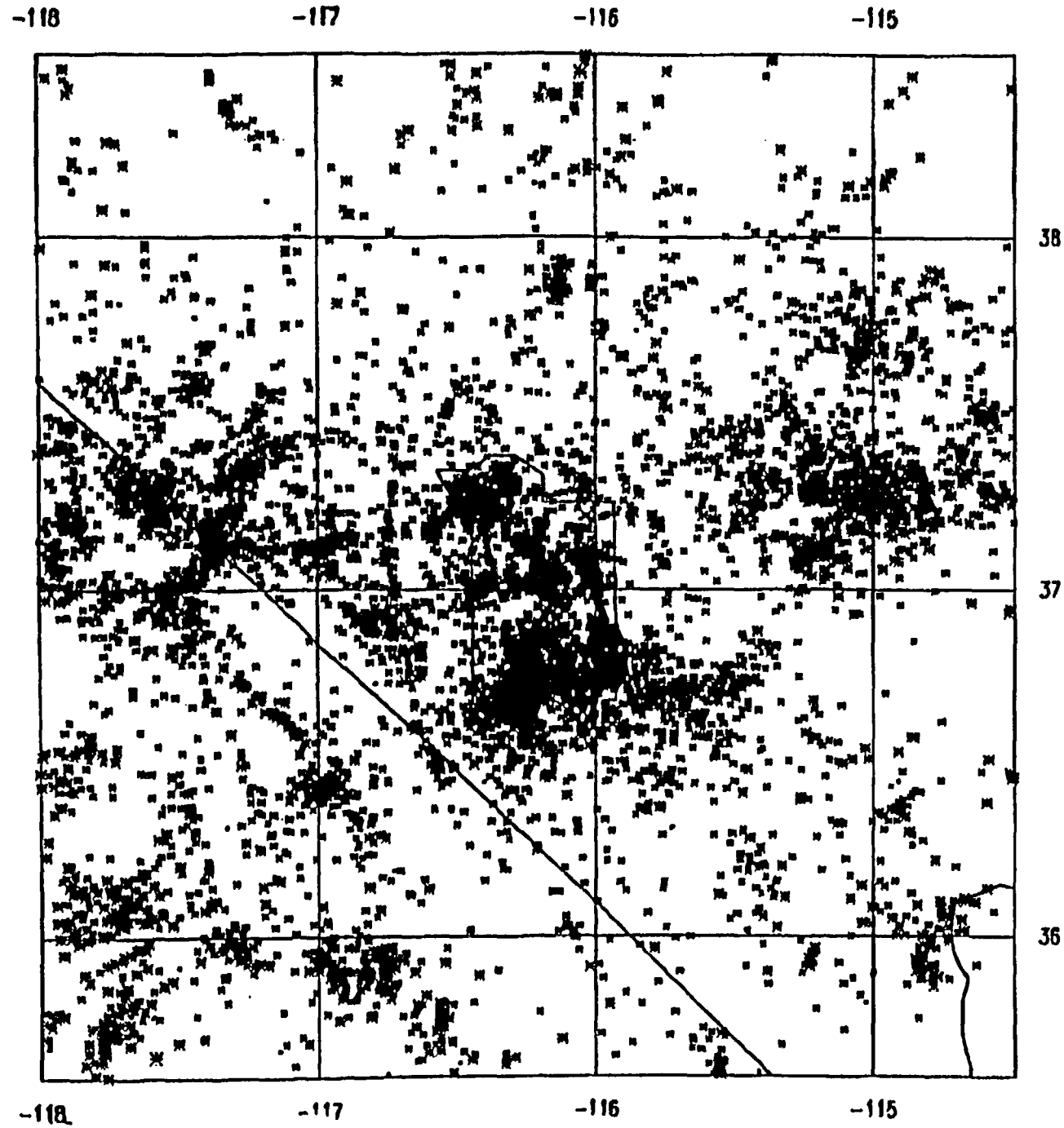
Seismic velocity and density measurements of local geology

Seismic reflection and refraction studies of local geology and wave propagation

Site response models based on empirical source functions and Green's functions

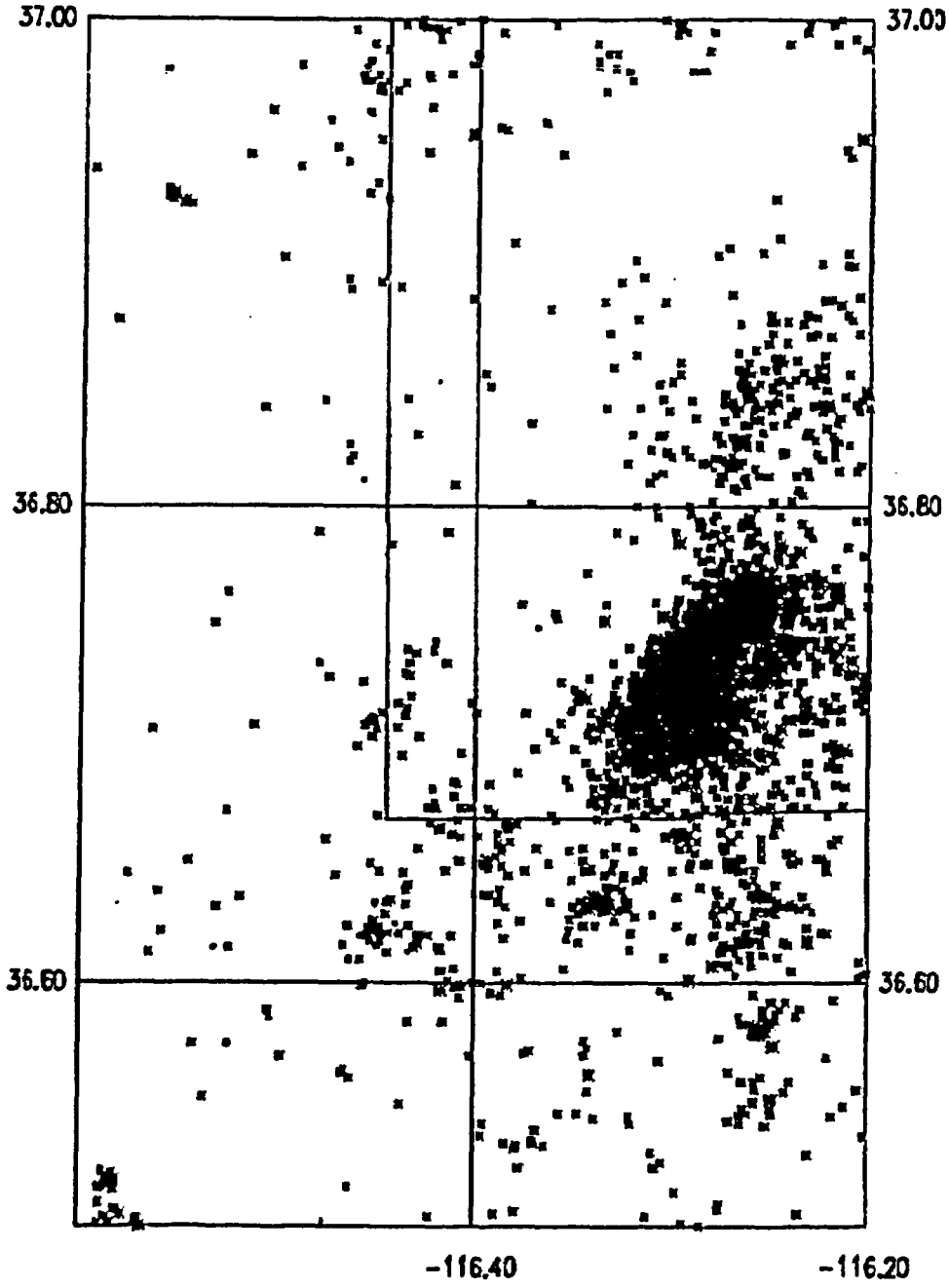
Numerical attenuation models based on wave propagation and site response models

1978 - 1992 EVENTS IN THE SOUTHERN GREAT BASIN



YUCCA MOUNTAIN SITE AREA

1978 - 1992 EVENTS IN THE SOUTHERN GREAT BASIN



PRELIMINARY PREDECISIONAL DRAFT MATERIAL

Data Used to Assess Fault Displacements

Detailed maps of local Quaternary faults

Detailed paleoseismic investigations of local Quaternary faults

Fault rupture models of primary and secondary fault ruptures

Seismic reflection studies to determine fault locations and geometries

Seismic source characteristics of local and regional faults

Empirical correlations between rupture displacement and moment magnitude

Fault kinematic indicators such as the orientations of slickenlines

Focal mechanisms, hypocenter distributions, and historical earthquake catalogs

Tectonic models of local geologic structures

Fault segmentation models and crustal stress measurements

Models of triggered slip associated with regional earthquakes and nuclear explosions

Testing frequency and yield estimates of future underground nuclear explosions

Data Used to Assess Fault Displacement Hazards and Vibratory Ground Motion Hazards

Locations and three-dimensional geometries of all relevant seismic sources

Tectonic models of local and regional structures

Style of faulting and depth distribution of plausible fault ruptures

Magnitude and recurrence distributions for all relevant sources

Fault rupture models of primary and secondary fault ruptures

Shallow and deep seismic source attenuation models

Earthquake and nuclear explosion source attenuation models

Surface and underground site-specific attenuation models

Accurate descriptions of uncertainties in all parameters and models listed above

4

DOE-NRC Technical Exchange on Seismic Hazards Assessment

Source Characterization

Davis Schwartz, U.S. Geological Survey

SEISMIC SOURCE CHARACTERIZATION AT YUCCA MOUNTAIN

GOAL:

TO QUANTIFY THE MAGNITUDES AND DISPLACEMENTS THAT A FAULT CAN PRODUCE AND THE DISTRIBUTION OF THESE IN SPACE AND TIME

REQUIRES:

RECOGNITION OF RECENTLY ACTIVE FAULTS OR REGIONS WITHIN THE CRUST THAT ARE POTENTIAL SOURCES OF FUTURE EARTHQUAKES

DEFINING THE GEOMETRY AND SENSE OF SLIP OF POTENTIAL EARTHQUAKE SOURCES

ASSESSMENT OF THE MAXIMUM MAGNITUDE OF POTENTIAL EARTHQUAKES FOR EACH SOURCE

ASSESSMENT OF RECURRENCE RATES FOR EARTHQUAKES OF VARIOUS SIZES

ASSESSMRENT OF THE POTENTIAL AMOUNT AND LOCATION OF SURFACE AND NEAR SURFACE DISPLACEMENTS ON EARTHQUAKE SOURCES

POTENTIAL EARTHQUAKE SOURCES

QUATERNARY SURFACE FAULTS

SOURCE ZONES--BACKGROUND SEISMICITY

BURIED STRUCTURES

VOLCANIC

FAULT ACTIVITY

DEFINITION:

FAULTS AND GEOLOGIC STRUCTURES THAT HAVE EXPERIENCED RECURRENT MOVEMENT DURING THE QUATERNARY PERIOD (≈2 MILLION YEARS) ARE INFERRED TO HAVE POTENTIAL FOR FUTURE EARTHQUAKES

ADDITIONAL CRITERIA:

ASSOCIATION WITH OBSERVED SEISMICITY

ASSOCIATION WITH A KNOWN QUATERNARY STRUCTURE

FAVORABLE ORIENTATION RELATIVE TO CONTEMPORARY STRESS REGIME

ALTERNATIVE TECTONIC MODELS

FAULT GEOMETRY

CHARACTERIZATION OF GEOMETRY BASED ON:

MAPPED LOCATION
DIP
DOWN DIP EXTENT

DATA FROM:

FAULT DIP MEASUREMENT AT SURFACE
SUBSURFACE IMAGING
THICKNESS OF SEISMOGENIC CRUST
TECTONIC MODELS

SENSE OF SLIP

RATIO OF VERTICAL TO HORIZONTAL COMPONENTS OF DISPLACEMENT

MAXIMUM MAGNITUDE EARTHQUAKES: QUATERNARY SURFACE FAULTS

MAGNITUDES WILL BASED ON EMPIRICAL MAGNITUDE-RUPTURE PARAMETER REGRESSIONS USING ESTIMATES OF FAULT RUPTURE DIMENSIONS AND DISPLACEMENTS DEVELOPED FROM GEOLOGIC AND PALEOSEISMOLOGIC DATA. MAGNITUDE ESTIMATES ARE TIME INDEPENDENT

METHODS:

FAULT SEGMENTATION

FAULT RUPTURE LENGTH

FAULT RUPTURE AREA

RUPTURE DISPLACEMENT

SEISMIC MOMENT AND MOMENT MAGNITUDE

MAGNITUDE ESTIMATES USING DIFFERENT TECHNIQUES: AN EXAMPLE FROM PAINTBRUSH FAULT*

	Mw
RUPTURE LENGTH	6.71
RUPTURE AREA	6.72
MAXIMUM DISPLACEMENT	6.72
SEISMIC MOMENT	6.77

*FAULT DIMENSION PARAMETERS ARE PRELIMINARY HIGHER END VALUES OF FIELD OBSERVATIONS

MAXIMUM MAGNITUDE EARTHQUAKES: SOURCE AREAS

MAGNITUDES WILL BASED ON:

HISTORICAL SEISMICITY

THRESHOLD MAGNITUDE FOR SURFACE FAULTING IN THIS AND ANALOGOUS TECTONIC SETTING

EARTHQUAKE RECURRENCE

DATA:

HISTORICAL SEISMICITY

PALEOSEISMIC RECURRENCE INTERVAL

FAULT SLIP RATE

RECURRENCE MODELS:

UNIFORM (QUASI-PERIODIC) RECURRENCE

TEMPORAL CLUSTERING

POISSON

DISPLACEMENT: QUATERNARY SURFACE FAULTS

ASSESS AMOUNT AND LOCATION OF SURFACE DISPLACEMENT FOR PRIMARY AND SECONDARY FAULTS

METHODS:

DETAILED FAULTING PATTERNS FROM SITE MAPPING

PALEOSEISMIC ESTIMATES OF SLIP PER EVENT

ANALOGY TO HISTORICAL BASIN AND RANGE SURFACE RUPTURES

FAULT KINEMATIC INDICATORS

EMPIRICAL RELATIONS BETWEEN Mw AND MAXIMUM AND AVERAGE DISPLACEMENT, WIDTH OF ZONE OF FAULTING, LENGTH OF SECONDARY FAULTS, AND AMOUNT OF SECONDARY DISPLACEMENT

5

DOE-NRC TECHNICAL EXCHANGE ON SEISMIC HAZARDS ASSESSMENT

GROUND MOTION ASSESSMENT

Paul Somerville - M&O

GROUND MOTION ASSESSMENT

Purpose: To translate source characterization into ground motion consequences

Methodology: Attenuation relations
Site effect adjustments

Validation: Use site ground motion data and relevant analogous data

GROUND MOTION ASSESSMENT

- Source and Path Effects
- Site Effects

METHODOLOGY

ATTENUATION RELATIONS

Describe peak acceleration, peak velocity and response spectral ordinates as a function of:

- Magnitude
- Distance
- Style of Faulting
- Site Conditions
- Earthquake or Explosion

METHODOLOGY

SITE EFFECT ADJUSTMENTS

Adjustments to Attenuation Relations for:

Shallow Velocity Gradient and Q
Variation with Depth below Surface
Topographic Effects (surface facilities)

GROUND MOTION ATTENUATION RELATIONS

EMPIRICAL METHODS

Mostly based on regression analysis of analogous recorded data

Validate by checking against site data

NUMERICAL METHODS

Can incorporate site data:

- empirical Green's function summation method
- empirical source function summation method

or parameters can be evaluated using site data:

- random process method

WEIGHTING OF EMPIRICAL AND NUMERICAL METHODS BY:

Degree of Use of Site Specific Data

Degree of Validation against site-specific data or relevant analogous data

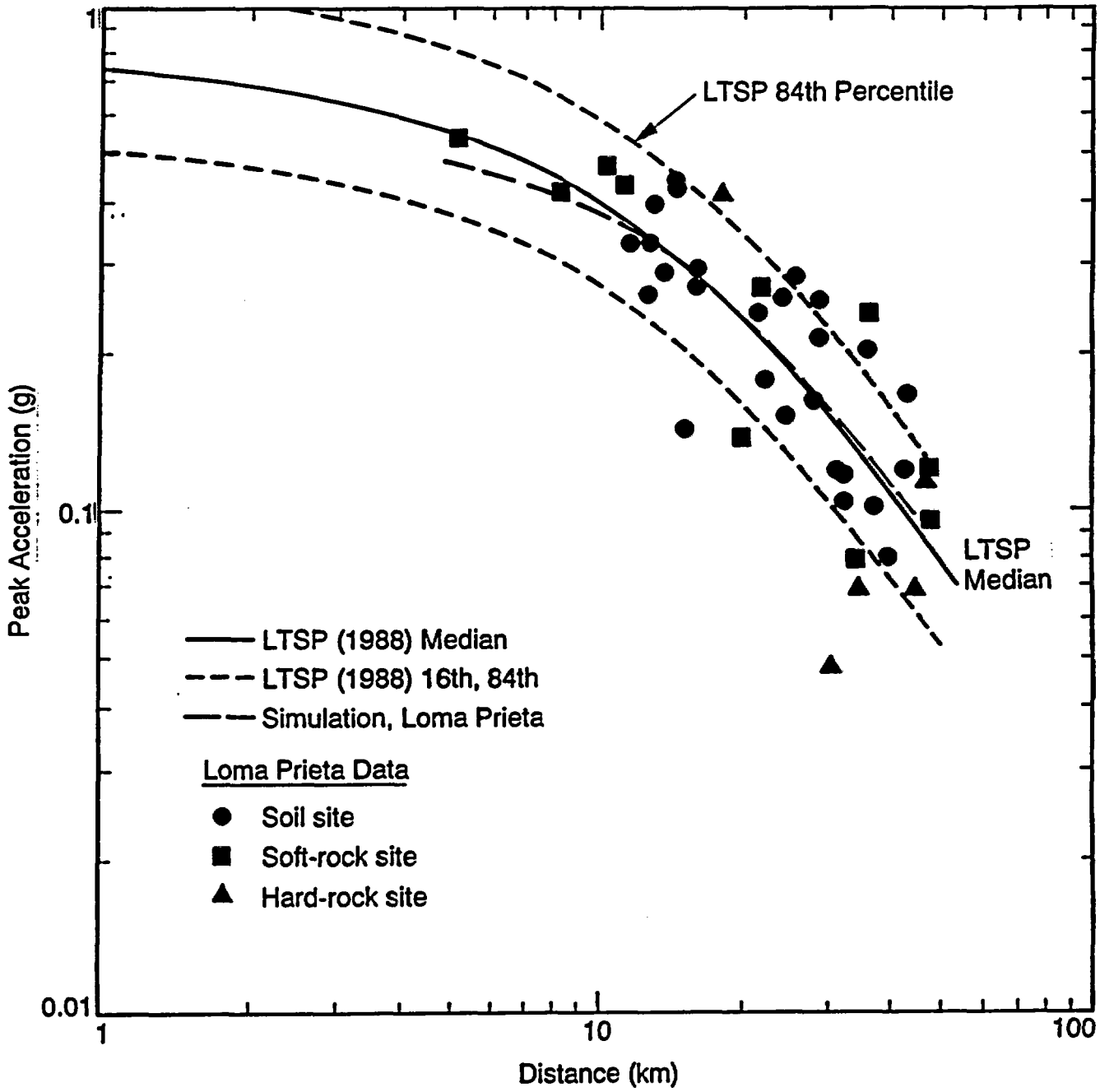
VALIDATION OF GROUND MOTION EVALUATIONS

Direct Validation against site-specific data

Indirect Validation against relevant analogous data

Test of the LTSP (1988) Attenuation Relation

Comparison with Peak Horizontal Accelerations from the 1989 Loma Prieta Earthquake



