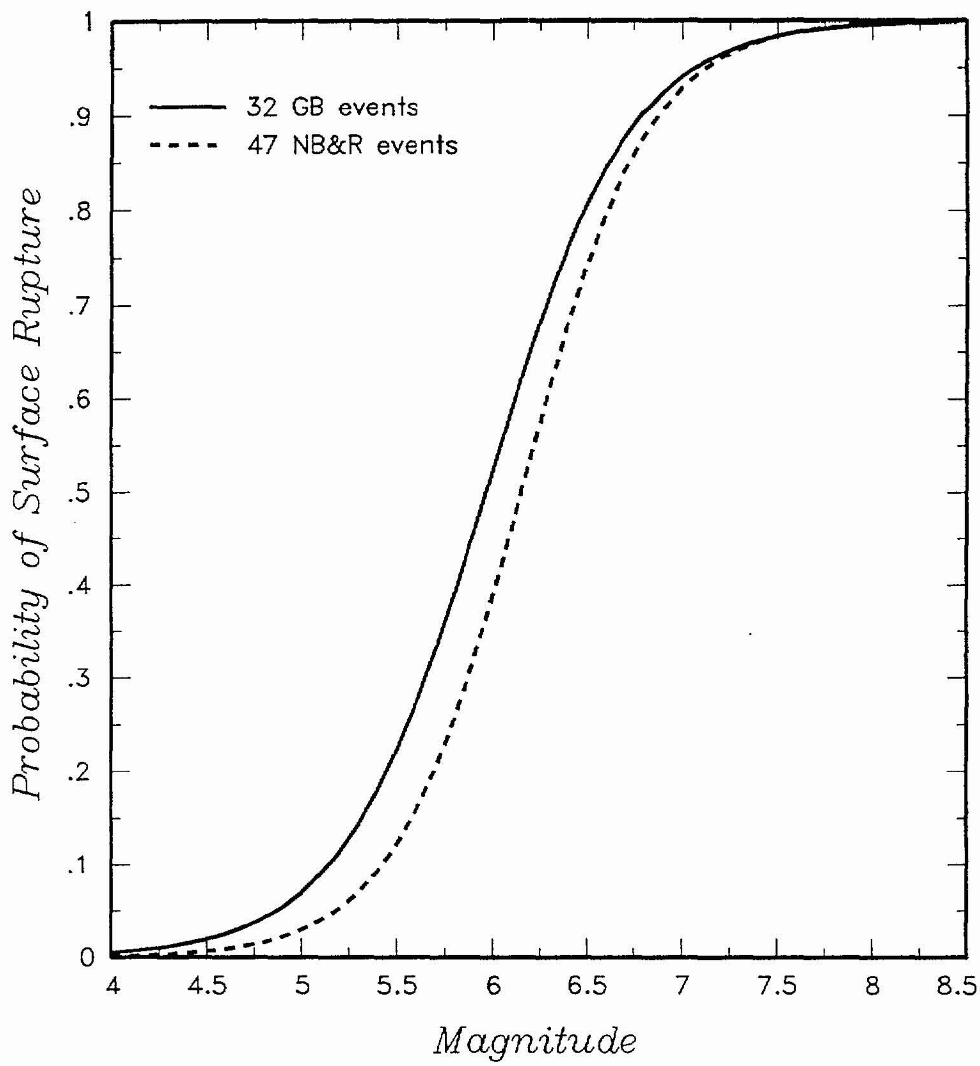


Figure SDO-12 Probability of surface rupture as a function of earthquake magnitude computed from various data sets given in S.K. Pezzopane and T.E. Dawson (USGS, written communication, 1996)

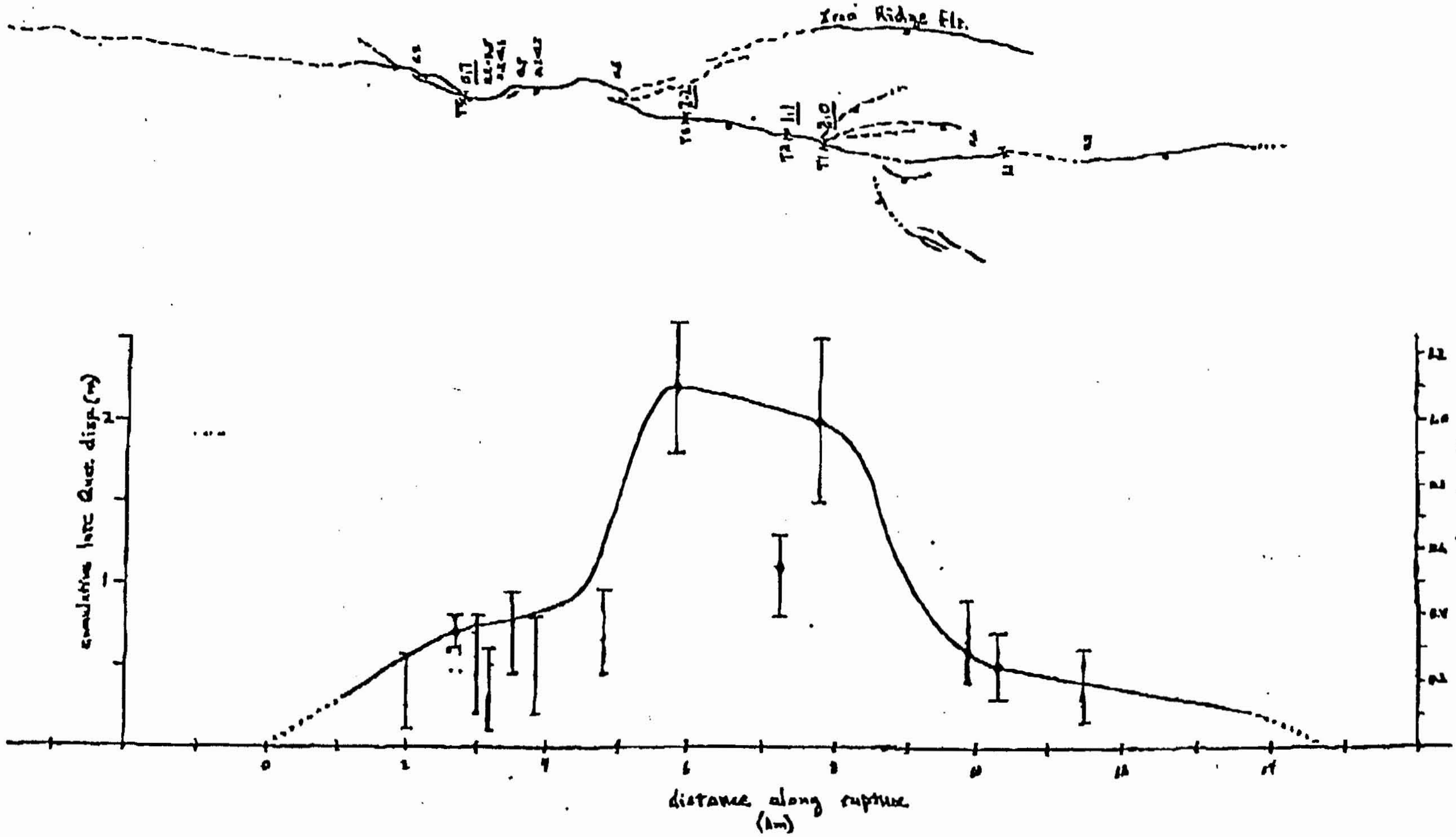


Figure SDO-13 Estimated mid- to late-Quaternary displacement along the Solitario Canyon fault. Strip map depicts displacement data from trench studies (Chap. 4.7 of U.S. Geological Survey, written communication, 1996) and scarp heights from Simonds *et al.* (1995). Graph depicts trench data (large dots) and scarp heights converted to estimated displacements (small dots). Left axis scales cumulative mid- to late-Quaternary displacement, and right axis scales *MD* based on 1/2 of the cumulative offset (a close approximation of the largest event).

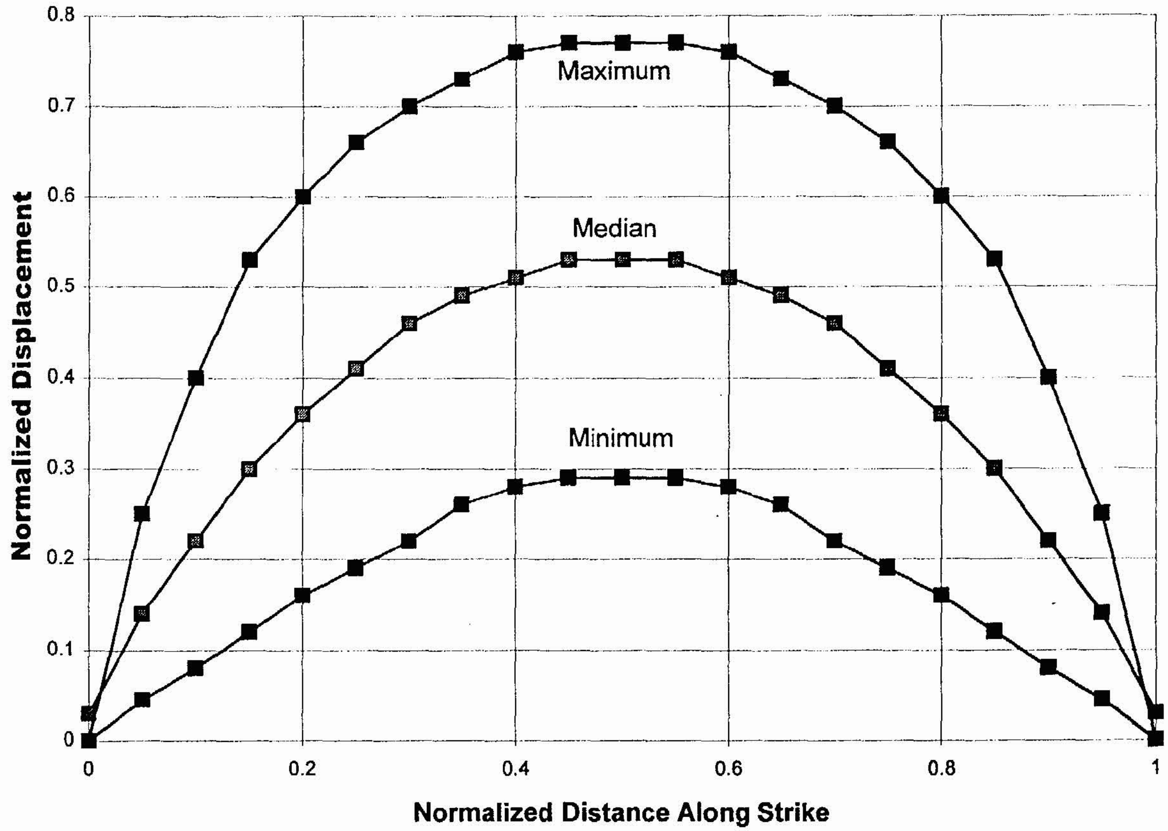


Figure SDO-14 Normalized slip along strike from five Basin and Range historic normal fault earthquake ruptures developed by the ASM team from data presented in Wheeler (1989).

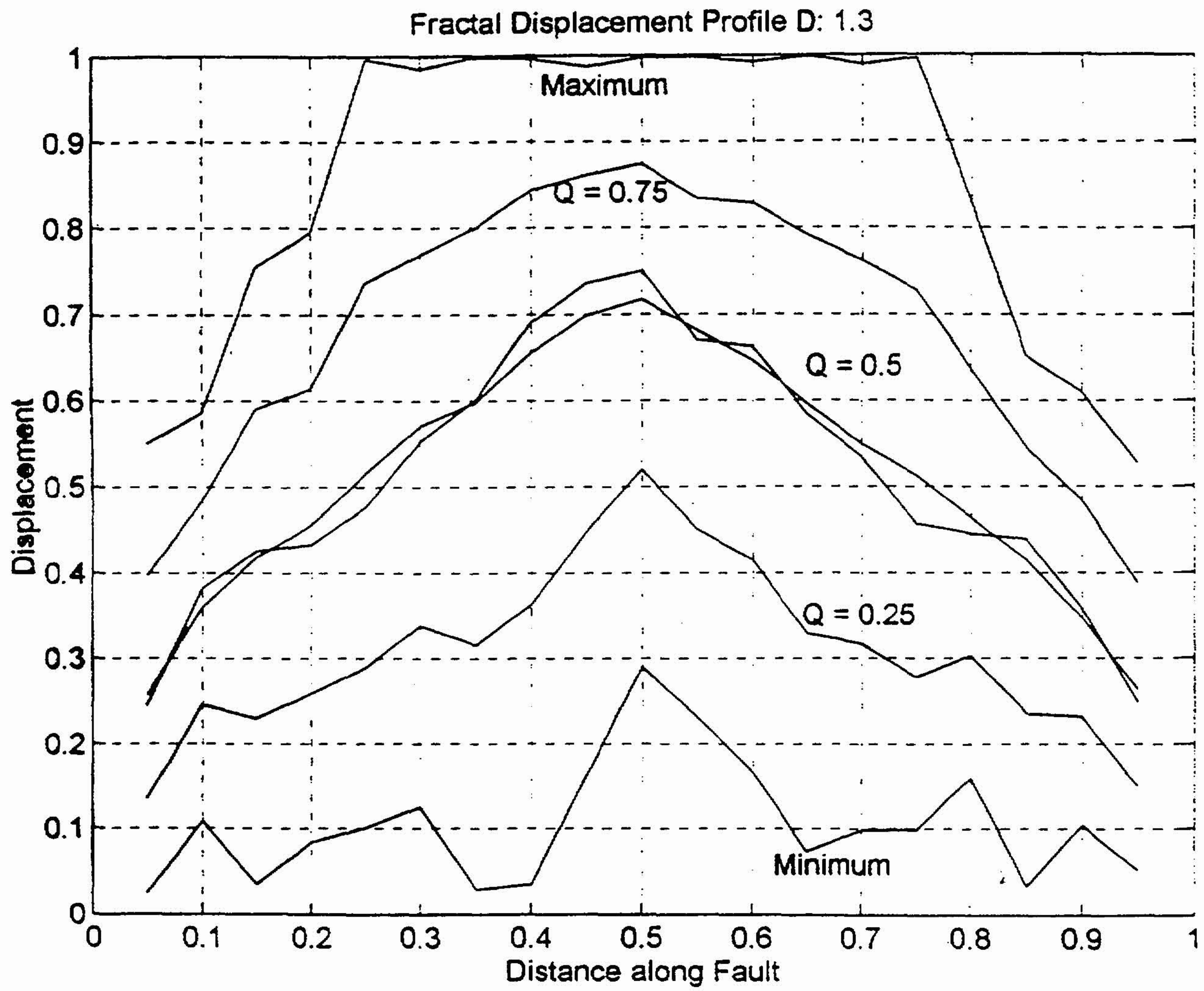


Figure SDO-15 Fractal displacement profiles developed by Ron Bruhn, University of Utah, to predict distribution for the ratio of displacement at a point to the maximum displacement in an earthquake.