LTSP - long term seismic program

SPECIFIC SOURCE AND PATH ISSUES TO BE EVALUATED

Dependence of ground motion on style of faulting

- geometrical effects
- lower stress drops of normal faulting events

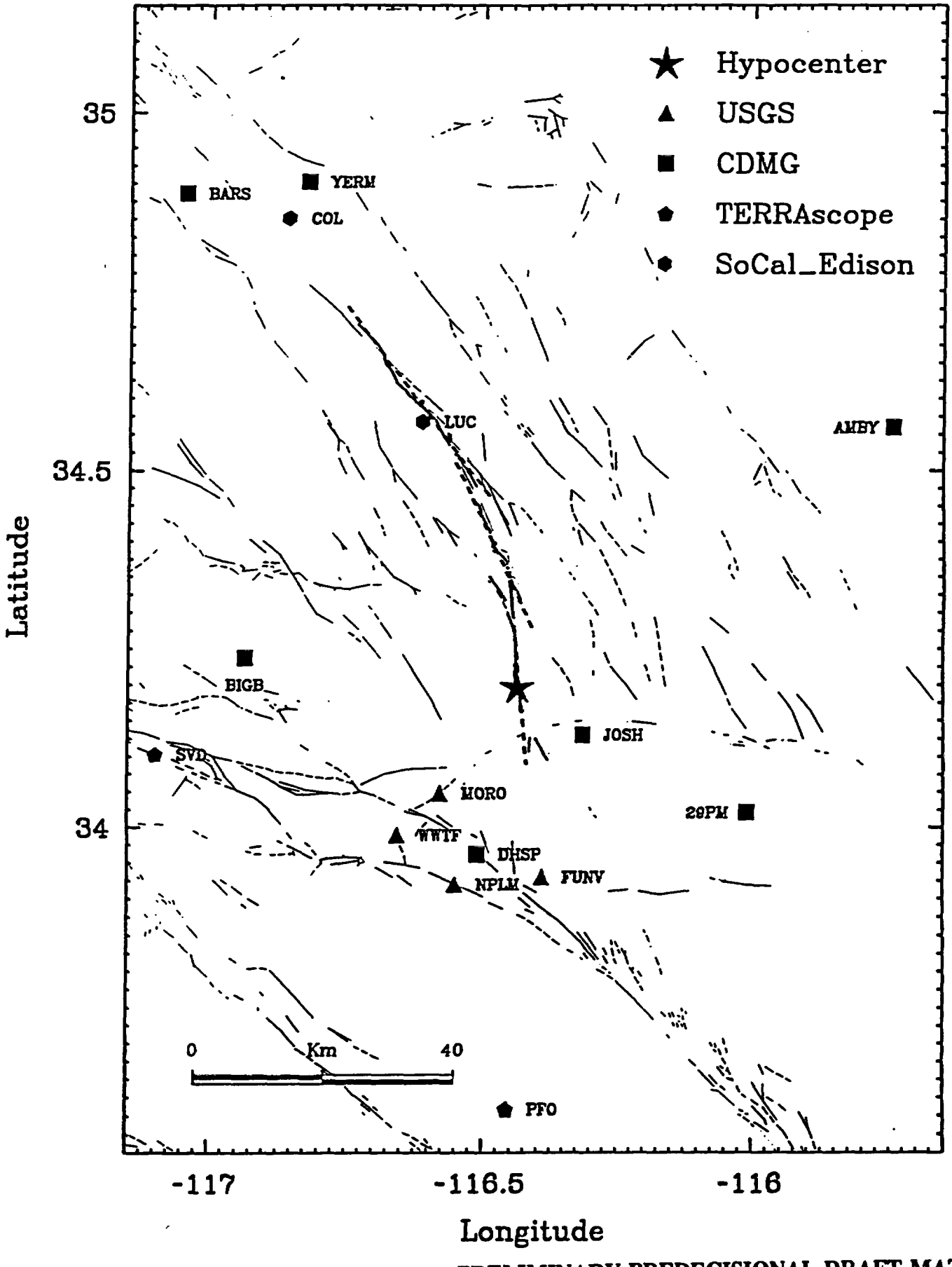
Vertical Ground Motions - differ from the Horizontal in:

- spectral shape
- distance dependence
- dispersion

Rupture Directivity Effects - adjustments for close distances

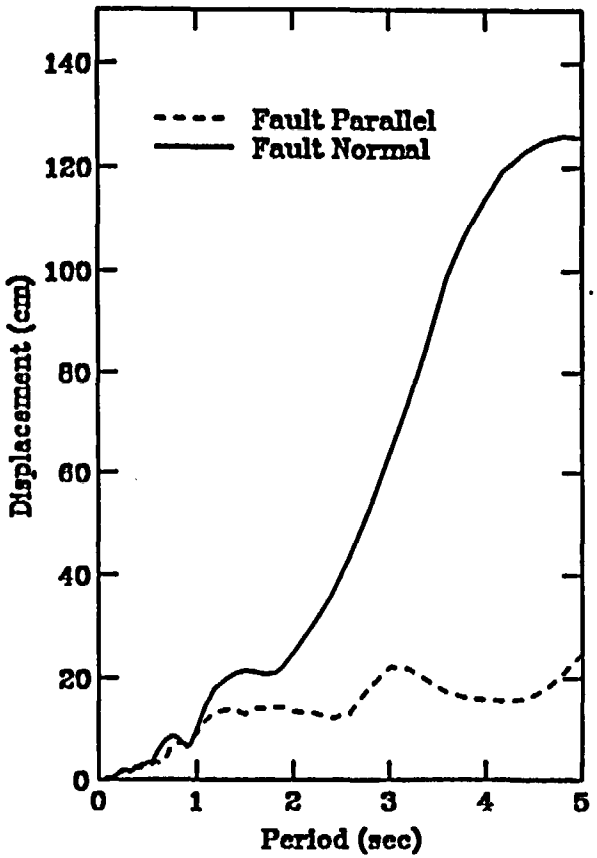
- dependence on style of faulting
- difference between fault normal and fault parallel motions

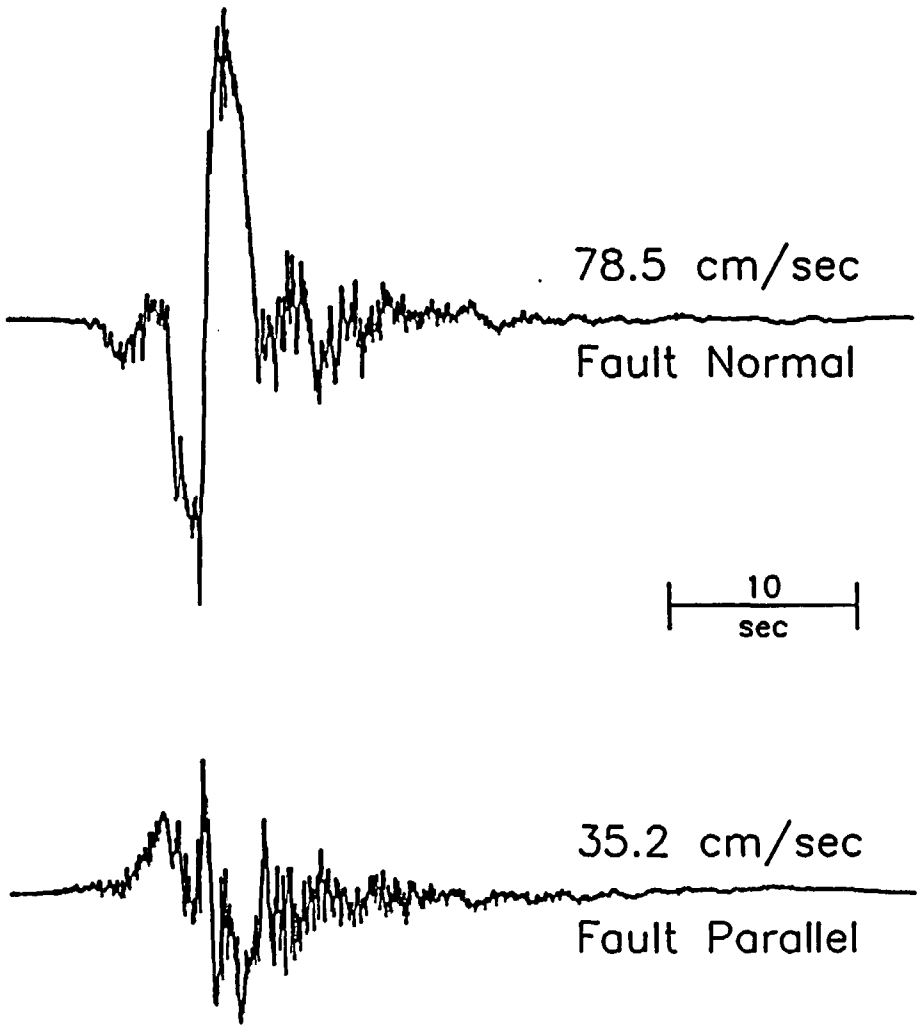
Strong Motion Stations



PRELIMINARY PREDECISIONAL DRAFT MATERIAL

Landers Earthquake, 28 June 92, Lucerne Ground Displacement





SITE EFFECT ADJUSTMENTS

Shallow Velocity Gradient and Q:

ratio of alluvial to rock motions

Variation with Depth below Surface:

ratio of downhole to surface motions

Topographic effects:

ratio of ridge crest to level ground motions

SITE EFFECT ADJUSTMENTS

Empirical methods - use motions recorded at site

Numerical methods - use synthetic seismograms validated against site data or relevant analogous data, to extrapolate to site-specific conditions

- 1D layer propagator method
- 2D or 3D ray theory
- 2D or 3D finite difference

GROUND MOTION DATA RECORDED AT YUCCA MOUNTAIN SITE

Earthquake and Explosion Sources

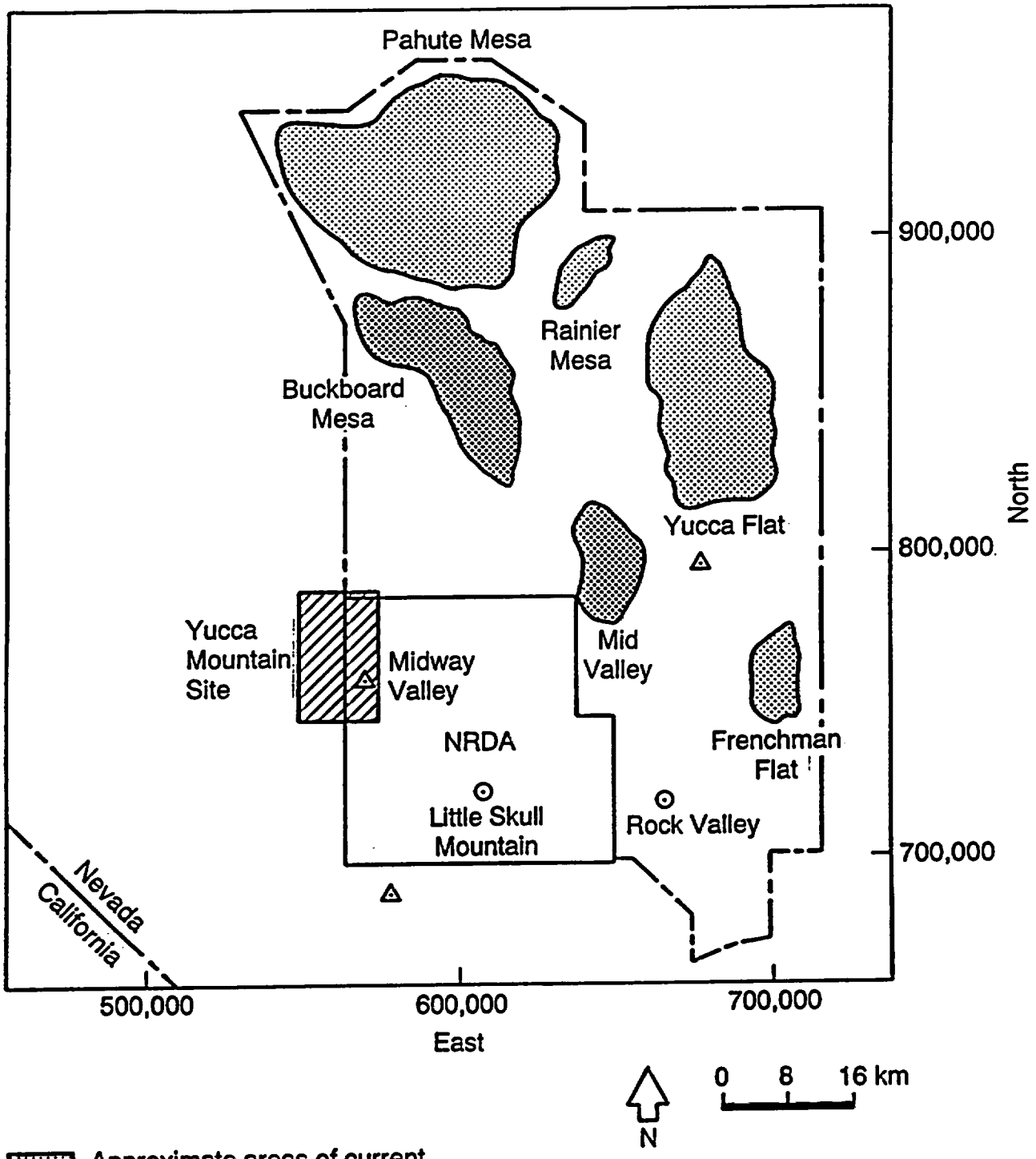
Surface and Downhole Sites

Soil and Rock Sites

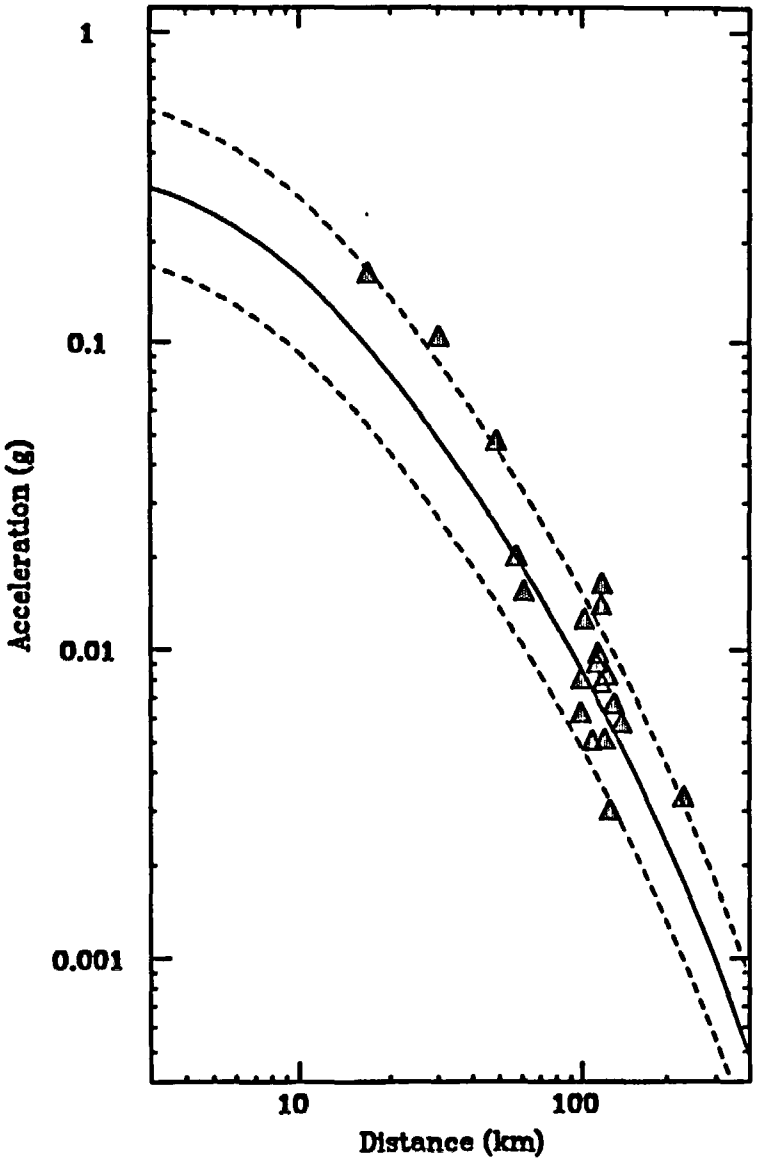
EXAMPLES OF REGION- AND SITE-SPECIFIC DATA FOR DIRECT VALIDATION

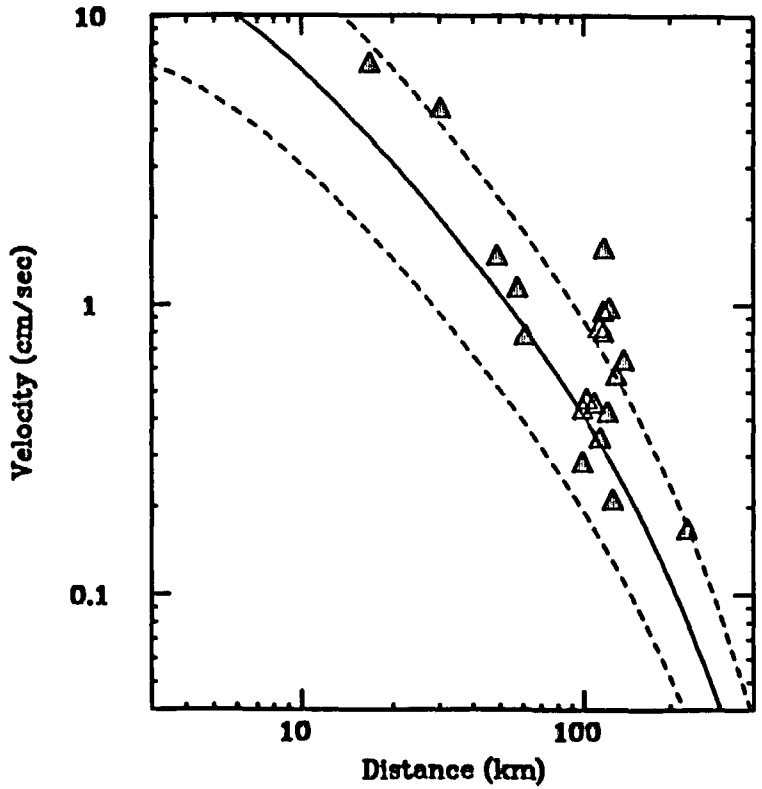
1. Attenuation of Ground Motion:

   Local Earthquake e.g., Little Skull Mountain Earthquake



29 June 1992, Little Skull Mountain Earthquake, M=5.56



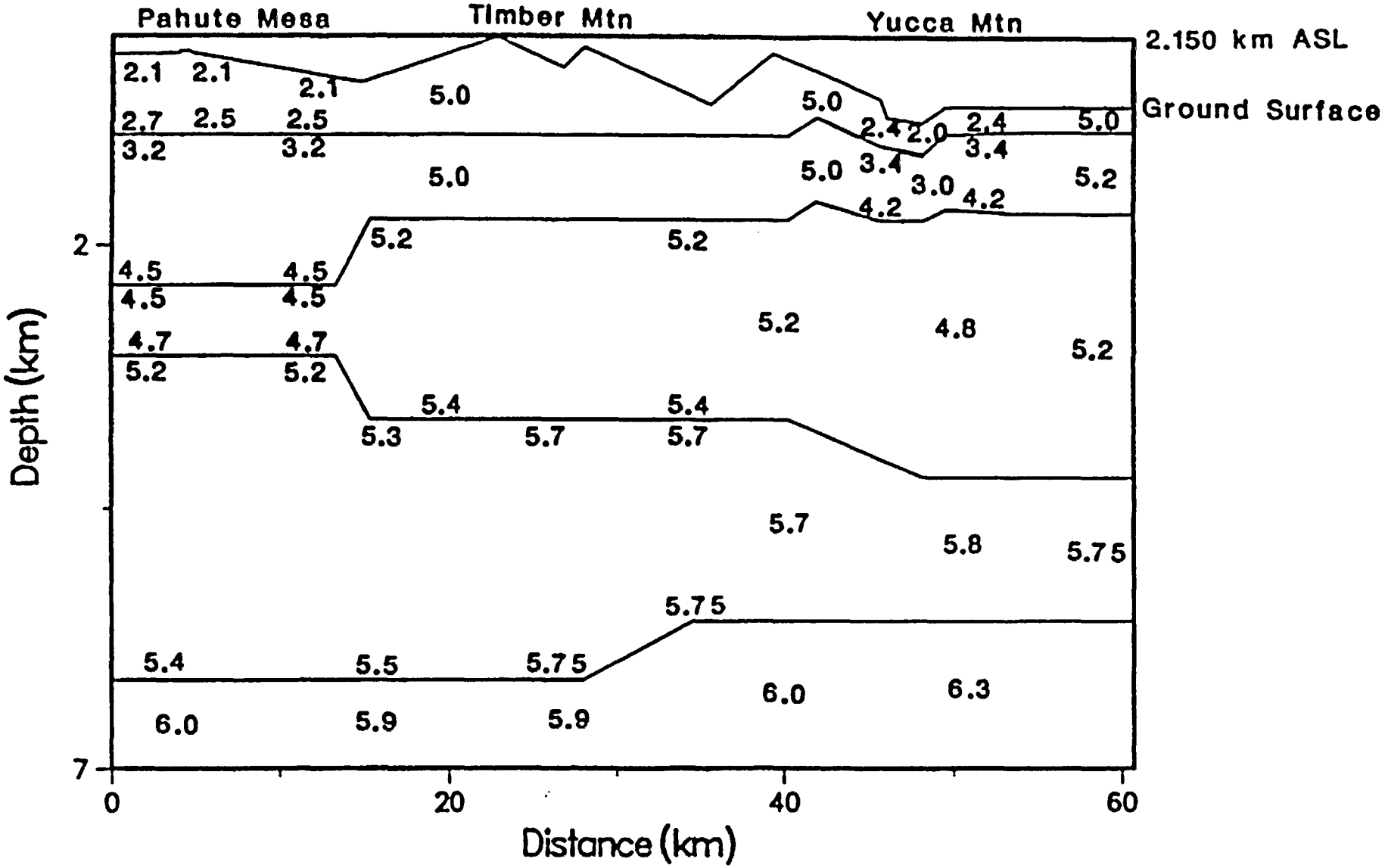


PRELIMINARY PREDECISIONAL DRAFT MATERIAL

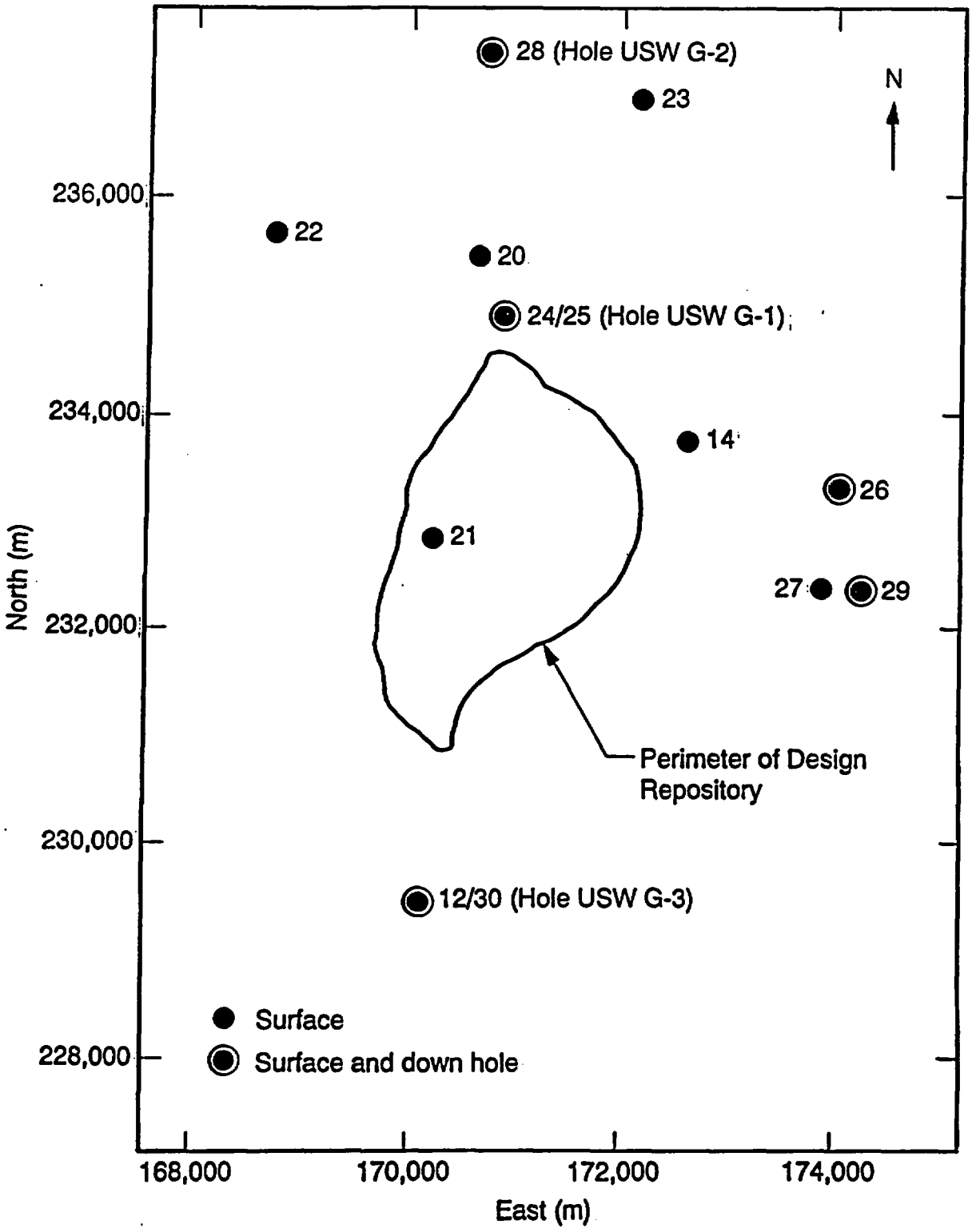
EXAMPLES OF REGION- AND SITE-SPECIFIC DATA FOR DIRECT VALIDATION

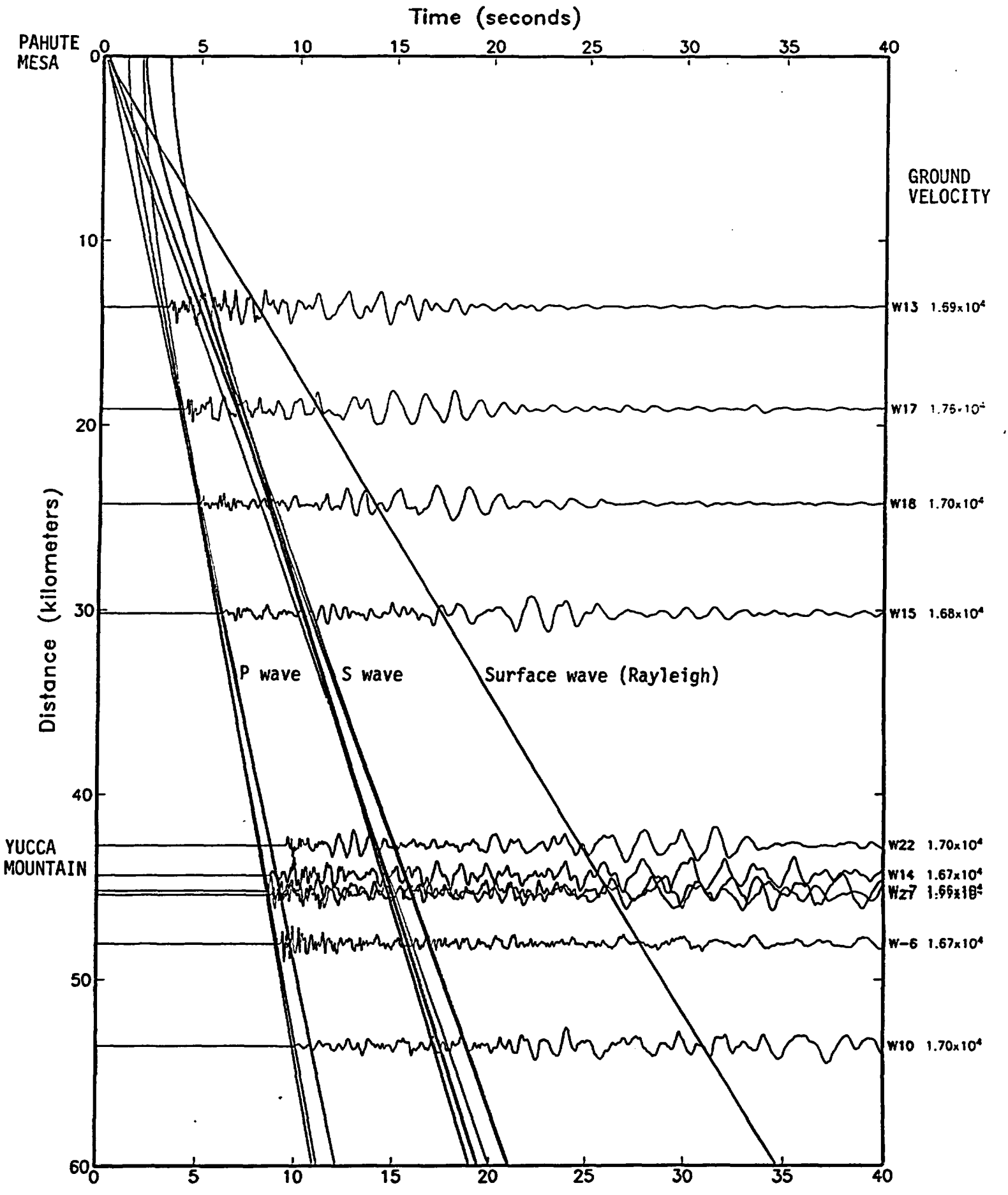
2. Resolution of Path and Site Effects

Source Depth Dependence of Surface Wave Excitation

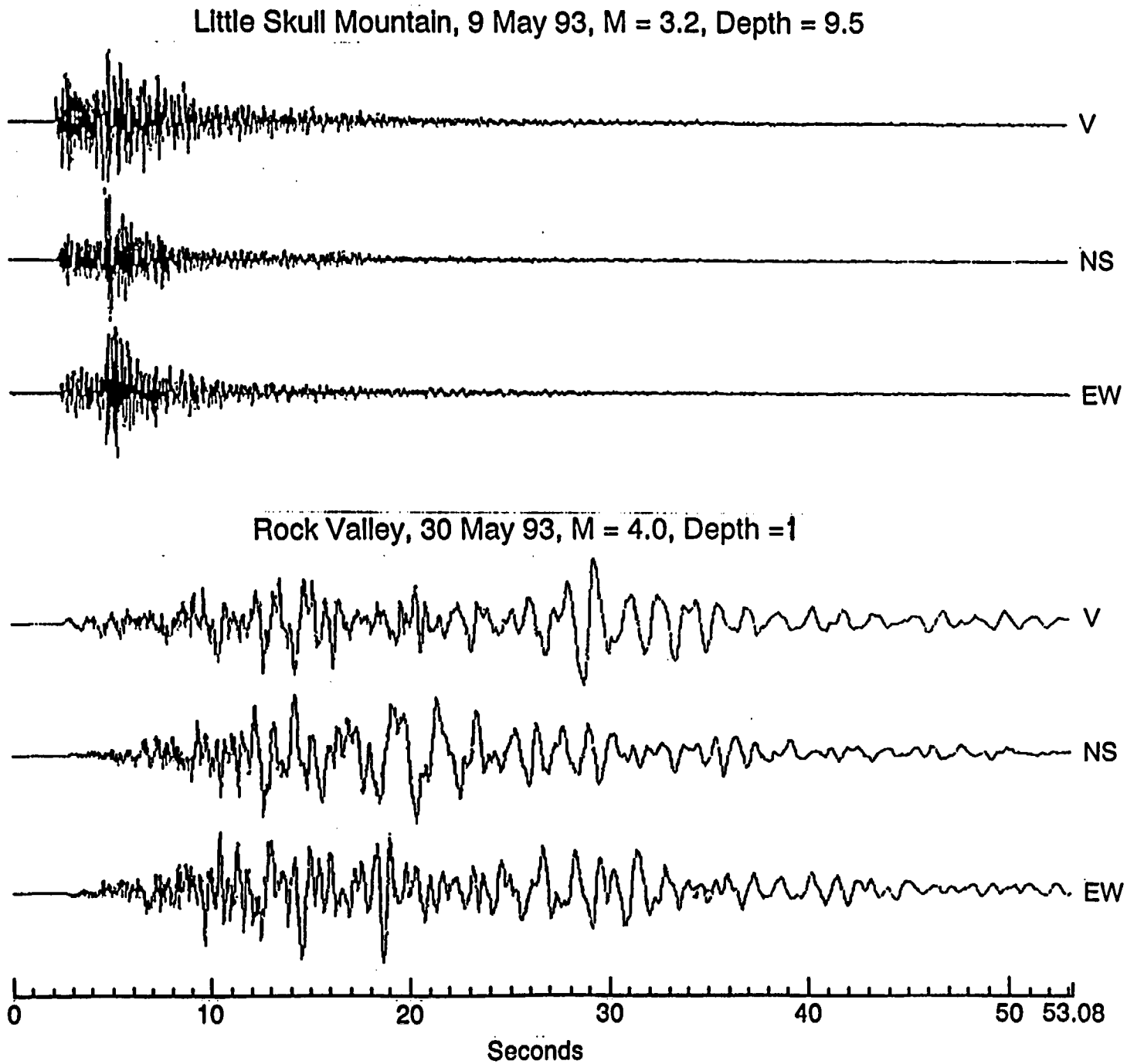


WTSI Strong Motion Recording Stations Near Yucca Mountain





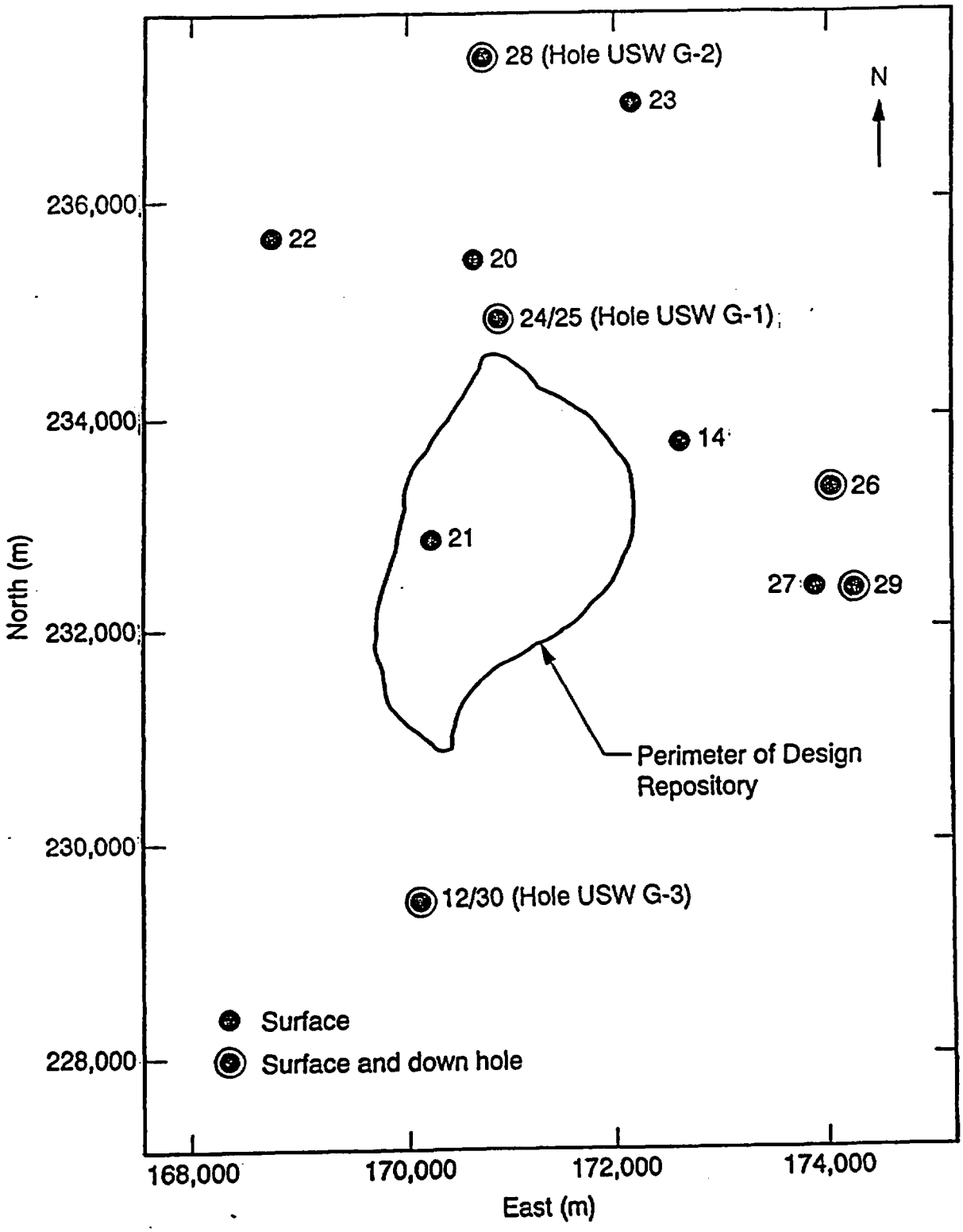
GROUND VELOCITY RECORDED AT MIDWAY VALLEY