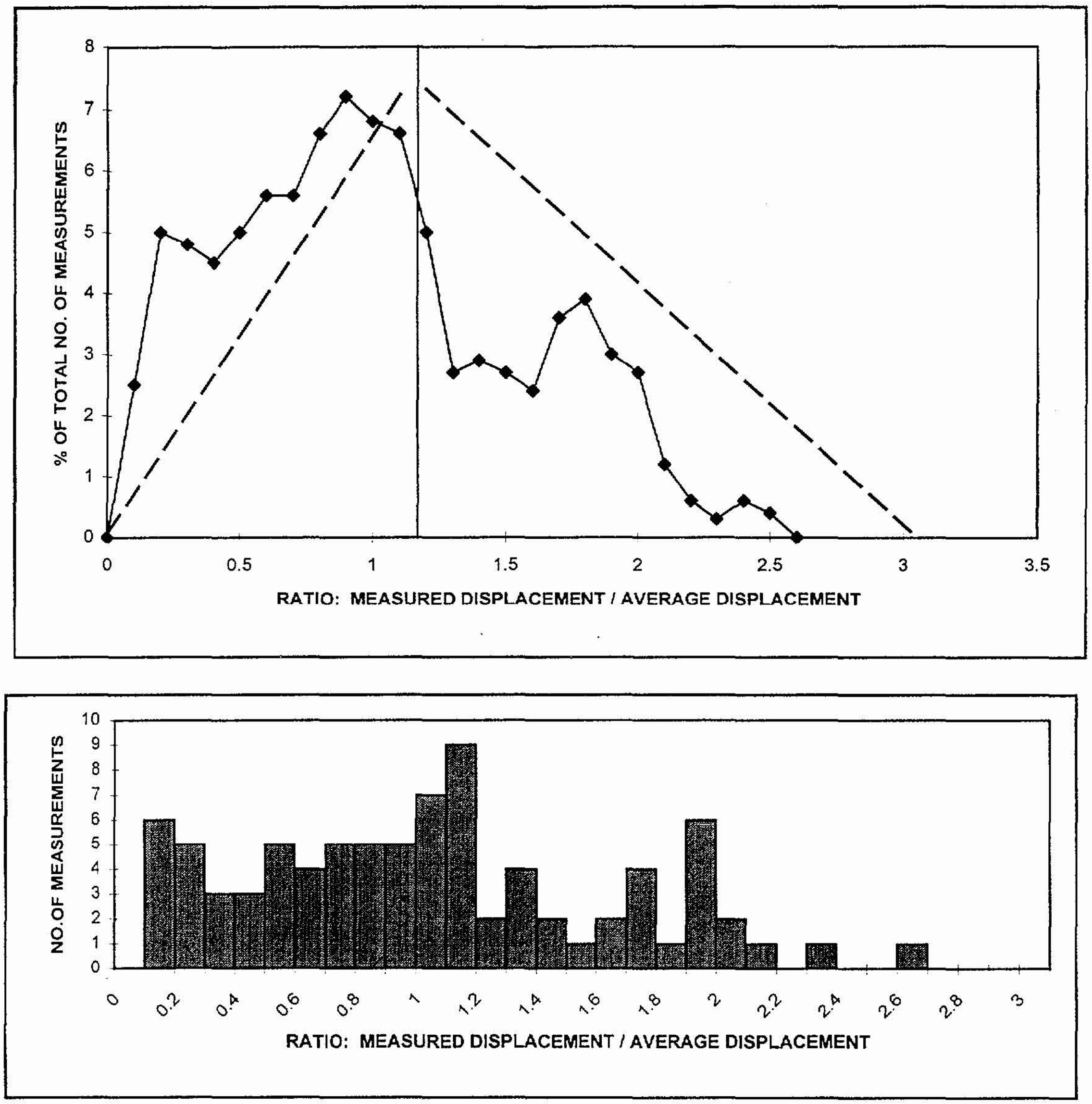


Figure SDO-16 Plots showing event-to-event variability in displacement relative to average displacement per event at a location along a fault based on data from paleoseismic investigations in the Yucca Mountain area.

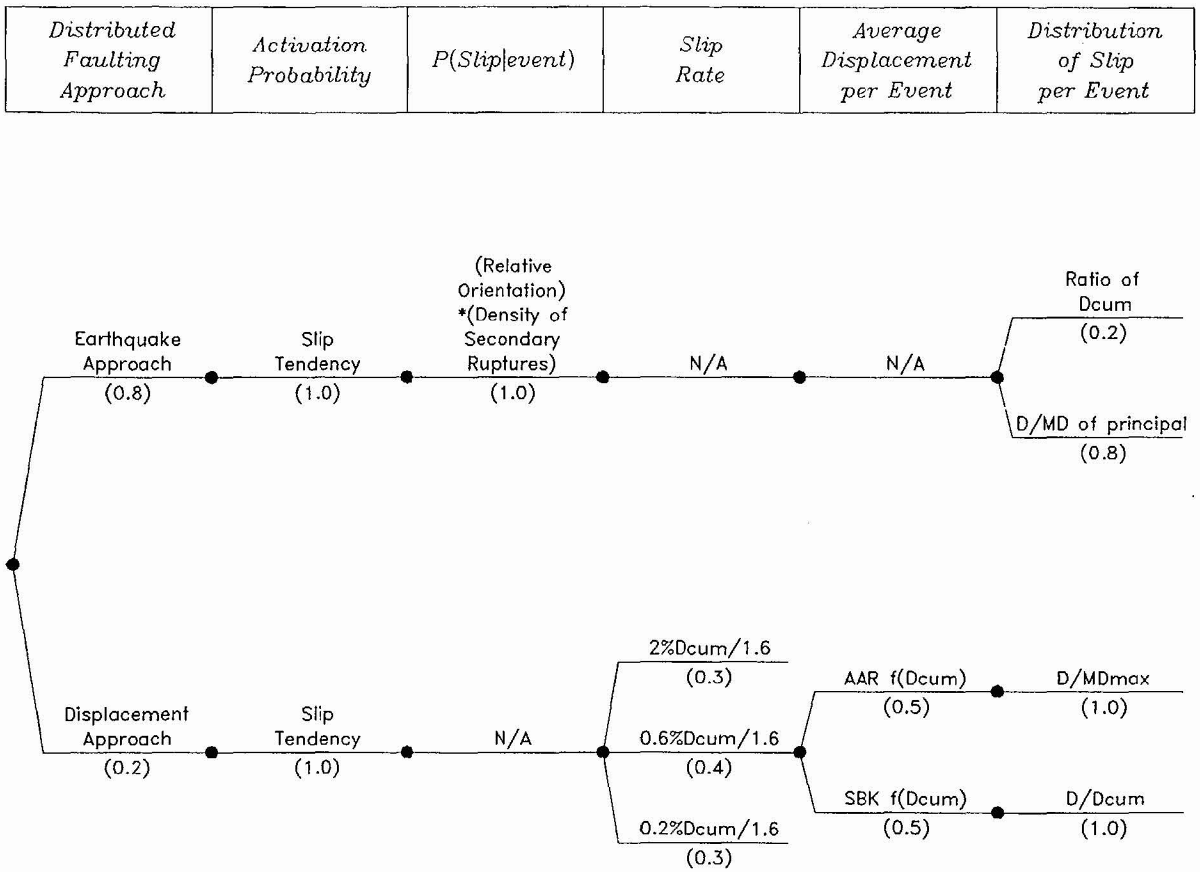


Figure SDO-17 Logic tree used to characterize distributed faulting displacement hazard.

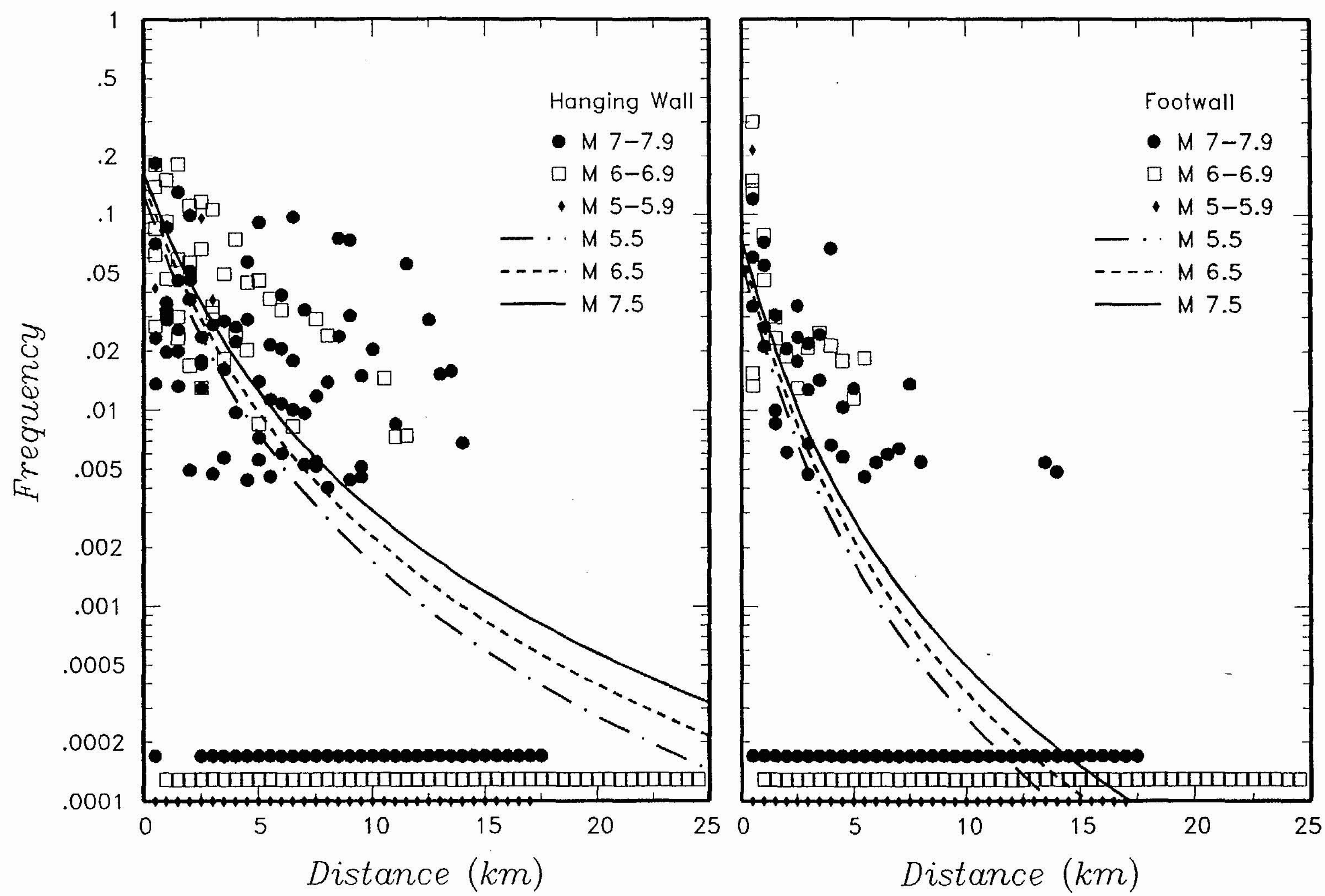


Figure SDO-18 Probability of induced distributed slip as a function of distance from the rupture and hanging wall/footwall location computed from the data presented in S.K. Pezzopane and T.E. Dawson (USGS, written communication, 1996). Curves show logistic regression fits to data.

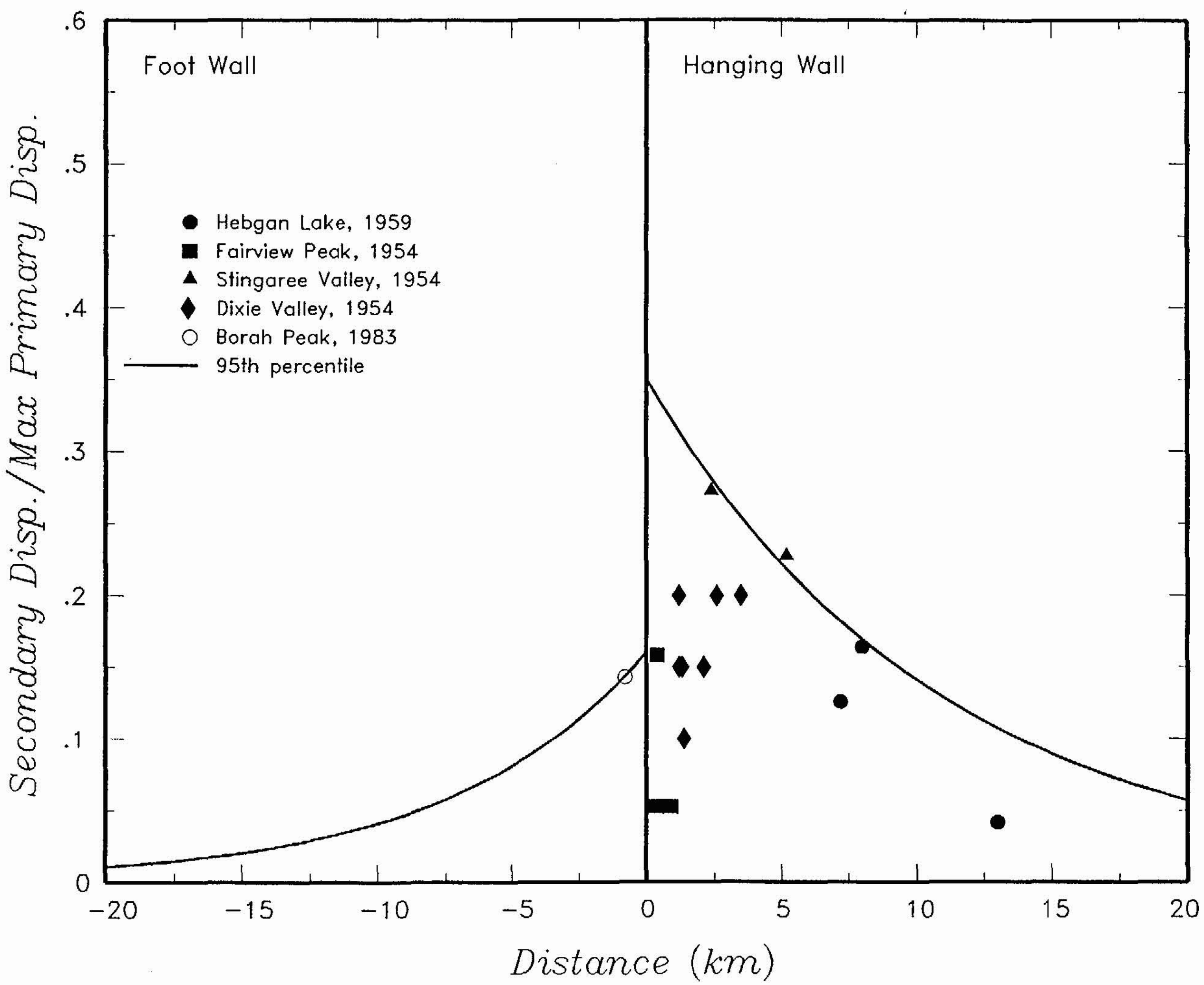


Figure SDO-19 Observed secondary faulting distribution normalized to main fault displacement for large scarp -forming, historic normal faulting earthquakes in the Basin and Range province.

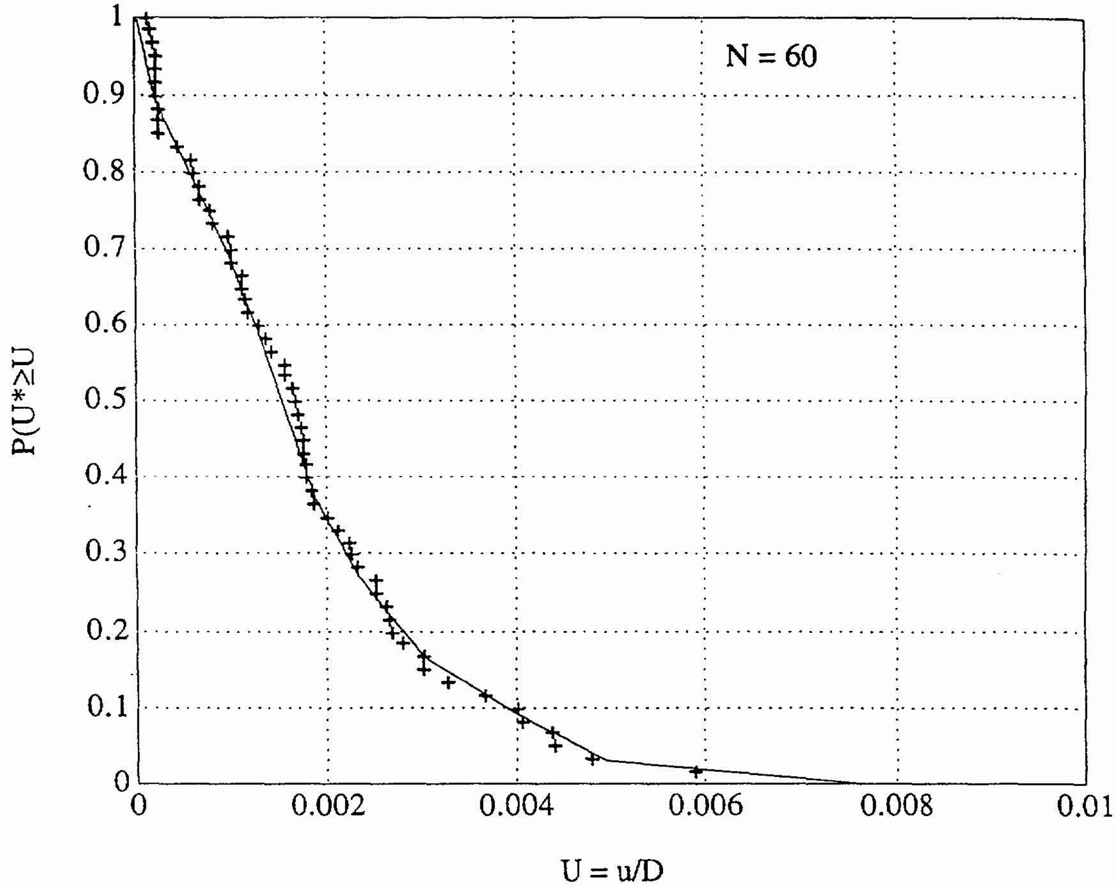


Figure SDO-20 Cumulative probability graph of D/D_{cum}, where D is fault slip per event and D_{cum} is the cumulative displacement on the fault surface at the point of interest. Function is derived from Yucca Mountain fault data synthesis of S.K. Pezzopane and T.E. Dawson (USGS, written communication, 1996) and discussions of Cowie and Scholz (1992) by SBK team.