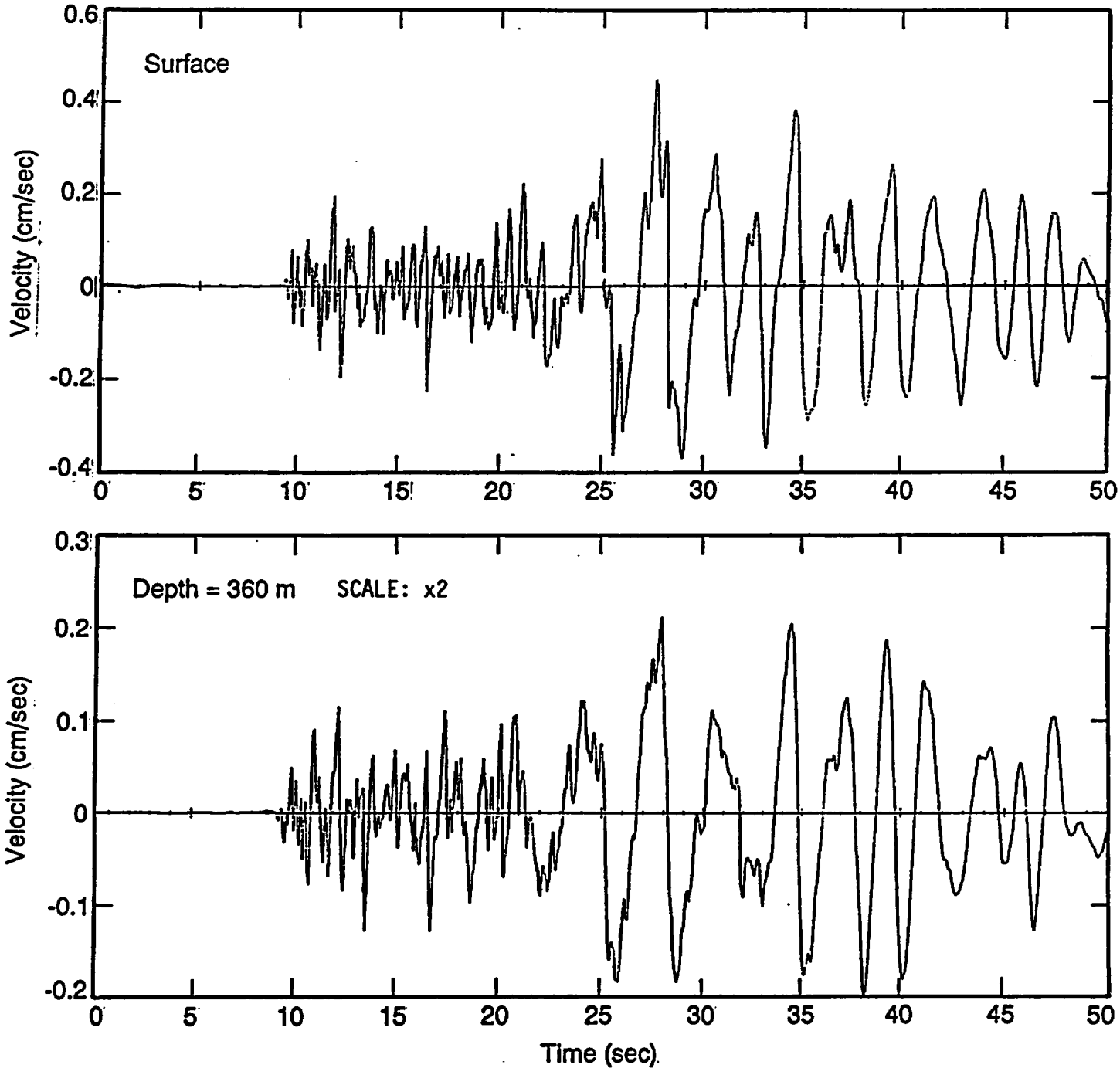
EXAMPLES OF REGION- AND SITE-SPECIFIC DATA FOR DIRECT VALIDATION

3. Variation of Ground Motion with Depth Below the Surface

WTSI Strong Motion Recording Stations Near Yucca Mountain

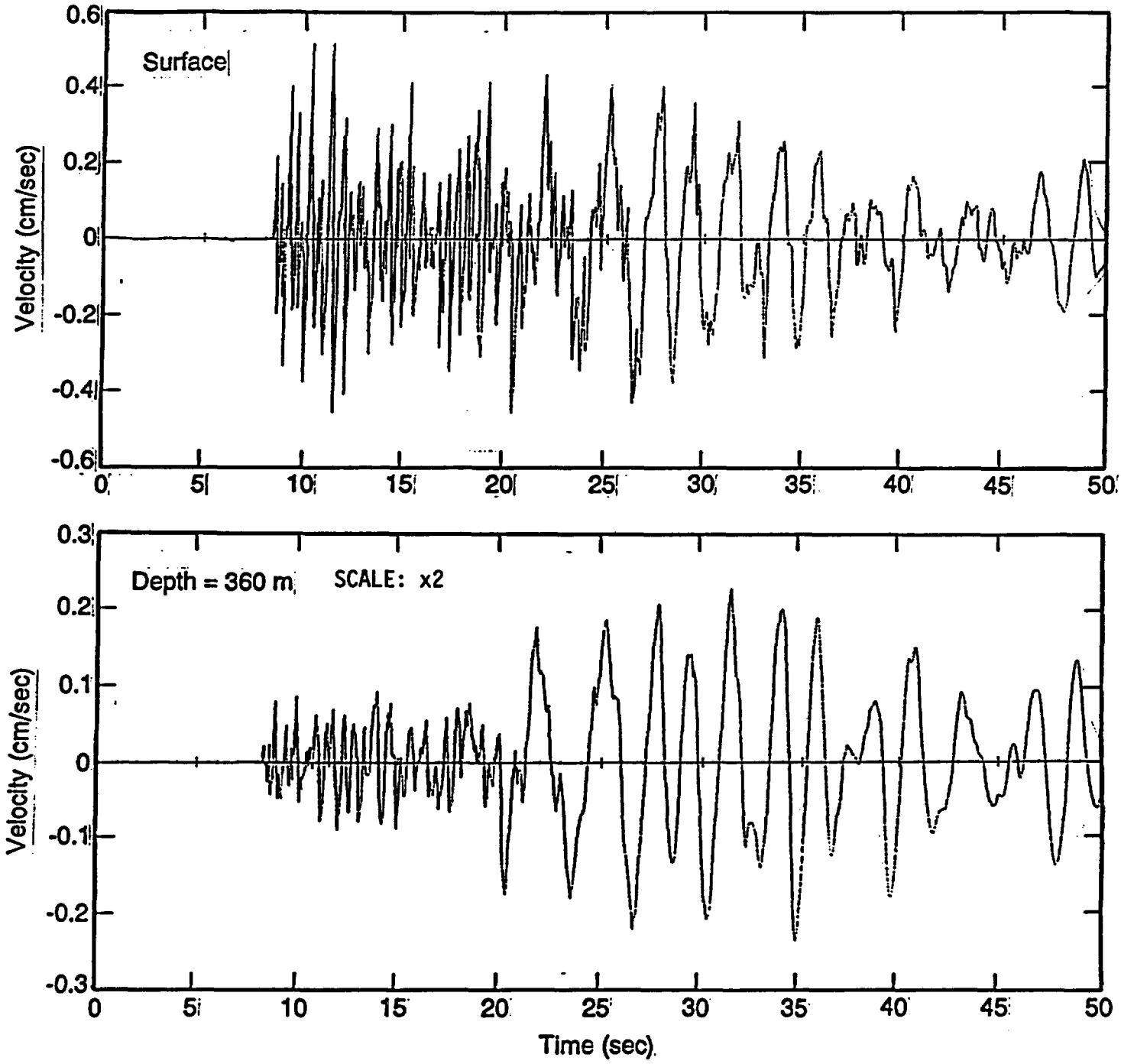


SALUT W30



USGS Well 3

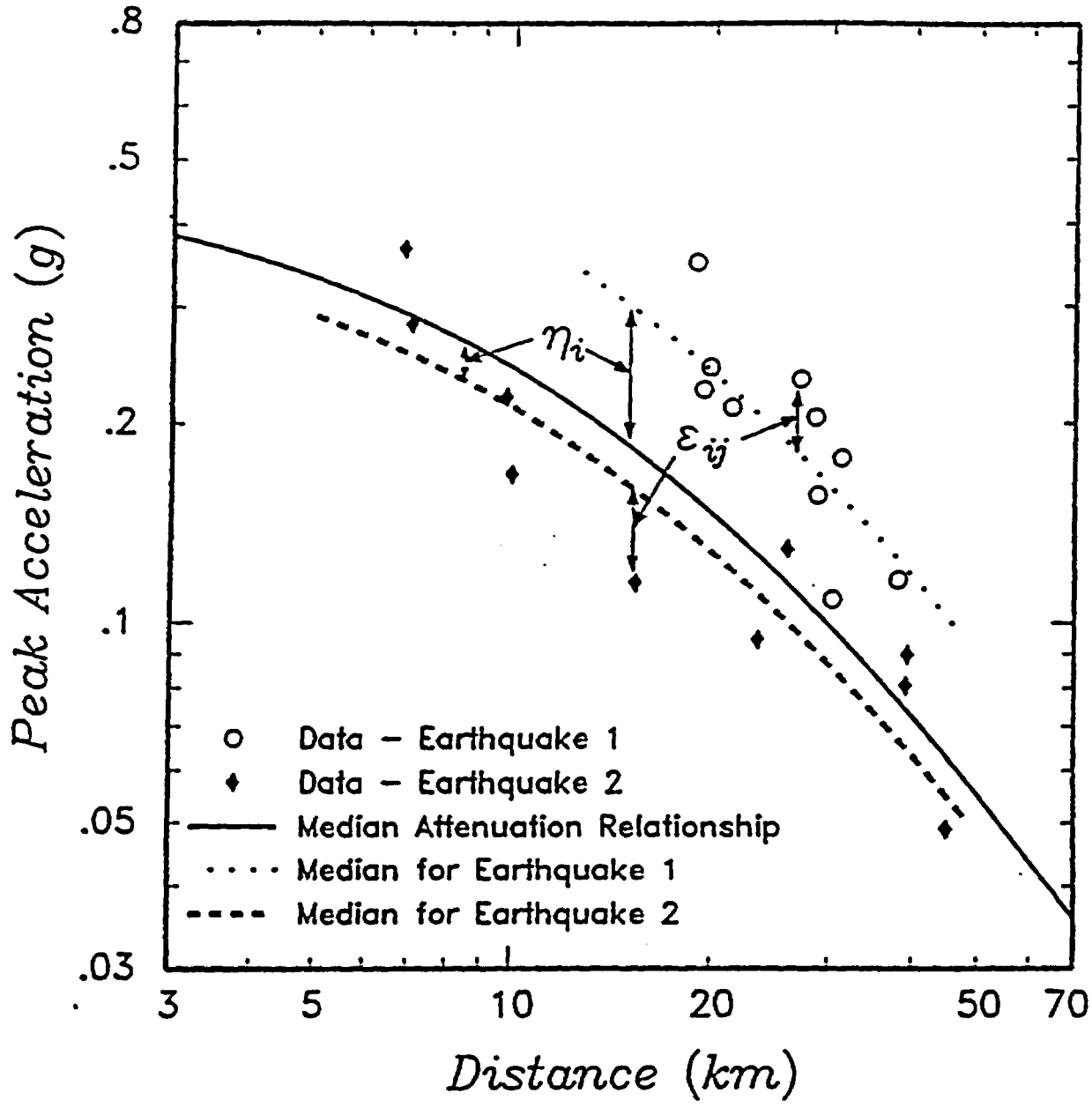
SALUT W25



VARIABILITY IN EMPIRICAL GROUND MOTION ASSESSMENTS

Inter- and Intra-Event Variability

Magnitude and Period Dependence of Variability



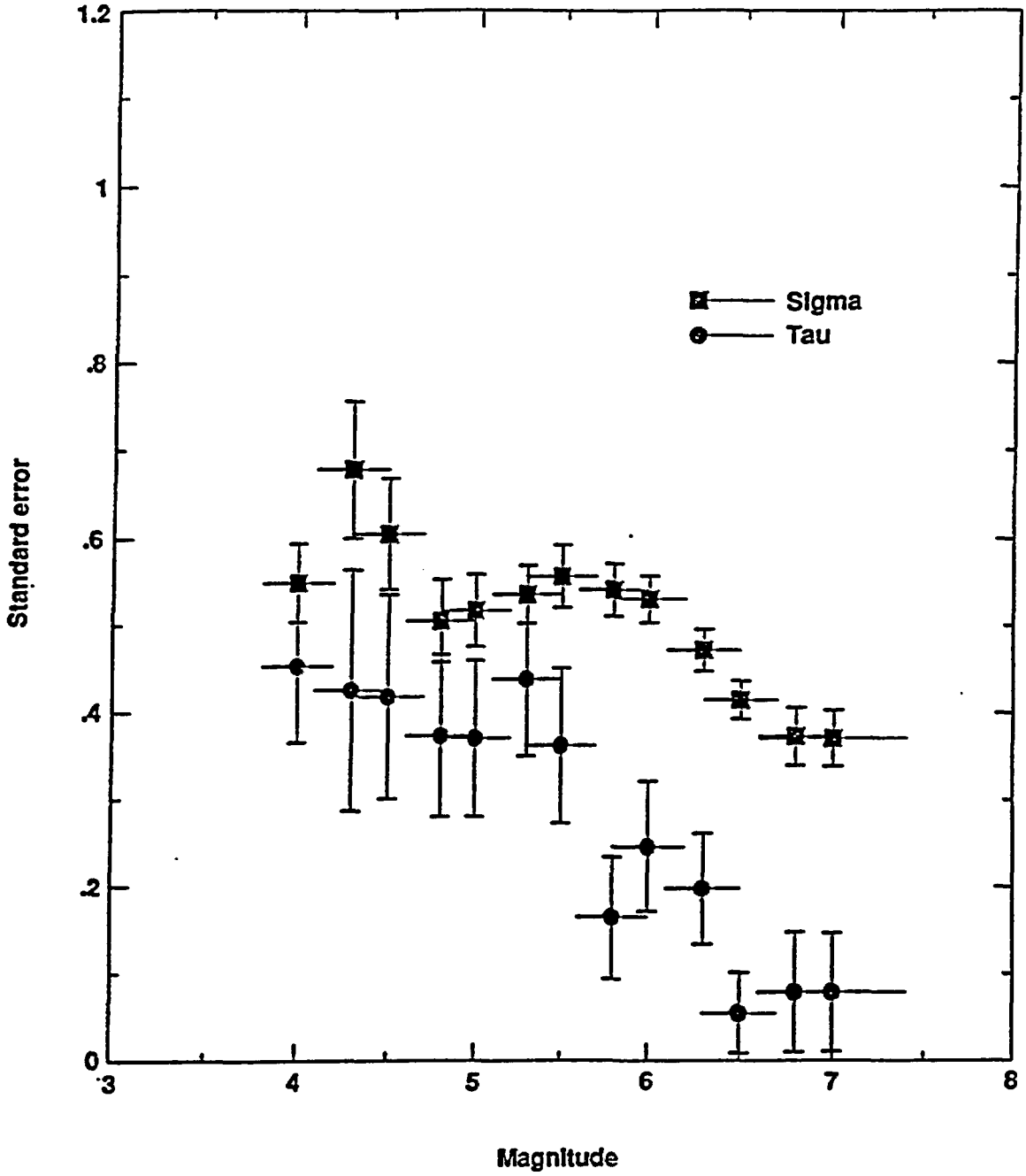


Figure WQ2-4

Interevent dispersion (τ) and intraevent dispersion (σ).