APPENDIX SDO-1
EVENT SCENARIOS FOR LOCAL FAULTS
(Page 1 of 3)

Event Scenarios	Occurrence Rates (events/yr)		
	Minimum	Preferred	Maximum
Paintbrush	1.96E-005	3.13E-005	7.174E-005
PC(N)	7.98E-006	1.27E-005	2.91E-005
PC(S)	4.63E-006	7.39E-006	1.69E-005
PC(N+S)	1.88E-006	3.00E-006	6.85E-006
PCN+BR	1.76E-007	2.82E-007	6.43E-007
PC(S)+BR	1.45E-006	2.32E-006	5.28E-006
PC+BR	1.76E-007	2.82E-007	6.43E-007
PC+SCR	1.88E-006	3.00E-006	6.85E-006
PC(S)+SCR	8.23E-007	1.31E-006	3.00E-006
PC+BR+SCR	1.76E-007	2.82E-007	6.43E-007
PC+ash event	4.31E-007	6.89E-007	1.57E-006
Stagecoach Road	2.44E-005	3.33E-005	5.00E-005
SCR	1.22E-005	1.67E-005	2.50E-005
SCR+PC(S)	2.24E006	3.06E-006	4.60E-006
SCR+PC	4.07E-006	5.56E-006	8.35E-006
SCR+ash event	1.83-006	2.50E-006	3.75E-006
SCR+SC	3.05E-006	4.16E-006	6.25E-006
SCR+PC+BR	1.02E-006	1.40E-006	2.10E-006
Solitario Canyon	1.47E-005	1.92E-005	2.7E-005
SC	8.45E-006	1.10E-005	1.55E-005
SC+SCR	1.84E-006	2.40E-006	3.38E-006
SC+ash event	2.57E-006	3.36E-006	4.73E-006
SC+SWW	1.84E-006	2.40E-006	3.38E-006
Iron Ridge	3.91E-006	4.98E-006	6.99E-006
IR	3.52E-006	4.48E-006	6.29E-006
IR+AW	2.61E-007	3.32E-007	4.66E-007
IR+AW+GD	1.30E-007	1.66E-007	2.33E-007

APPENDIX SDO-1
EVENT SCENARIOS FOR LOCAL FAULTS
(Page 2 of 3)

Event Scenarios	Occurrence Rates (events/yr)		
	Minimum	Preferred	Maximum
Fatigue Wash	3.46E-006	6.06E-006	1.16E-005
FW	2.22E-006	3.98E-006	7.45E-006
FW+SWW	3.71E-007	6.49E-007	1.24E-006
FW+SW+NW	1.24E-007	2.16E-007	4.14E-006
FW+SW+SCF	2.47E-007	4.33E-007	8.29E-007
FW+ash event	4.94E-007	8.66E-007	1.65E-006
S. Windy Wash	1.3E-005	1.96E-005	2.78E-005
SWW	8.16E-006	1.23E-005	1.75E-005
SWW+SCF	1.08E-006	1.63E-006	2.31E-006
SWW+FW	6.76E-007	1.02E-006	1.45E-006
SWW+SC	4.03E-007	6.08E-007	8.62E-007
SWW+CW	8.06E-007	1.22E-006	1.72E-006
SWW+SCF+NCF	4.03E-007	6.08E-007	8.62E-007
SWW+FW+NWW	4.03E-007	6.08E-007	8.62E-007
SWW+FW+SCF	2.73E-007	4.12E-007	5.84E-007
SWW+ash event	8.19E-007	1.23E-006	1.75E-006
Individual Faults			
PC (N + S)	2.24E-006	2.91E-006	8.3E-006
PC (N)	7.98E-006	1.27E-005	2.91E-005
PC (S)	4.63E-006	7.39E-006	1.69E-005
SCR	1.22E-005	1.67E-005	2.50E-005
SC	8.45E-006	1.10E-005	1.55E-005
IR	3.52E-006	4.48E-006	6.29E-006
FW	2.22E-006	3.89E-006	7.45E-006
SWW	8.16E-006	1.23E-005	1.75E-005
Linked Faults		Scenarios:	
PC+SCR	2.98E-006	4.28E-006	7.60E-006
PC(S)+SCR	1.53E-006	2.19E-006	3.80E-006
PC(S)+BR	1.45E-006	2.32E-006	5.28E-006
SCR+SC	2.45E-007	3.28E-006	4.82E-006
IR+AW	2.61E-007	3.32E-007	4.66E-007
IR+AW+GD	1.30E-007	1.66E-007	2.33E-007
FW+SWW	5.24E-007	8.35E-007	1.35E-006
SWW+FW+NWW	2.64E-007	4.12E-007	6.38E-007
SWW+CW	4.03E-007	6.08E-007	8.62E-007

APPENDIX SDO-1
EVENT SCENARIOS FOR LOCAL FAULTS
(Page 3 of 3)

Event Scenarios	Occurrence Rates (events/yr)		
	Minimum	Preferred	Maximum
Distributed Faults			
PC(N)+BR	1.76E-007	2.82E-007	6.43E-007
PC+BR+SCR	5.98E-007	8.41E-007	1.37E-006
PC+BR	1.76E-007	2.82E-007	6.43E-007
SC+SWW	1.12E-006	1.50E-006	2.12E-006
FW+SWW+SCF	2.60E-007	4.23E-007	7.07E-007
SWW+SCF	1.08E-006	1.63E-006	2.31E-006
SWW+SCF+NCF	4.03E-007	6.08E-007	8.62E-007
ash event	1.22E-006	1.73E-006	2.69E-006

APPENDIX SDO-2
ANALYSIS OF PALEOSEISMIC DATA

REPRESENTATIVE AGES

Representative or nominal ages were ascribed to the paleoseismic data to make the use of this information more tractable (especially, given the time frame for the analysis) and transparent. There are, however, large uncertainties associated with these age data; we handle these in the relative weighting of event scenarios. Most of the ages and displacements used for the local faults at Yucca Mountain came from the Seismotectonic Framework Report produced by the U.S. Geological Survey. In particular, Table 5-1, "Event Displacements and Timing Data from Paleoseismic Studies of Yucca Mountain Faults", was used extensively.

PAINTBRUSH CANYON FAULT

Paleoseismic Earthquake Recurrence Information:

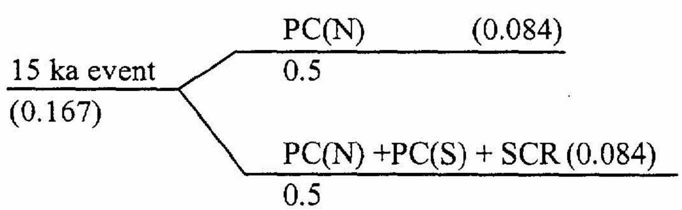
Six to nine events in the last 300 to 410 ka along the Paintbrush Canyon fault have been revealed by trenching. However, four to six of these events have occurred in the last 100 to 150 ka. Either paleoevents prior to 100 to 150 ka have been erased or left no record where the fault has been examined, or earthquake occurrence is becoming more frequent post 100 to 150 ka. In either case, it makes the most sense to calibrate earthquake recurrence for future predictions of the next earthquakes on the last 100 to 150 ka. The preferred number of events is five, the midpoint, and the preferred age is 120 ka. The most recent event occurred at 15 ka.

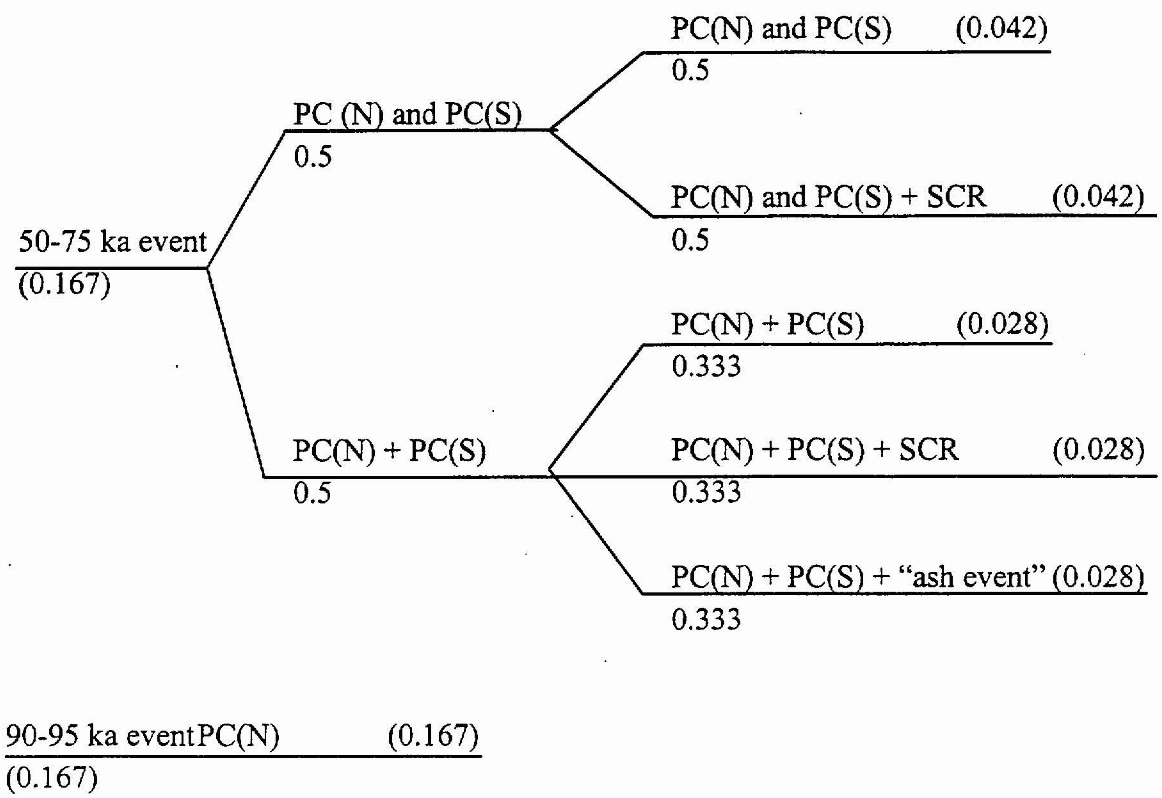
	Raw Average Earthquake Recurrence Intervals	Corrected Average Earthquake Recurrence Intervals - Most Recent Event and Elapsed Time Removed
Min.	17 kyr	17 kyr
Pref.	24 kyr	26 kyr
Max.	38 kyr	45 kyr

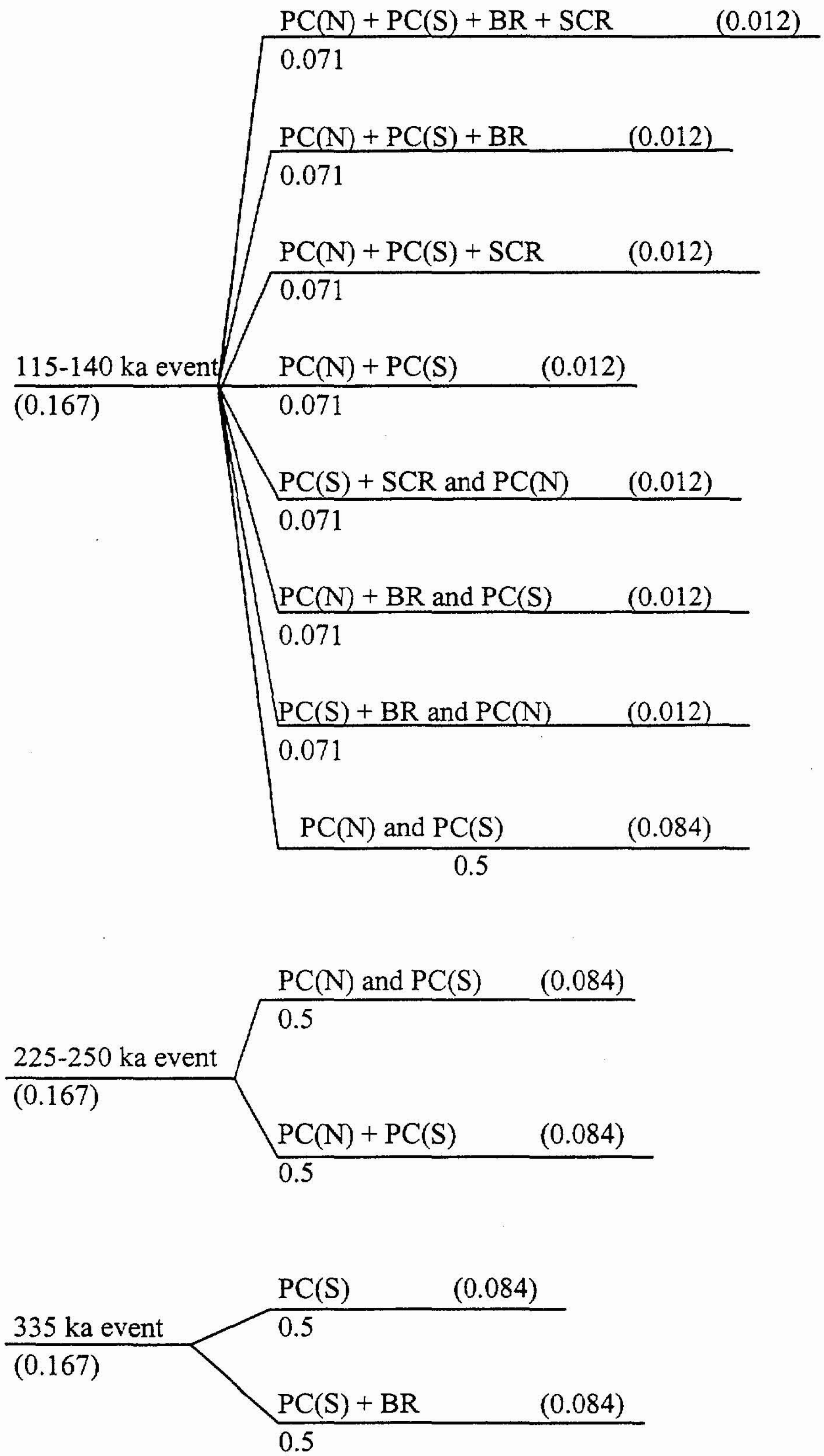
Similar to the average recurrence interval, the interseismic intervals examined are for the last 100 to 150 ka. Considering the preferred ranges presented in Chapter 5 of the U. S. Geological Survey Synthesis Report, interseismic intervals were estimated by subtracting the extreme values. The range of values for the interseismic intervals is 15 to 60 kyr. The average of all the estimates, 38 kyr, is taken as the preferred value.

	Moment Rate Recurrence	Average Earthquake Recurrence	Preferred Interseismic Interval	Averaged Earthquake Recurrence	Maximum Earthquake Occurrence Rate (events/yr)
Min.	8.6 kyr	17 kyr	15 kyr	14 kyr	7.14×10^{-5}
Pref.	31 kyr	26 kyr	38 kyr	32 kyr	3.13×10^{-5}
Max.	47 kyr	45 kyr	60 kyr	51 kyr	1.96×10^{-5}

Relative Frequency	Nominal Age of the Event	Surface Displacement	Possible Event Scenarios
(0.167)	15 ka	0.05/0.2/0.2	PC(N) + PC(S.?, poss. erased) + SCR or PC(N)
(0.167)	50-75 ka	0.44/0.62/0.77	PC(N) + "ash event" or PC(S) + SCR or PC(N) and PC(S)
(0.167)	90-95 ka	0.53/0.98/1.43	PC(N)
(0.167)	115-140 ka	0.29/0.4/1.40	PC(N) + PC(S) + BR + SCR or PC(N) +PC(S) PC(N) + PC(S) + BR or PC(N) + PC(S) + SCR PC (N) + BR or PC(S) + BR PC(N) and PC(S)
(0.167)	225-250 ka	0.35/0.47/0.69	PC(N) + PC(S) or PC(N) and PC(S)
(0.167)	335 ka	0.88/1.67/2.05	PC(S) + BR




50-75 ka event
(0.167)
PC (N) and PC(S)
0.5
PC(N) and PC(S) (0.042)
0.5
PC(N) and PC(S) + SCR (0.042)
0.5
PC(N) + PC(S)
0.5
PC(N) + PC(S) (0.028)
0.333
PC(N) + PC(S) + SCR (0.028)
0.333
PC(N) + PC(S) + "ash event" (0.028)
0.333
90-95 ka eventPC(N) (0.167)
(0.167)


PC(N) + PC(S) + BR + SCR (0.012)
0.071
PC(N) + PC(S) + BR (0.012)
0.071
PC(N) + PC(S) + SCR (0.012)
0.071
115-140 ka event
(0.167)
PC(N) + PC(S) (0.012)
0.071
PC(S) + SCR and PC(N) (0.012)
0.071
PC(N) + BR and PC(S) (0.012)
0.071
PC(S) + BR and PC(N) (0.012)
0.071
PC(N) and PC(S) (0.084)
0.5
PC(N) and PC(S) (0.084)
0.5
225-250 ka event
(0.167)
PC(N) + PC(S) (0.084)
0.5
PC(S) (0.084)
0.5
335 ka event
(0.167)
PC(S) + BR (0.084)
0.5

Final Relative Weighting:

(0.407)	PC(N)
(0.236)	PC(S)
(0.096)	PC(N) + PC(S)
(0.009)	PC(N) + BR
(0.074)	PC(S) + BR
(0.009)	PC(N) + PC(S) + BR
(0.096)	PC(N) + PC(S) + SCR
(0.042)	PC(S) + SCR
(0.009)	PC(N) + PC(S) + BR + SCR
(0.022)	PC(N) + PC(S) + "ash event"