VARIABILITY IN GROUND MOTION ASSESSMENTS USING NUMERICAL METHODS

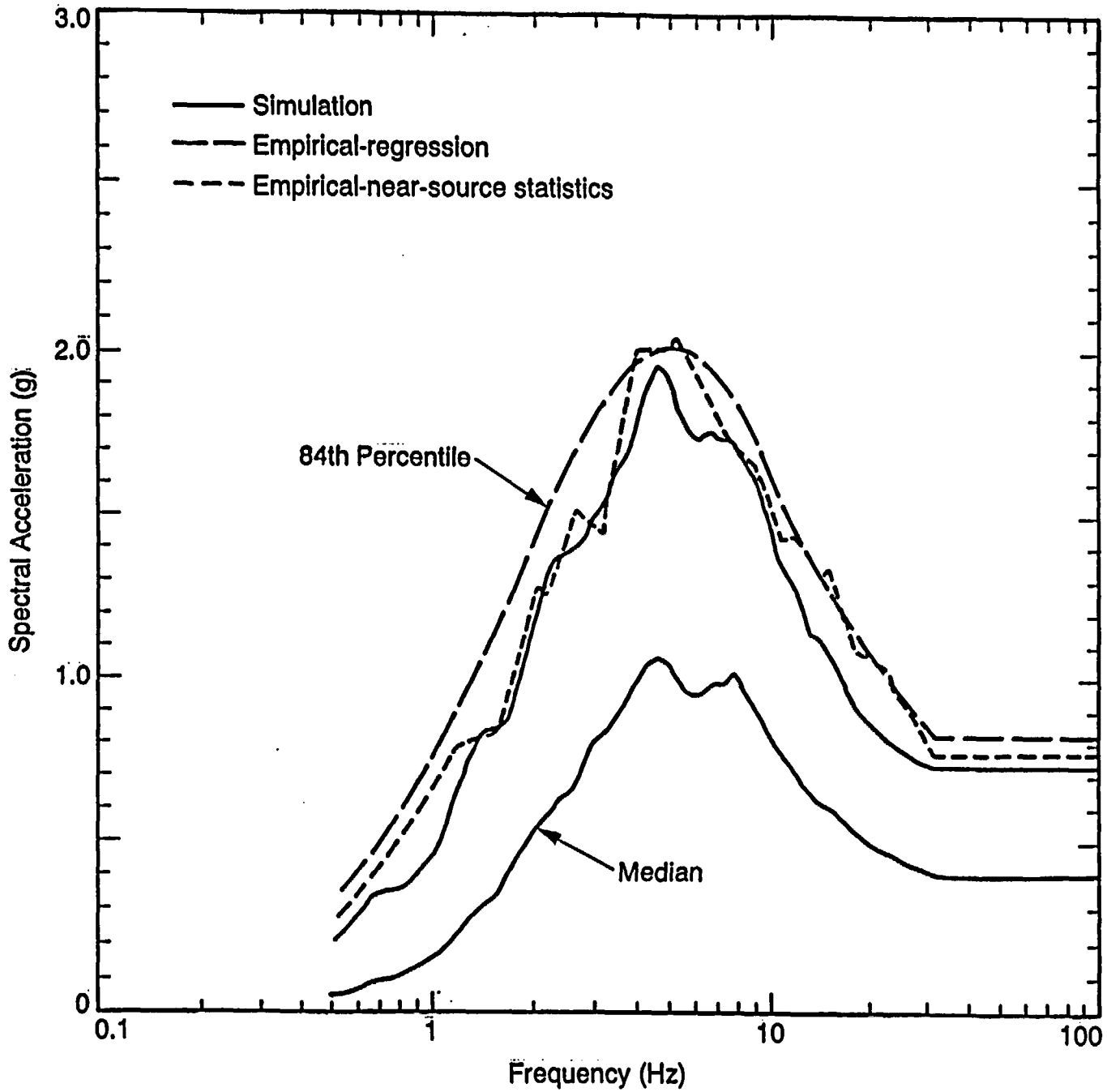
Modeling and Random Uncertainty -

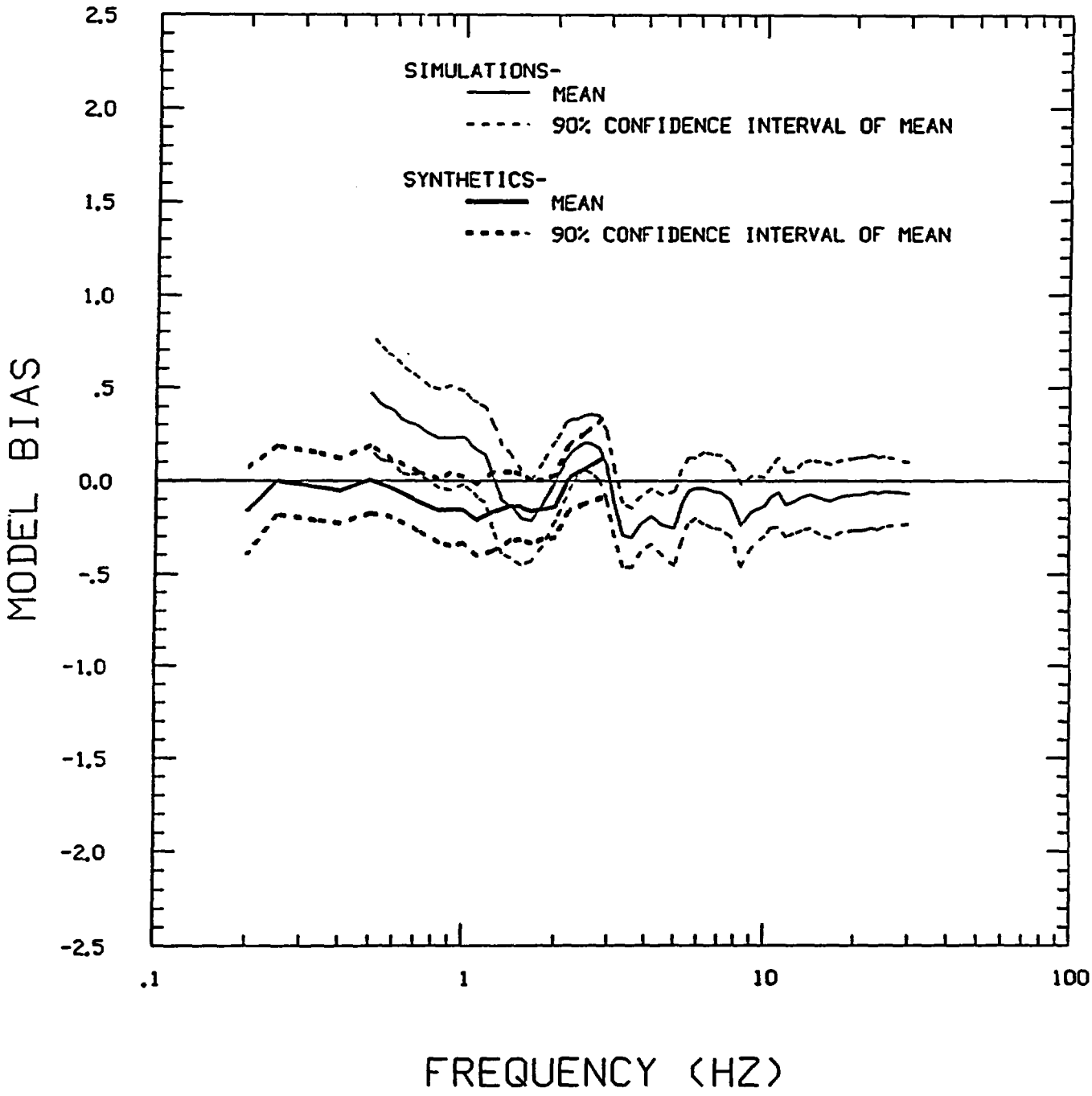
from comparison with recorded data

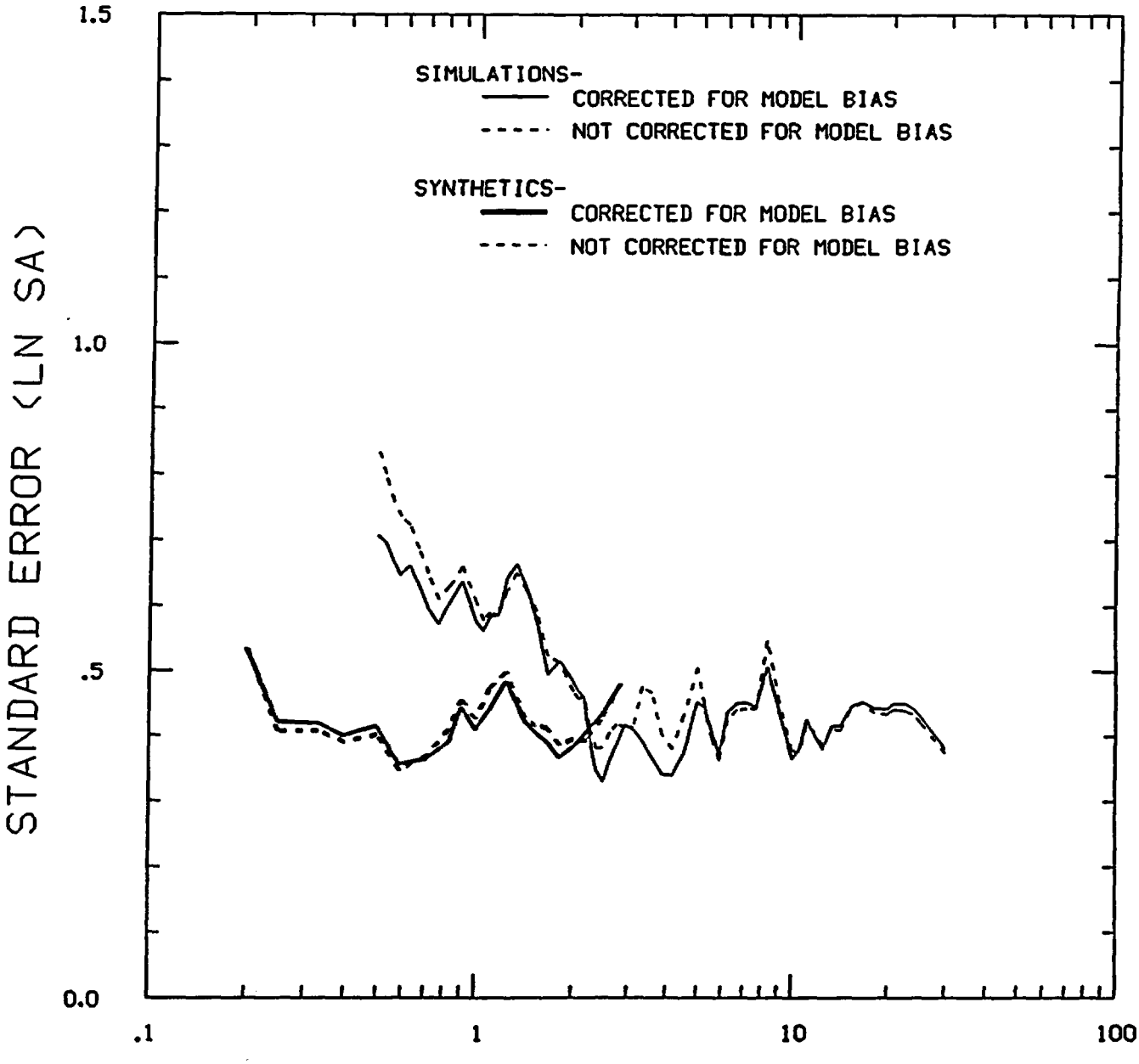
Parametric Uncertainty -

from uncertainty in source, path and site effects at Yucca Mountain

Diablo Canyon L.T.S.P.







SUMMARY OF GROUND MOTION ASSESSMENT

METHODOLOGY:

Attenuation Relations
Site Effect Adjustments

- Empirical Methods
- Numerical Methods

VALIDATION:

Uses site ground motion data and analogous data

UNCERTAINTY:

Explicitly treated

FESSP

Fission Energy & Systems Safety Program

DOE-NRC TECHNICAL EXCHANGE ON SEISMIC HAZARD ASSESSMENT

Seismic Hazard Calculation and Treatment of Randomness and Uncertainty

Jean B. Savy

Fission Energy Systems Safety Program
Lawrence Livermore National Laboratory

November 17, 1993

The Seismic Hazard Assessment provides the results necessary for determination of a set of seismic design parameters

- A ground motion value whose probability of exceedance is determined. (Probabilistic method)
  - — Hazard Curves
  - — Uniform Hazard Spectra
  - — Site specific spectra scaled to safety performance goal seismic hazard level
  - — Site specific deterministic motions from controlling seismic sources
- The contributors to the hazard are identified, randomness and uncertainty quantified and sensitivity analyses performed.

General Goals of the Seismic Hazard Methodology

1. Experience based

   - Use experience gained from recent methodology development and applications reviewed and accepted by NRC.

2. Data - Driven

   - Incorporate all relevant data from site characterization program.

   - Expand data collection if need indicated.

3. Issue focused

   - Address issues specific to YM project (e.g., pre- and post closure)

General Goals of the Seismic Hazard Methodology *(cont'd)*

4. Proper treatment of randomness and uncertainty

   - Specific evaluations of various sources of uncertainty. (Scientific and data)

5. Flexible

   - Accommodate scientific interpretations consistent with scientific understanding and data.

6. Includes Sensitivity Analysis

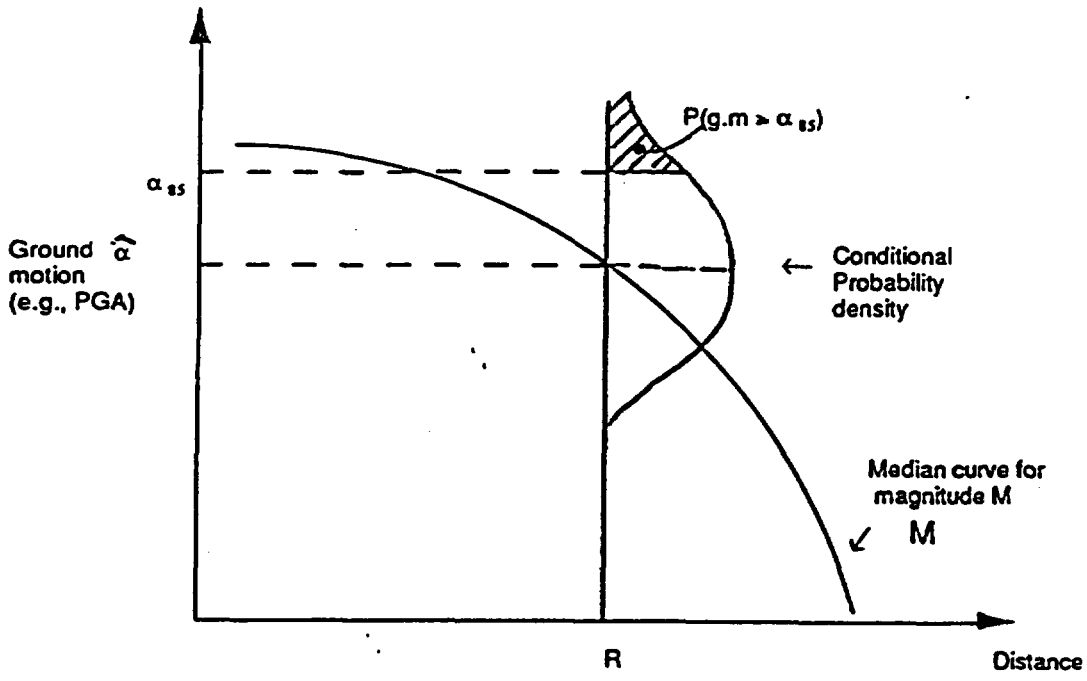
   - Identify important contributors to uncertainty, helps set priorities for collection of additional data that could reduce uncertainty.

7. Documentation

   - Credibility of the results relies on demonstrated validity of input data which in turn depends on documentation, traceability, quality assurance.

The Probabilistic Seismic Hazard Model

1. <u>Attenuation relationships</u> predict the ground motion at the site when the location, type and magnitude of the earthquake is known. (M, R)



- Given M & R, the actual value of ground motion is not known with certainty, due to random uncertainty; the attenuation relationship gives the conditional probability density of ground motion.

- For example: median gm = $\hat{\alpha}$
  85th percentile = α_{85}

PRELIMINARY DRAFT
INFORMATION ONLY

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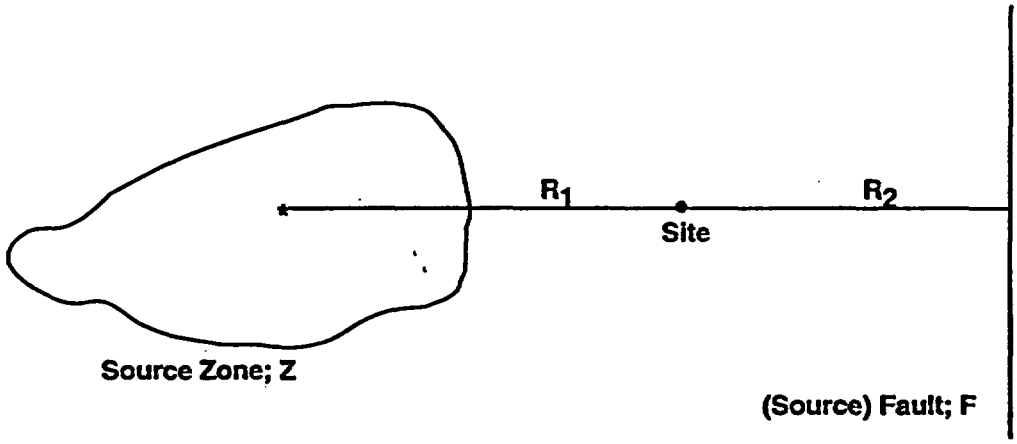
The Probabilistic Seismic Hazard Model *(cont'd)*

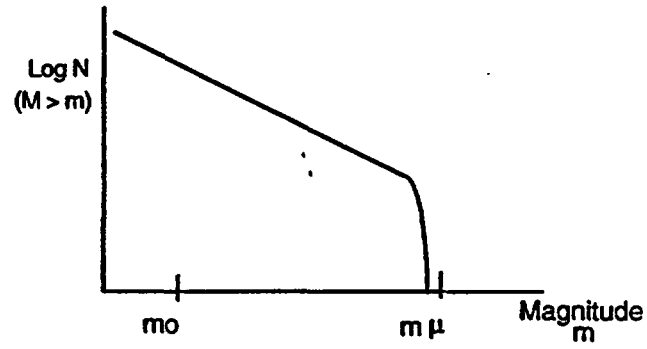
1. <u>The seismic source evaluation</u> identifies where earthquakes with common causal physical process will occur.



Areal source Z or fault F express the randomness and uncertainty in location of future earthquakes.

The Probabilistic Seismic Hazard Model *(cont'd)*

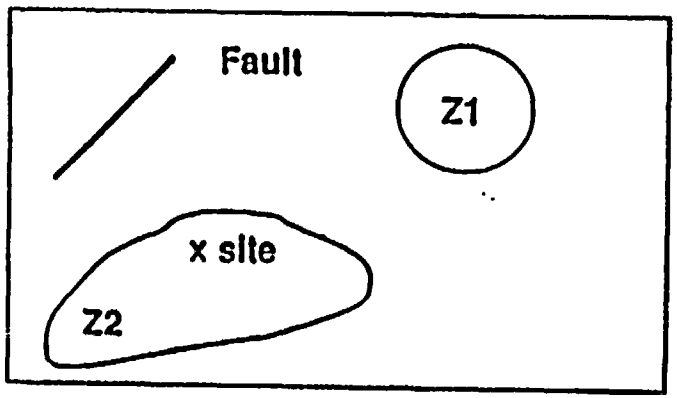
3. The recurrence relationship describes the rate of occurrence of earthquakes in a seismic source and gives the relative distribution as a function of magnitude.



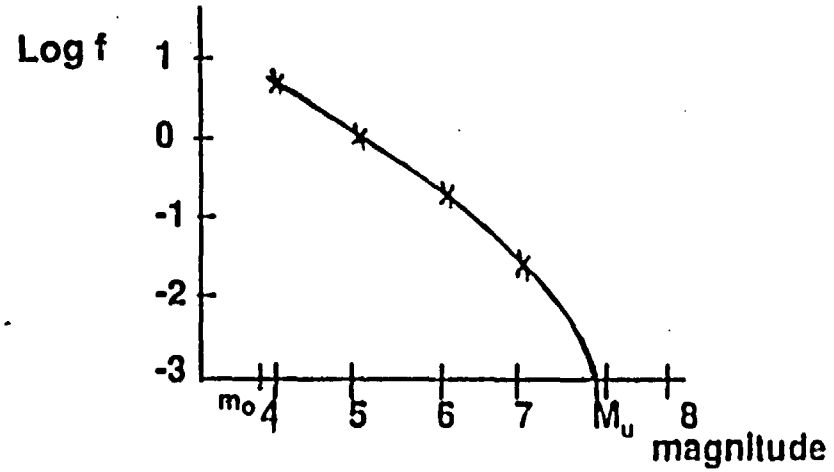
4. Regardless of magnitude or location within a source, the occurrence of events is evaluated by a recurrence relationship. The Poisson relationship is the most generally applicable, but other relationships can easily be accommodated.

Integration

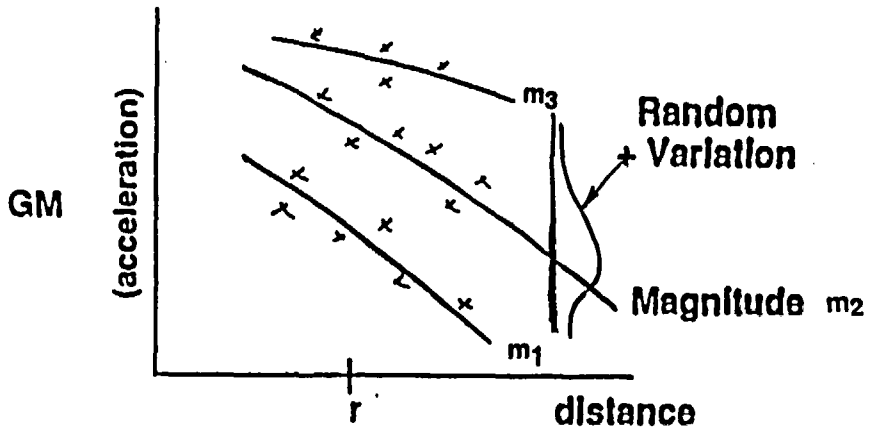
Step 1. Earthquake Locations (Zonation)



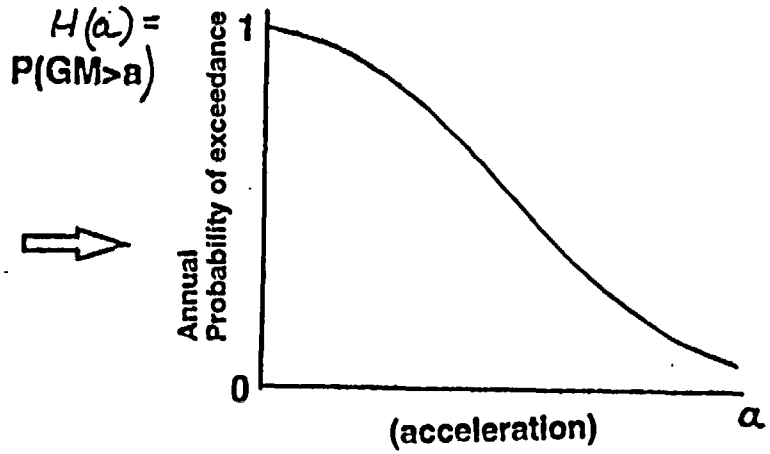
Step 2. Earthquake and Magnitude



Step 3. <u>Ground Motion description</u>
Attenuation Model



Step 4. Ground Motion Distribution $H(a)$



PRELIMINARY DRAFT
INFORMATION ONLY

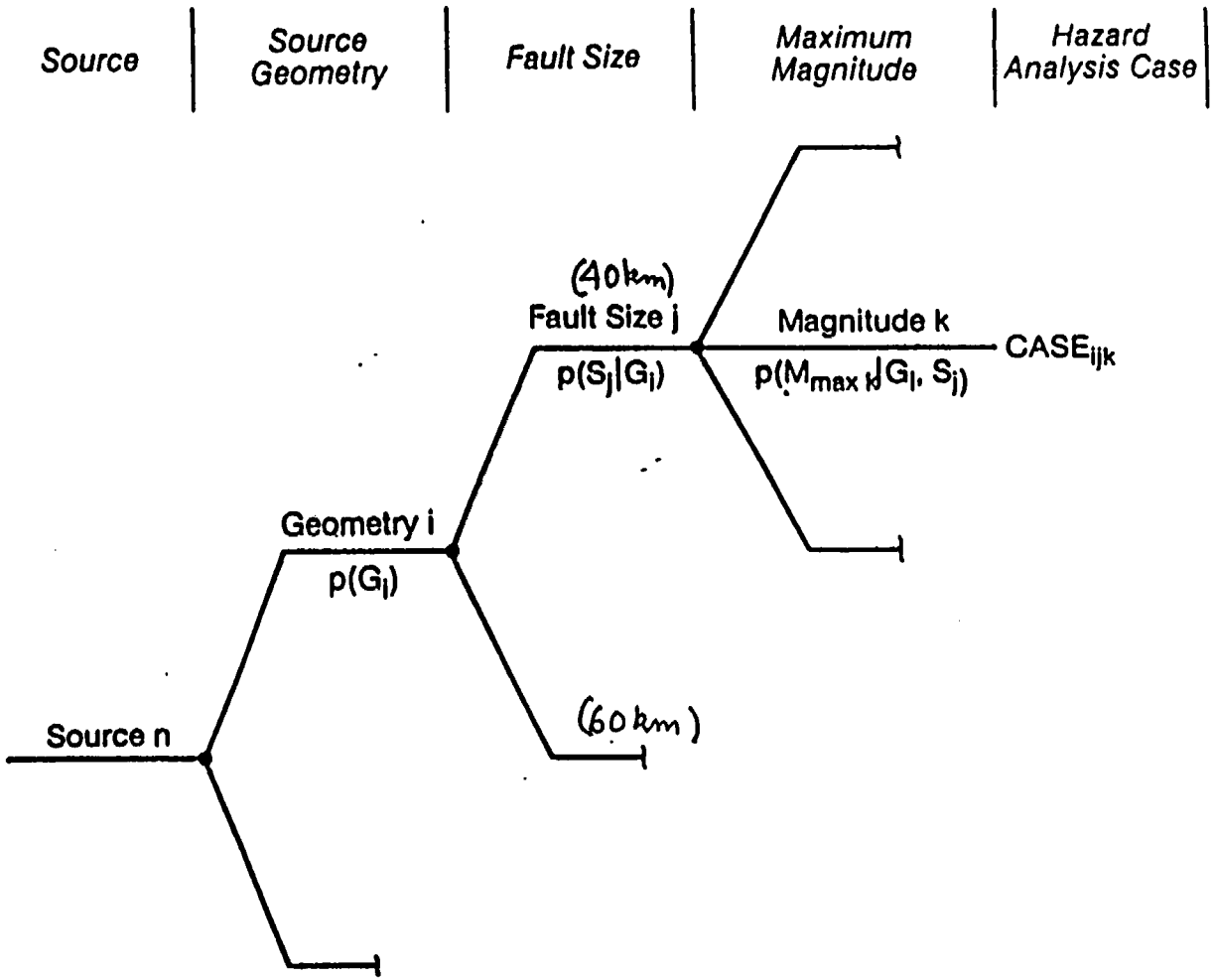
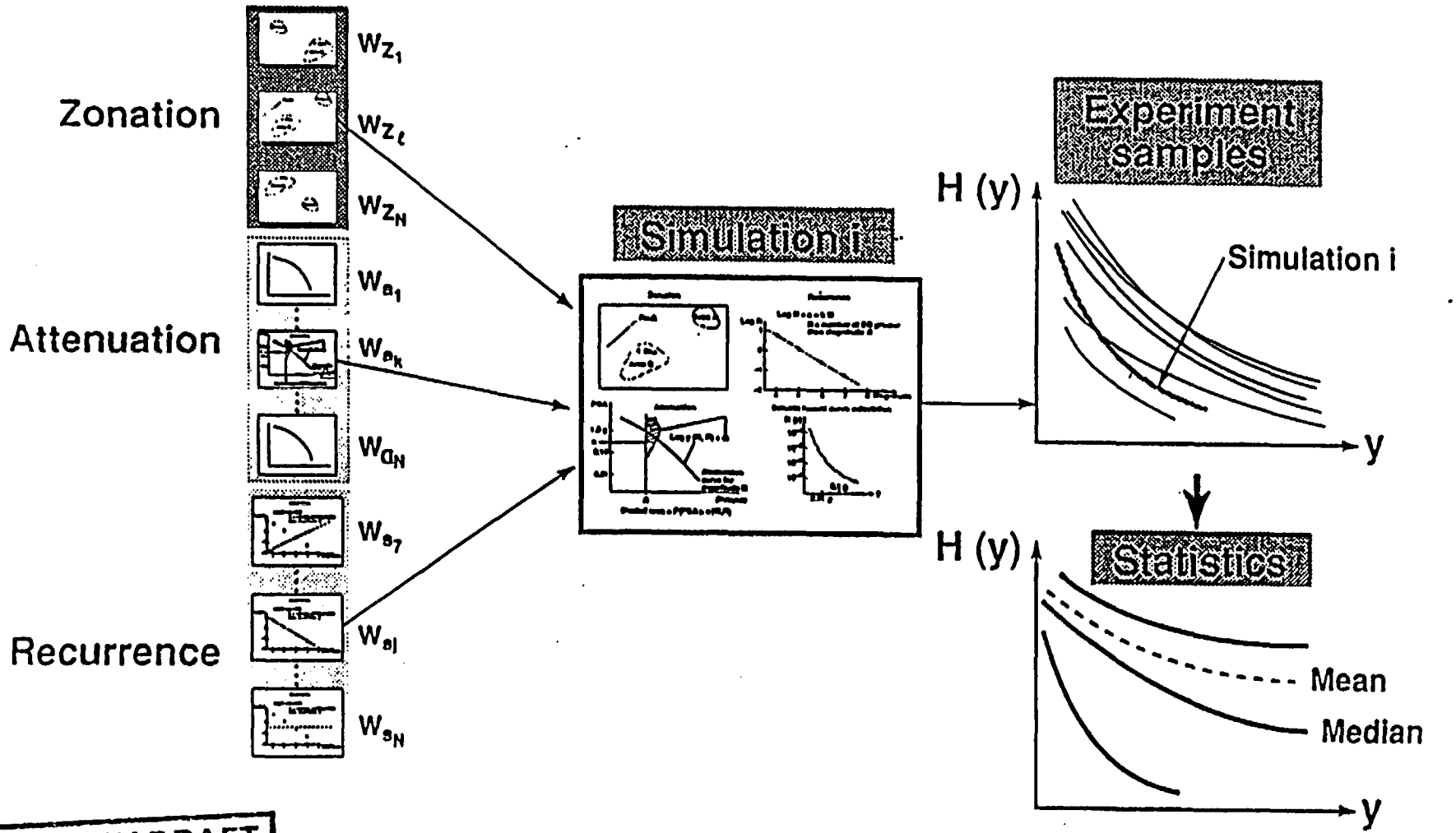


Figure D2. Typical source logic tree for expressing input interpretations and propagating uncertainties.

Fig. D3 Monte Carlo simulation to propagate uncertainties



PRELIMINARY DRAFT
INFORMATION ONLY

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Results format:

1. Hazard curves
   - — Fully reflect randomness uncertainty.
   - — Mean hazard curve and fractile determinations
   - — PGA., PSRV for a range of frequencies

2. Sensitivity to each element of the input interpretations.
   - — Seismic sources
   - — Recurrence
   - — Maximum Magnitude
   - — Ground Motion Attenuation

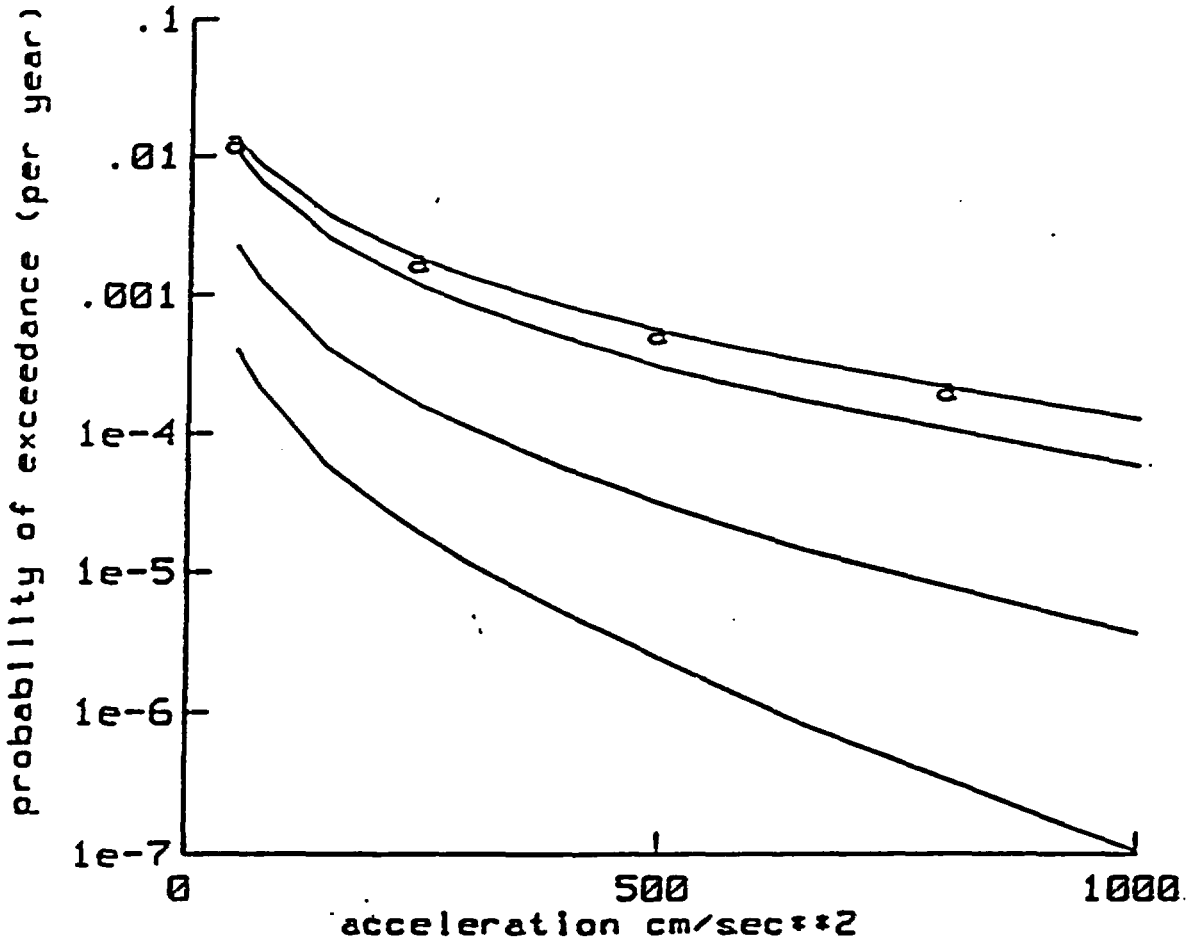

Figure E1-2 **Illustration of PSHA Output Based on the Ground Motion Parameter PGA Showing Envelopes of the 15th, 50th, Expected Values and 85th Percentiles of the Seismic Hazard, SH(g), Uncertainty Distributions**

DOE-NRC TECHNICAL EXCHANGE
ON
SEISMIC HAZARDS ASSESSMENT

FAULT DISPLACEMENT HAZARD

KEVIN J. COPPERSMITH
GEOMATRIX CONSULTANTS, INC.