STAGECOACH ROAD FAULT

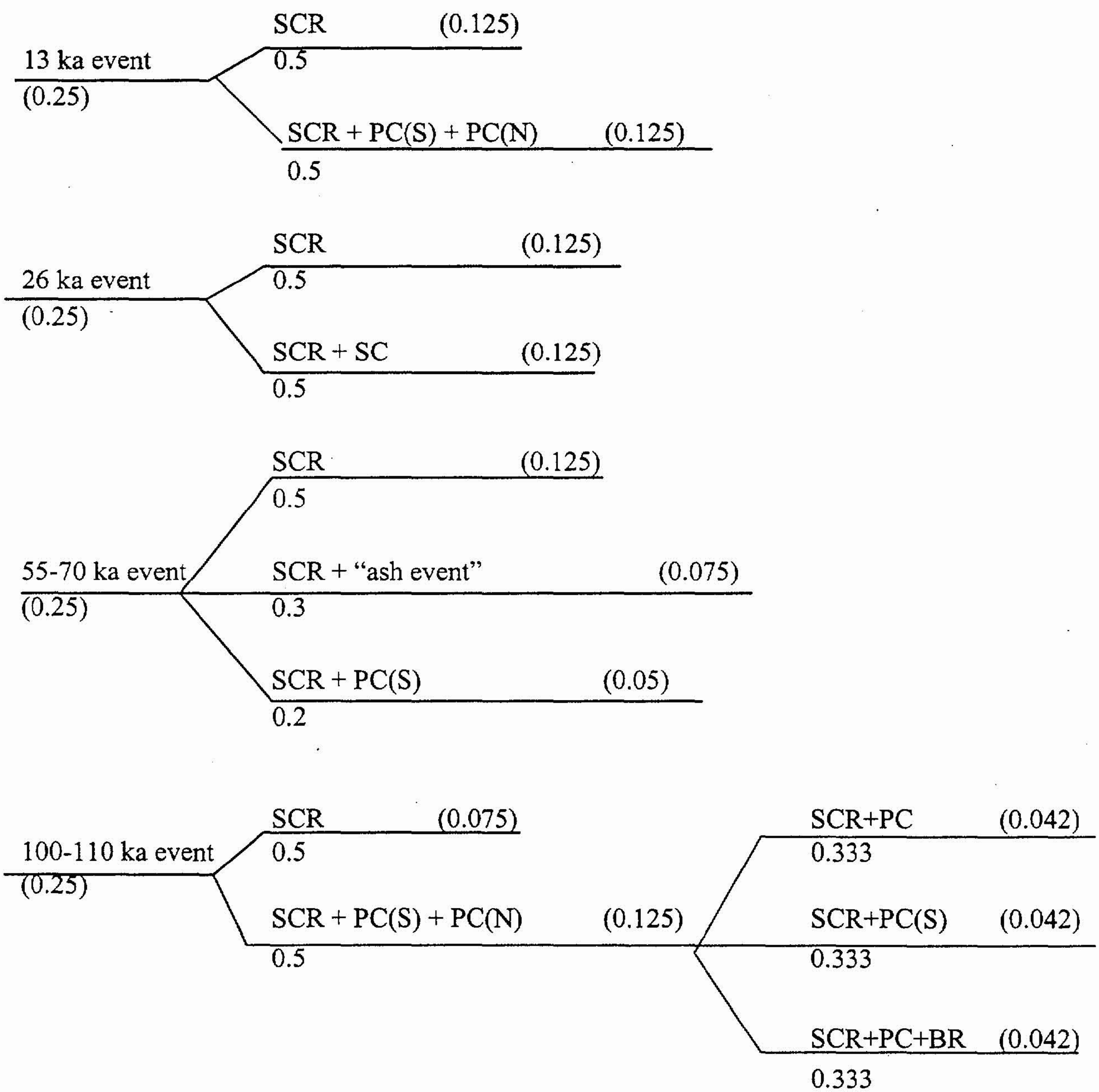
Paleoseismic Earthquake Recurrence Information:
Four events have occurred in the last 98 to 118 ka, with a preferred value of 108 ka. The most recent event was 6 to 15 ka, with a preferred value of 13 ka.

	Raw Average Earthquake Recurrence Intervals	Corrected Average Earthquake Recurrence Intervals Most Recent Event and Elapsed Time Removed
Min.	25 kyr	28 kyr
Pref.	27 kyr	32 kyr
Max.	30 kyr	34 kyr

Considering the preferred ranges presented in Chapter 5 of the U. S. Geological Survey Synthesis Report, interseismic intervals were estimated by subtracting the extreme values. Preferred value interseismic intervals ranged from 13 kyr to 55 kyr; the average interseismic interval is 34 kyr.

	Moment Rate Recurrence	Average Earthquake Recurrence	Preferred Interseismic Interval	Averaged Earthquake Recurrence	Maximum Earthquake Occurrence Rate (events/yr)
Min.	18 kyr	28 kyr	13 kyr	20 kyr	5×10^{-5}
Pref.	24 kyr	32 kyr	34 kyr	30 kyr	3.33×10^{-5}
Max.	35 kyr	34 kyr	55 kyr	41 kyr	2.44×10^{-5}

Relative Frequency	Nominal Age of the event	Surface Displacement	Poss. Event Scenarios
(0.25)	13 ka	0.4/0.43/0.82 m	SCR or SCR + PC(S.?, poss erased) + PC(N)
(0.25)	26 ka	0.28/0.59/0.77 m	SCR or SCR + SC
(0.25)	55-70 ka	0.25/0.57/0.99 m	SCR + "ash event" or SCR + PC(S) or SCR
(0.25)	100-110 ka	0.26/0.67/0.87 m	SCR + PC(S) + PC(N) or SCR



Final Relative Weighting:

(0.5)	SCR
(0.092)	SCR + PC(S)
(0.167)	SCR + PC(S) + PC(N)
(0.075)	SCR + "ash event"
(0.125)	SCR + SC
(0.042)	SCR+PC+BR

SOLITARIO CANYON FAULT

Paleoseismic Information:

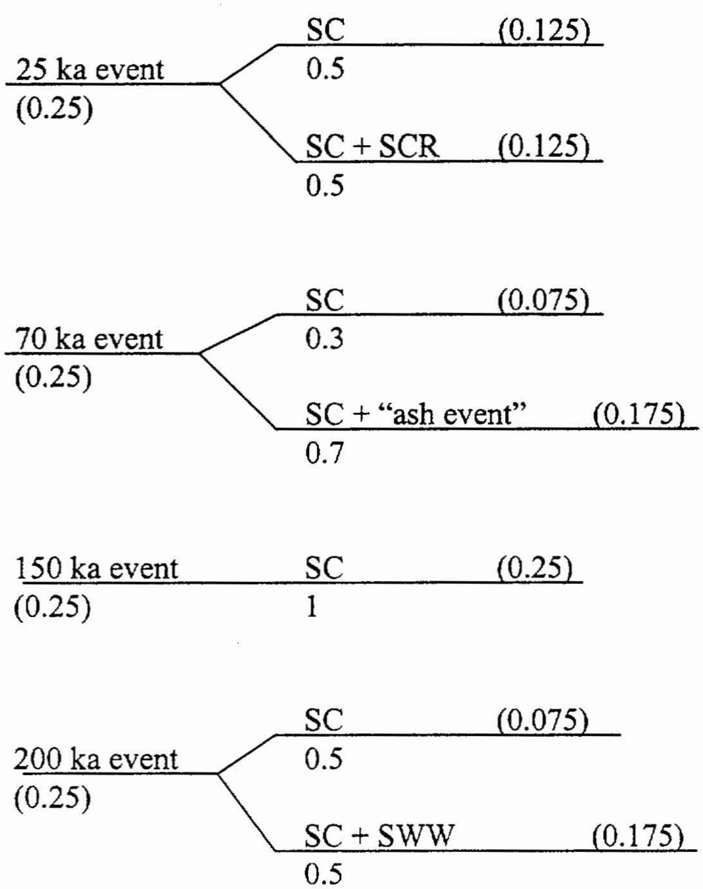
Four events have occurred over the last 150 to 250 ka (preferred 200 ka). The most recent event occurred at about 25 ka.

	Raw Average Earthquake Recurrence Intgervals	Corrected Average Earthquake Recurrence Interval Most Recent Event and Elapsed Time Removed
Min.	38 kyr	42 kyr
Pref.	50 kyr	58 kyr
Max.	63 kyr	75 kyr

Interseismic intervals of preferred values are 45, 50, and 80 kyr, with an average of 58 kyr.

	Moment Rate Recurrence	Average Earthquake Recurrence	Preferred Interseismic Recurrence	Average Earthquake Recurrence	Maximum Earthquake Occurrence Rate (EVENTS/YR)
Min.	23 kyr	42 kyr	45 kyr	37 kyr	2.7×10^{-5}
Pref.	40 kyr	58 kyr	58 kyr	52 kyr	1.92×10^{-5}
Max.	50 kyr	75 kyr	80 kyr	68 kyr	1.47×10^{-5}

Relative Frequency	Nominal Age of the event	Surface Displacement	Poss. Event Scenarios
(0.25)	25 ka	0.05/0.1/0.2 m	SC or SC + SCR
(0.25)	70 ka	1.00/1.20/1.40 m	SC + "ash event"
(0.25)	150 ka	0.2/0.3/0.4 m	SC
(0.25)	200 ka	0.3/0.5/0.7 m	SC + SWW or SC



Final Relative Weighting:

(0.575)	SC
(0.125)	SC+SCR
(0.175)	SC + "ash event"
(0.125)	SC + SWW

FATIGUE WASH FAULT

Paleoseismic Information:

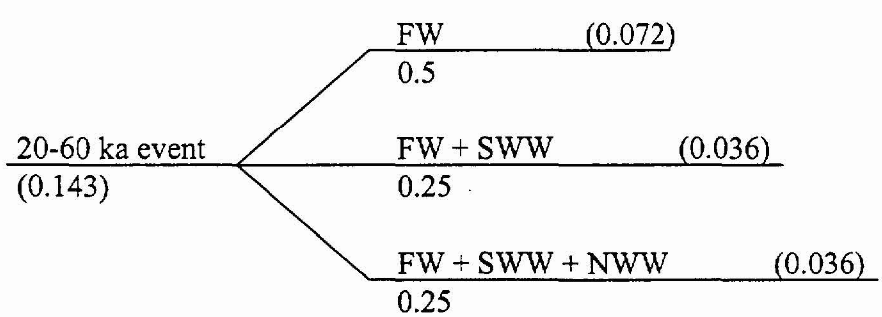
Three to four events (four preferred) have occurred within the last 450 to 730 ka (assume 600 ka for preferred value. The most recent event was 20 to 60 ka ago (the midpoint, 40 ka is used for preferred).