NOVEMBER 17, 1993

FAULT DISPLACEMENT HAZARD

Description of Hazard

Differential fault displacement beneath/through facility associated with earthquakes.

Attributes of Methodology

Incorporates site-specific knowledge and uncertainties associated with:

1. **The locations, sizes, and rates of earthquake occurrences**

2. **The locations and amounts of displacement given earthquake occurrences**

COMPONENTS OF FAULT DISPLACEMENT HAZARD ASSESSMENTs

Seismic Source Evaluation

Defines faults that may be causes of earthquakes:

- **Probability of activity**
- **Three-dimensional geometry**
- **Sense of slip**
- **Segmentation**
- **Maximum earthquake magnitude**
- **Slip rate**
- **Recurrence intervals and rates**

COMPONENTS OF FAULT DISPLACEMENT HAZARD ASSESSMENTS (CONT'D)

Fault Rupture Evaluation

Defines the fault pattern, amount of offset, and likelihood of displacement through particular sites:

- Primary faults: earthquake generators, empirical patterns of surface rupture
- Secondary faults: empirical constraints on width of zone as function of hanging-wall/footwall, sense of slip, earthquake magnitude
- Use of detailed mapping of Yucca Mountain to assess location and behavior of minor mapped faults

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- Amount of offset: assessed from paleoseismic data, kinematic indicators of slip components, empirical relationships of primary slip and primary vs. secondary slip

- Likelihood of primary fault displacement: constrained primarily by fault slip rate: average rate of surface faulting or average seismic moment rate; paleoseismic data on recurrence intervals and slip per event will also be used

- Likelihood of secondary fault displacement: empirical relationships with amount of primary slip and earthquake magnitude

- Possibility of development of "new" faults and previously unmapped faults will be included

- Consideration to possible differences in locations and amounts of displacement at surface versus at depth

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FAULT DISPLACEMENT HAZARD

PRODUCTS

- Hazard curves of the probability of exceeding various amounts of displacement at various facility locations
- For repository, integrated probability distribution for entire repository area, which incorporates length of faulting

FAULT DISPLACEMENT HAZARD

CONCLUSIONS

- Hazard method makes full use of site-specific fault behavior and paleoseismic data developed for Yucca Mountain vicinity
- Includes empirical observations of length of faulting, amount of slip, rupture complexity, width of fault zone, amount of secondary slip
- Method explicitly includes considerations of secondary faulting, new faults, previously unmapped faults, and surface versus subsurface fault displacement
- Probabilistic approach provides for uncertainty treatment and ensures products compatible with performance assessment applications

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DOE-NRC TECHNICAL EXCHANGE
ON
SEISMIC HAZARDS ASSESSMENT

RECENT PRACTICE IN
SEISMIC HAZARD ASSESSMENT

KEVIN J. COPPERSMITH
GEOMATRIX CONSULTANTS, INC.

NOVEMBER 17, 1993

RECENT PRACTICE
IN SEISMIC HAZARD ASSESSMENT

Purpose of Discussion

- To show that the methodology represents the state-of-the-practice.

- To demonstrate that the major elements of the methodology have been used extensively in the nuclear industry.

ELEMENTS OF THE SEISMIC HAZARD ANALYSIS METHODOLOGY

- **Probabilistic:** Rate consideration, explicit uncertainty treatment
- **Site-Specific:** Versus regional, site conditions
- **Explicit Uncertainty Treatment:** Quantification of uncertainties, documentation
- **Fault Displacement Hazard:** Probability of coseismic differential fault displacement
- **Vibratory Ground Motion:** At several spectral frequencies

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ELEMENTS OF THE SHA METHODOLOGY IN OTHER STUDIES

Studies	Elements of the SHA Methodology					
	Probabilistic	Site Specific	Explicit Uncertainty Treatment	Fault Displacement Hazard	Vibratory Ground Motion	Reviewed or Endorsed by NRC
LLNL EUS	X		X		X	X
EPRI EUS	X		X		X	X
LLNL/EPRI Resolution[1]	X?	X?	X		X?	
EPRI Eq & Tect	X	X	X	X		
10 CFR 100 Appendix B[1]	X?	X?	X?		X?	X?
ASCE HLNWR[1]		X?	X?	X?	X?	
Diablo Canyon Power Plant	X	X	X[2]		X	X
IPEEE	X?	X	X[3]			X
DOE NPH	X	X	X		X	X
This Methodology	X	X	X	X	X	

[1]Study in progress; elements that are likely to be included are queried
[2]Yes for probabilistic, Yes for deterministic
[3]Yes for probabilistic

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RECENT AND ONGOING SEISMIC HAZARD STUDIES

LLNL Seismic Hazard Methodology for Eastern U.S.

- Probabilistic method using interpretations of multiple experts in seismicity and ground motions
- Methodology updated for New Production Reactor project

EPRI Seismic Hazard Methodology for Eastern U.S.

- Probabilistic method using multiple teams of experts
- Emphasis on documentation of assessments

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LLNL/EPRI Resolution Project

- Ongoing study sponsored by NRC, DOE, and EPRI; completion 9/94
- Aimed at developing an approved seismic hazard methodology for the next decade; recommendations made by Senior Seismic Hazard Analysis Committee
- Strong focus on use of expert judgment (e.g. individuals versus teams, role of integrator/facilitator, what is elicited)
- Intended audience: seismic hazard analysts

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EPRI Yucca Mountain Earthquakes and Tectonics Project

- Purposes: to quantify knowledge and uncertainties associated with fault displacement at YM; to demonstrate methods for eliciting expert judgment
- Diverse group of experts focused on difficult technical issue: data-driven, unique approaches, mutual respect
- Probabilistic results used for performance assessment

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Proposed 10 CFR 100 Appendix B Methodology

- Revision process is ongoing; finalization by early 1994
- Dual approach: PSHA with deaggregation ("hybrid"); traditional deterministic
- Target hazard probability level established from existing plants

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ASCE Guidelines and Recommendations for High Level Nuclear Waste Repositories

- In preparation, finalization expected in early 1994
- Performance-goal based process for establishing target hazard probability levels; deaggregation of hazard to identify controlling magnitudes and distances (hybrid procedure)
- Guidance on fault displacement hazard assessment: data needed and approaches recommended

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Diablo Canyon Power Plant Long Term Seismic Program

- Reevaluation of seismic design bases using both probabilistic and deterministic methods
- Intensive data-driven analysis, regulatory review, documentation
- Seismic margins evaluated using probabilistic risk assessment and seismic margins methodology

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NRC Guidance for the Individual Plant Examination of External Events (IPEEE)

- To identify potential seismic vulnerabilities
- Probabilistic (PRA) or deterministic (SMM) methodologies
- Use LLNL/EPRI for eastern U.S.; conduct own study in western U.S.

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DOE Design/Evaluation Criteria for Natural Phenomena Hazards

- Graded approach using four performance categories, each with a performance goal for behavior and a target probabilistic risk goal
- Target hazard probabilities from performance-based approach; hybrid
- Final and draft standards for implementation

RECENT PRACTICE IN SEISMIC HAZARD ASSESSMENT

CONCLUSIONS

- All of the basic elements of the seismic hazard analysis methodology have been used in practice for nuclear facilities
- Recent and ongoing experience provides an opportunity to shape method to best utilize the strengths of past studies
- Basic elements are state-of-the-practice; unique aspects of Yucca Mountain SHA are recognized and provided for (e.g., 10,000 years)

FESSP

Fission Energy & Systems Safety Program

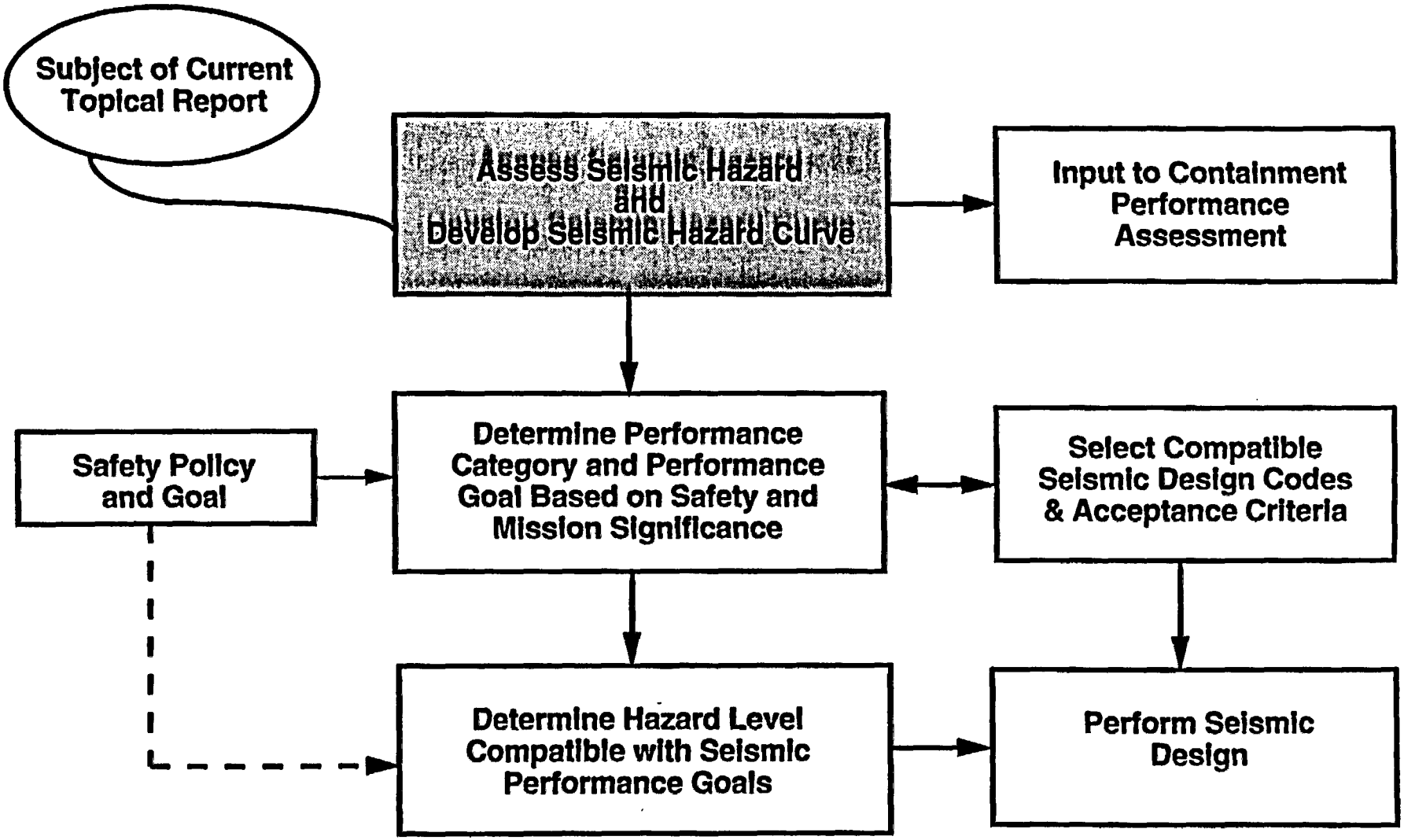
DOE-NRC TECHNICAL EXCHANGE ON SEISMIC HAZARD ASSESSMENT

Use and Suitability of the Proposed Methodology for Performance Assessment and Facility Seismic Design

Quazi A. Hossain
Lawrence Livermore National Laboratory

November 17, 1993

SM93-197QAH-YMP-1



SM93-197QAH-YMP-2

The seismic hazard assessment methodology fits the needs of performance assessment and performance goal-based facility seismic design

- Containment performance of the repository will be evaluated with respect to EPA's 40CFR Part 191 environmental radiation protection criteria.

- Surface and subsurface facilities must be designed to meet acceptable safety performance goals and requirements of 10CFR60.

- The proposed methodology will provide probabilistic determination of seismic hazard for both containment performance assessment and facility seismic design.

Evaluation of post-closure containment performance of the repository will require assessment of dose/release amount as a function of exceedance probability

- The results of seismic hazard evaluation will need to be presented in a curve of dose/release consequences versus probability that such dose/release will be exceeded. (Part of an integrated assessment)

- Examples of postulated post-closure seismic scenarios:

  — Failure of waste containers due to faulting.
  — Changes in rock permeability due to faulting and strain build-up.
  — Rise in the water table caused by earthquake stresses.

- Evaluation of these scenarios requires probabilistic assessment of seismic hazard.

Conventional and purely deterministic design method may not be appropriate for repository facilities with unconventional performance requirements

- Conventional Design Method:
  - — Uncertainties in Loading definition not explicitly considered.
  - — Uncertainties in component fragilities are accounted for only indirectly through the use of experience - based load factors.
  - — Does not permit determination of risk.
  - — Cannot rationally consider very low probability loading events.
  - — Does not provide rational gradation of design according to safety significance of components. (i.e. - risk consistent performance goal based design)

DOE is considering a safety performance goal-based seismic design methodology for which probabilistic assessment of seismic hazard is essential

- Safety Performance Goal–Based Seismic Design Method:
  - — Risk-consistent probabilistic target performance goals in terms of permissible failure rates are established based on safety and mission significance.
  - — Deterministic seismic design and acceptance criteria are established to achieve target safety performance goals.
  - — Seismic hazard is assessed consistent with deterministic design and seismic design safety performance goals.
- However, ...

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Safety performance goal-based method for the seismic design of repository facilities will be subject of a subsequent topical report

- This topical report will only outline the method that DOE is currently using in its other nuclear and hazardous facility design evaluation.

- Development of the safety performance goal-based method for the repository facility seismic design will be facility specific and include:

  - Consideration of unique seismic performance requirements
  - Structure, System, and Component Performance Categorization
  - Design consideration for fault-rupture loads
  - Additional benchmarking for subsurface facility components

DOE's seismic hazard assessment methodology can be suitably and effectively used with the safety performance goal-based seismic design method

- The method leads to consistent determination of seismic hazard level, analysis/evaluation requirements, and design acceptance criteria that are consistent with safety goal.
- Linkage between seismic design and safety performance goal is distinct and rationally established.
- Very low probability scenarios can be evaluated in a rational manner.
- Permits rational consideration of design for fault-rupture loads.
- Enables quantitative safety performance assessment with strong technical support.
- Fully documented for technical review and regulatory decision-making.

The seismic hazard assessment methodology represents the state-of-the-practice with major elements similar to those of other established or proposed seismic hazard methodologies

- LLNL and EPRI Methodologies
- EPRI's Yucca Mountain Earthquake and Tectonics Project
- Proposed 10CFR100 Appendix B Methodology
- Methodology outlined in ASCE Subcommittee's draft guideline

Licensing precedence using the major elements of the proposed methodology exists

- NRC Topical Review of EPRI's Probabilities Seismic Hazard Methodology: SER
- Diablo Canyon Long Term Seismic Program: SER
- EPRI NP 6395-D "Probabilistic Seismic Hazard Evaluations at Nuclear Plant Sites in the Central and Eastern United States: Resolution of the Charleston Earthquake Issue,": Staff acceptance
- NUREG/CR-5250, "Seismic Hazard Characterization of 69 Nuclear Plant Sites East of the Rocky Mountains".
- NUREG-1150, "Severe Accident Risks: An Assessment for Five Nuclear Power Plants".
- NRC Guidance on IPEEE: Generic letter 88-20, Supplement 4

CONCLUSIONS

- Proposed seismic hazard assessment methodology represents the state-of-the-practice.
- Major elements of this methodology have been accepted by the NRC as part of other methodologies.
- Major elements of this methodology have been applied in projects and programs that have been reviewed/endorsed by the NRC.
- Proposed hazard assessment methodology will provide results in a probabilistic format that is suitable and essential for risk consistent safety performance goal-based repository seismic design and containment performance assessment.

Civilian Radioactive Waste
Management System

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TRW Environmental Safety
Systems Inc.

DOE-NRC TECHNICAL EXCHANGE ON SEISMIC HAZARDS ASSESSMENT

SUMMARY

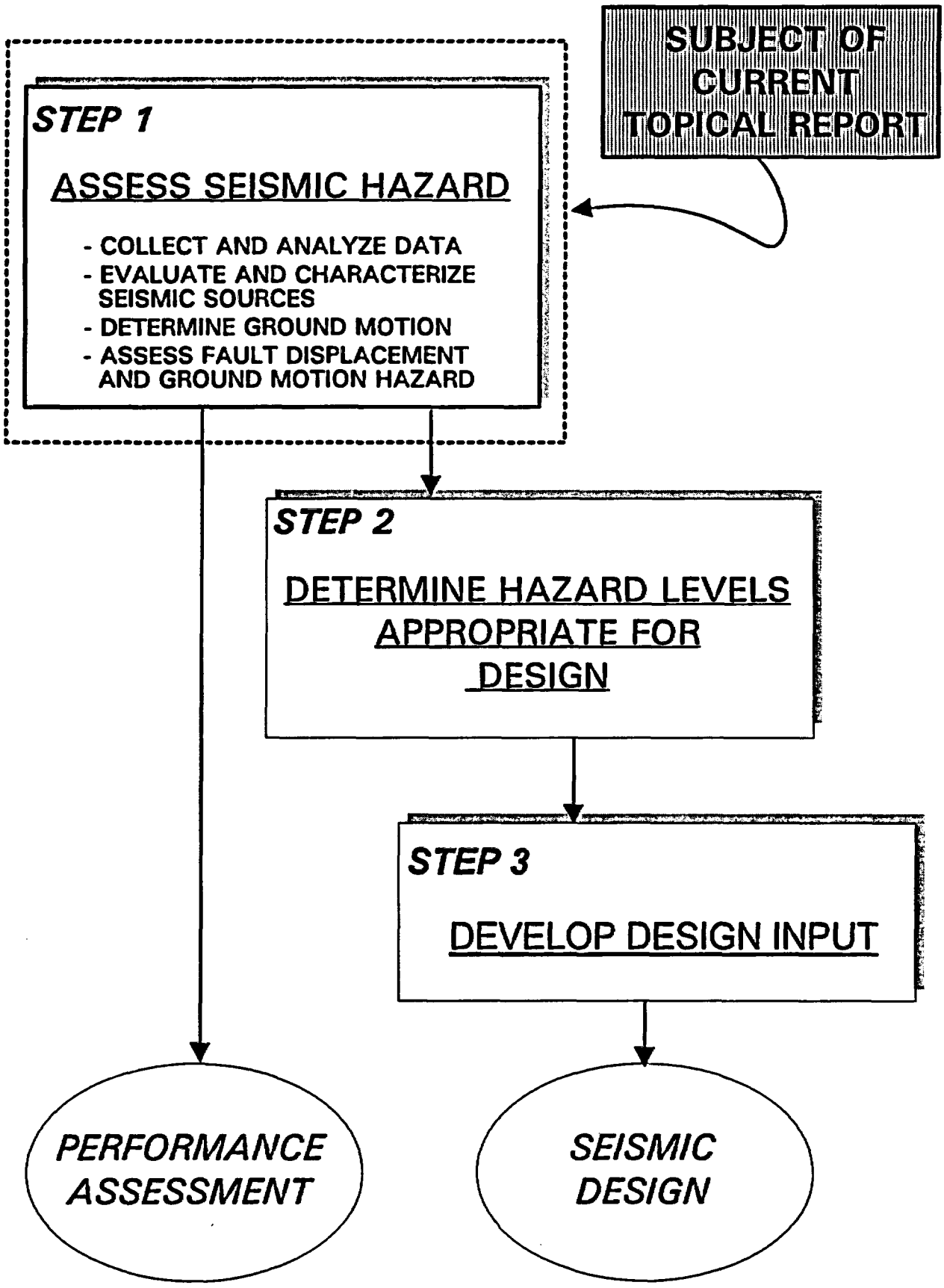
C. Thomas Statton
November 17, 1993

B&W Fuel Company
Duke Engineering & Services, Inc.
Fluor Daniel, Inc.

INTERA Inc.
JK Research Associates, Inc.
E. R. Johnson Associates, Inc.

Logicon RDA
Morrison Knudsen Corporation
Woodward-Clyde Federal Services

SEISMIC HAZARDS PROGRAM



METHODOLOGY

- **EXPERIENCE-BASED**
  - Recent developments in seismic hazard assessment provide foundation for current methodology
- **RELIES ON EXTENSIVE DATA COLLECTION AND ANALYSIS**
- **METHODOLOGY COMPONENTS**
  - Source Evaluation and Characterization
  - Ground Motion / Attenuation Relations
  - Ground Motion Hazard Assessment
  - Fault Displacement Hazard Assessment
- **SUPPORTS APPLICATIONS**
  - Seismic Design
  - Performance Assessment

DATA COLLECTION AND ANALYSIS

- **TECTONICS PROGRAM**
  - Focuses on data to support seismic hazard assessment
    - » Paleoseismic studies
    - » Seismicity and ground motion studies
    - » Analytical and synthesis studies

SOURCE EVALUATION AND CHARACTERIZATION

- **IDENTIFICATION OF SOURCES**
  - Quaternary faults, areal sources, volcanic sources and UNEs
  - Consistent with approach in NUREG 1451
- **MAXIMUM MAGNITUDE**
  - For faults, based on geologic and paleoseismic data
  - For areal sources, limited by magnitude of surface faulting events
- **RECURRENCE**
  - Based on available paleoseismic and historical seismicity data

GROUND MOTION / ATTENUATION RELATIONS

- **EMPIRICAL METHODS**
  - Based on regional and site recordings
- **NUMERICAL METHODS**
  - Combine data with an understanding of fault rupture processes

- **Both methods will be used to evaluate near-field and site effects**

GROUND MOTION HAZARD ASSESSMENT

- **PROBABILISTIC FRAMEWORK**
  - Provides a robust extension of NUREG-1451 methodology to calculate ground motion hazard
  - Variability explicitly incorporated
    - » Randomness and uncertainty
    - » Logic tree and Monte Carlo approaches will be evaluated
  - Sensitivity analyses incorporated
    - » Provide full understanding of hazard
    - » Identify dominant sources at given hazard levels
    - » Examine sensitivity of results to parameter variation
  - Inputs and interpretations documented

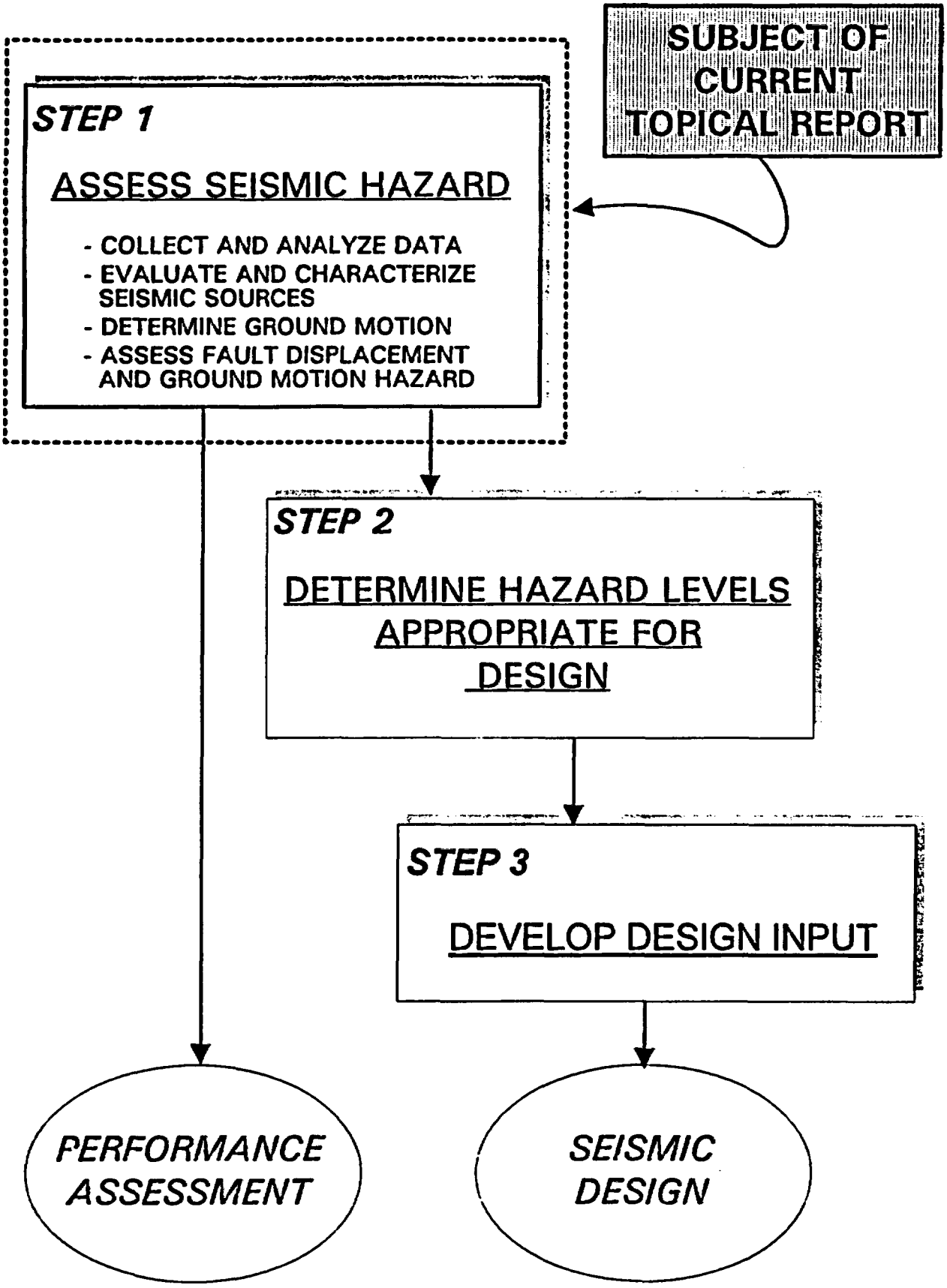
FAULT DISPLACEMENT HAZARD ASSESSMENT

- **PROBABILISTIC FRAMEWORK**
  - Provides robust extension of NUREG-1451 methodology to include recurrence and secondary faulting
  - Variability explicitly incorporated
  - Sensitivity analyses incorporated

REMAINING STEPS

- DETERMINATION OF SEISMIC HAZARD LEVELS
- DEVELOP SEISMIC DESIGN INPUTS
- SEISMIC DESIGN AND PERFORMANCE ASSESSMENT

SEISMIC HAZARDS PROGRAM



SUMMARY

- **A PROBABILISTIC FRAMEWORK IS APPROPRIATE FOR FAULT DISPLACEMENT AND GROUND MOTION HAZARD ASSESSMENT**
  - It allows incorporation of all data, including information on recurrence, in the assessment of hazard
  - It allows variability in interpretations to be explicitly incorporated
  - It provides a full understanding of contributions to hazard at the site, including those from a traditional deterministic approach
  - It provides a basis for rational (performance-goal based) seismic design

SUMMARY
(cont)

- THE METHODOLOGY ACCOMODATES SITE SPECIFIC CONCERNS
  - Alternative tectonic models
  - Alternative recurrence relations
  - Near-field ground motion effects

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DOE-NRC TECHNICAL EXCHANGE ON SEISMIC HAZARDS ASSESSMENT

SITE CHARACTERIZATION ANALYSIS (SCA) OPEN ITEMS

David F. Fenster
November 17, 1993

B&W Fuel Company
Duke Engineering & Services, Inc.
Fluor Daniel, Inc.

INTERA Inc.
JK Research Associates, Inc.
E. R. Johnson Associates, Inc.

Logicon RDA
Morrison Knudsen Corporation
Woodward-Clyde Federal Services

SCA COMMENTS AND THE TOPICAL REPORT

- 10 SCA COMMENTS ARE ADDRESSED IN WHOLE OR IN PART BY THE TOPICAL REPORT

- GROUPED ACCORDING TO CATEGORIES
  - Alternative tectonic models
  - Fault displacement hazard
  - Significant faults
  - Deterministic assessment of fault displacement hazard
  - Slip rate
  - 10,000-year cumulative slip earthquake

ALTERNATIVE TECTONIC MODELS

- **COMMENTS**
  - – 8 Alternative tectonic models not fully integrated into the site characterization plan
  - – 48 Use of slip rates may not be conservative, especially for some alternative tectonic models
  - – 61 Assumption that future faulting will follow old faulting patterns is not adequately supported
  - – 68 Detachment faults not treated as earthquake sources
  - – 71 Lack of approach to identifying significant faults, especially consideration of those from alternative tectonic models

ALTERNATIVE TECTONIC MODELS

- **TOPICAL REPORT**
  - DOE's methodology explicitly addresses alternative conceptual models in the way seismic sources (faults) and seismic source zones (buried or undetected faults) are characterized
  - The probabilistic approach explicitly addresses uncertainties and credible scenarios supported by data
  - Alternative tectonic models must be explicitly considered in a probabilistic assessment of seismic sources
  - Tectonic models that involve new faulting, and associated uncertainties, are explicitly accommodated by the methodology
  - Characterization of seismic sources will include an evaluation of detachment faults

FAULT DISPLACEMENT HAZARD

- **COMMENTS**
  - 36 How will the presence of faults within the perimeter drift be addressed with respect to system performance
  - 48 Use of slip rates may not be conservative, especially in light of the potential for secondary faulting

FAULT DISPLACEMENT HAZARD

- TOPICAL REPORT
  - Evaluation of fault displacement sources will be based on available data
  - Secondary faulting will be evaluated on the basis of empirical data from the site and from similar tectonic regions
  - The probability of new faults forming rather than old faults being reactivated can be assessed based on the data being collected by mapping and trenching activities
  - The hazard in the vicinity of Facilities Important To Safety (FITS) will be assessed based on data from trenching studies and on the assessments of new or secondary faulting related to movement on a primary fault located a some distance from a FITS
  - The methodology provides fault displacement hazard results appropriate for assessment of system performance.

SIGNIFICANT FAULTS

- **COMMENTS**
  - 47 Approach to performance assessment, including identification of significant faults, may result in an inaccurate assessment
  - 64 Identification of significant Quaternary faults is inadequate
  - 71 How will significant Quaternary faults be identified to evaluate performance issues?

SIGNIFICANT FAULTS

- **TOPICAL REPORT**
  - **Probabilistic seismic hazard assessment provides a rational method to evaluate the significance of faults to design and performance assessment**
  - **Source's contribution to overall hazard at any given level of fault displacement or ground motion can be assessed**

DETERMINISTIC ASSESSMENT OF FAULT DISPLACEMENT HAZARD

- **COMMENTS**
  - 48 Use of fault slip rates is not conservative; deterministic assessments should be used for fault displacement
  - 62 Use of standoff distances from faults is unclear; deterministic assessments should be used for fault displacement

DETERMINISTIC ASSESSMENT OF FAULT DISPLACEMENT HAZARD

- TOPICAL REPORT
  - Probabilistic approach is favored because it allows for use of all relevant data, including recurrence information
  - Probabilistic methodology encompasses traditional deterministic assessments
  - Probabilistic methodology allows assessment of significance of all sources, including traditional deterministic events
  - Probabilistic methodology explicitly and properly incorporates uncertainty, including that associated with secondary and new faulting, and alternative tectonic models
  - Probabilistic methodology facilitates sensitivity analyses to identify dominant sources, and to assess important contributors to overall uncertainty

SLIP RATE

- **COMMENT**
  - **48 Use of slip rate to characterize seismic hazard is not conservative**

SLIP RATE

- **TOPICAL REPORT**
  - **Slip rate is just one of the types of data to be used in characterizing seismic sources**
  - **When available, fault-specific paleoseismic histories will be used to characterize sources, including evaluations of displacement and recurrence**
  - **Detailed paleoseismic investigations of faults within the site area currently underway**

10,000-YEAR CUMULATIVE SLIP EARTHQUAKE

- **COMMENT**
  - **66 It is questionable whether the 10,000 Cumulative Slip Earthquake can properly characterize fault activity**

10,000-YEAR CUMULATIVE SLIP EARTHQUAKE

- TOPICAL REPORT
  - The 10,000 -year cumulative slip earthquake has been dropped from the DOE methodology
  - Recurrence information is properly incorporated through a probabilistic assessment

SUMMARY

- **THE METHODOLOGY:**
  - Explicitly accommodates alternative tectonic models
  - Provides a meaningful assessment of fault displacement hazard, including incorporation of secondary and new faulting
  - Coupled with iterative performance assessments and design analyses, provides a rational basis for evaluating the significance of seismic sources
  - Encompasses traditional deterministic assessments, and also explicitly incorporates information on recurrence and uncertainties
  - Uses all available data to characterize seismic sources, not just slip rate
  - Does not use the 10,000-year cumulative slip earthquake

Civilian Radioactive Waste Management System
Management & Operating Contractor

TRW
TRW Environmental Safety Systems Inc.

DOE-NRC TECHNICAL EXCHANGE ON SEISMIC HAZARDS ASSESSMENT

STATE OF NEVADA COMMENTS OCTOBER 26, 1993 LETTER

David F. Fenster
November 17,1993

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COMMENT 1:
POSTCLOSURE PERIOD CONCERN

- FIRST FACILITY WITH A 10,000 YEAR PERFORMANCE PERIOD

- METHODOLOGY PROVIDES APPROPRIATE INPUT FOR PERFORMANCE ASSESSMENTS

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COMMENT 2: POTENTIALLY ADVERSE CONDITIONS

- **INPUT TO HAZARD ASSESSMENT REQUIRES:**
  - Data on magnitude and frequency of earthquakes
  - Data on fault parameters and structural relationships
  - Data on paleoseismic behavior of faults during the Quaternary
- **GEOLOGICAL / SEISMOLOGICAL DATA COLLECTED BY SITE CHARACTERIZATION STUDIES WILL RESULT IN ABILITY TO ADDRESS PACs**
- **LA ANNOTATED OUTLINE PROCESS, ISSUE RESOLUTION INITIATIVE AND ITERATIVE EVALUATIONS**

COMMENT 3:
GEOLOGIC SETTING

- DOE RESPONSE TO SITE CHARACTERIZATION ANALYSIS COMMENT 75 PROVIDES OPERATIVE DEFINITION OF GEOLOGIC SETTING
- METHODOLOGY EXPLICITLY ADDRESSES THE EVALUATION OF FAULT SOURCES AND SEISMIC SOURCE ZONES, INCLUDING "BLIND" FAULTS AND "TRIGGERED" EVENTS
- METHODOLOGY EXPLICITLY ADDRESSES ALTERNATIVE CONCEPTUAL MODELS AND UNCERTAINTIES

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COMMENT 4:
DETERMINISTIC / PROBABILISTIC LINKAGE

- PROBABILISTIC METHODOLOGY ENCOMPASSES TRADITIONAL DETERMINISTIC ASSESSMENTS
- WORST-CASE SCENARIOS INCLUDED WITHIN THE PROBABILISTIC FRAMEWORK
- PROBABILISTIC METHODOLOGY USES ALL DATA AND PROVIDES A MORE COMPLETE UNDERSTANDING OF HAZARD THAN DETERMINISTIC APPROACH

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COMMENT 5A:
REPOSITORY FAULT DISPLACEMENT

- METHODOLOGY EXPLICITLY INCORPORATES REPOSITORY FAULT DISPLACEMENT, INCLUDING POSSIBLE PRIMARY, SECONDARY AND NEW FAULTING
- PROBABILISTIC METHODOLOGY INCORPORATES MORE DATA THAN DETERMINISTIC ASSESSMENT, INCLUDING INFORMATION ON RECURRENCE AND UNCERTAINTIES
- METHODOLOGY BUILDS ON APPROACH PRESENTED IN NUREG-1451

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COMMENT 5B:
NEAR FIELD GROUND MOTION

- NEAR-FIELD GROUND MOTION EFFECTS WILL BE EVALUATED AND INCORPORATED IN HAZARD ASSESSMENT WHERE APPROPRIATE

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COMMENT 6:
ESF SEISMIC DESIGN

- CONSERVATIVE INTERIM DESIGN BASIS PROVIDES FOR WORKER SAFETY DURING SPAN OF ESF ACTIVITY
- FINAL SUPPORT SYSTEM FOR A POTENTIAL REPOSITORY WILL BE IMPLEMENTED AT A LATER DATE

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