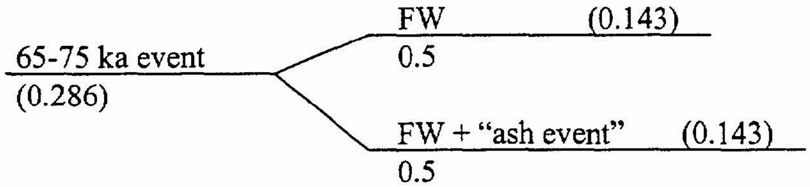
	Raw Average Earthquake Recurrence Intervals	Corrected Average Earthquake Recurrence Intervals Most Recent Event and Elapsed Time Removed
Min.	113 kyr	130 kyr
Pref.	150 kyr	187 kyr
Max.	243 kyr	237 kyr

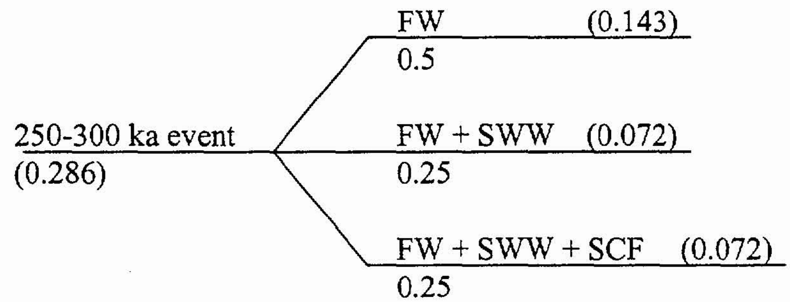
Interseismic intervals of the preferred values range from 28 to 480 kyr, with an average of 183 kyr. A possible other minimum interseismic interval can be calculated from comparing the extremes of 65-60=5 kyr, but this is deemed wholly unreasonable given the trench information available along and geomorphic expression of the Fatigue Wash fault.

	Moment Rate Recurrence	Average Earthquake Recurrence	Preferred Interseismic Interval	Averaged Earthquake Recurrence	Maximum Earthquake Occurence Rate (events/yr)
Min.	100 kyr	130 kyr	28 kyr	86 kyr	1.16×10^{-5}
Pref.	125 kyr	187 kyr	183 kyr	165 kyr	6.06×10^{-6}
Max.	150 kyr	237 kyr	480 kyr	289 kyr	3.46×10^{-6}

Relative Frequency	Nominal Age of the Event	Surface Displacement	Poss. Event Scenarios
(0.143)	20-60 ka	large fractures	FW + SWW + NWW or FW + SWW or FW
(0.286)	65-75 ka	0.15/0.25/0.35 m	FW + "ash event"
(0.286)	250-300 ka	/1.25/ m	FW + SWW + SCF or FW + SWW or FW
(0.286)	450-730 ka	/0.54/ m	FW







Final Relative Weighting:

(0.643)	FW
(0.107)	FW + SWW
(0.036)	FW + SWW + NWW
(0.071)	FW + SWW + SCF
(0.143)	FW + "ash event"

SOUTHERN WINDY WASH FAULT

Paleoseismic Information:

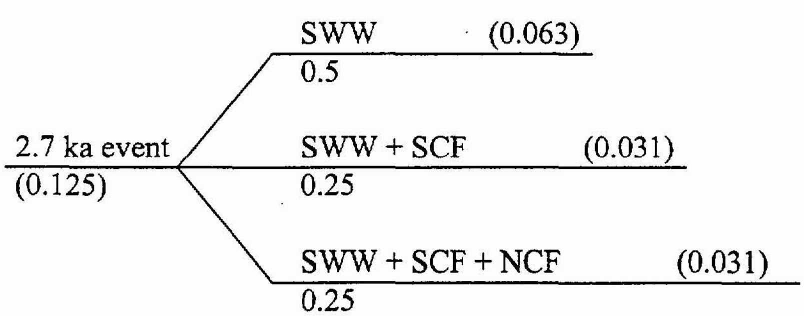
Eight events have occurred in the last 390 to 450 ka (preferred 400 ka). The most recent event occurred about 2.7 ka age.

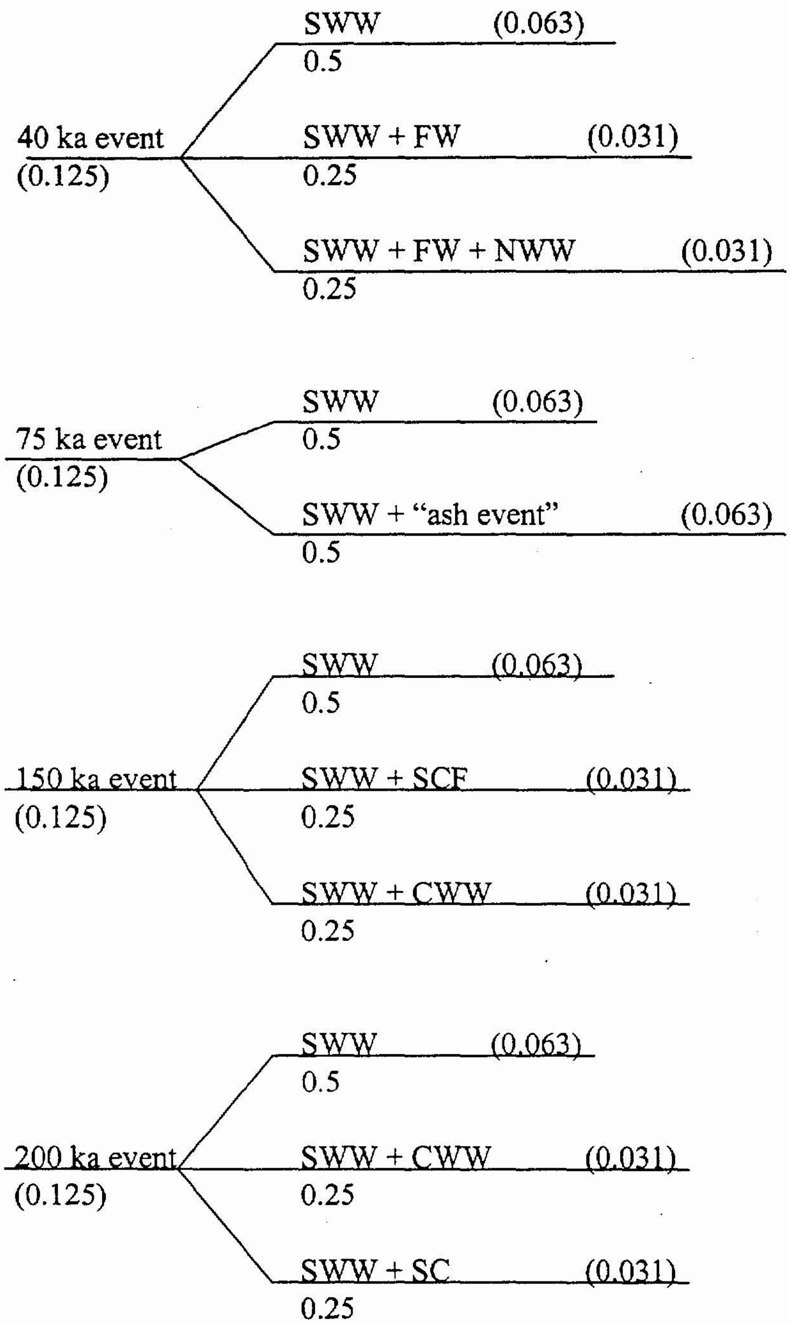
	Raw Average Earthquake Recurrence Intervals	Corrected Average Earthquake Recurrence Intervals Most Recent and Elapsed Time Removed
Min.	49 kyr	55 kyr
Pref.	50 kyr	57 kyr
Max.	56 kyr	64 kyr

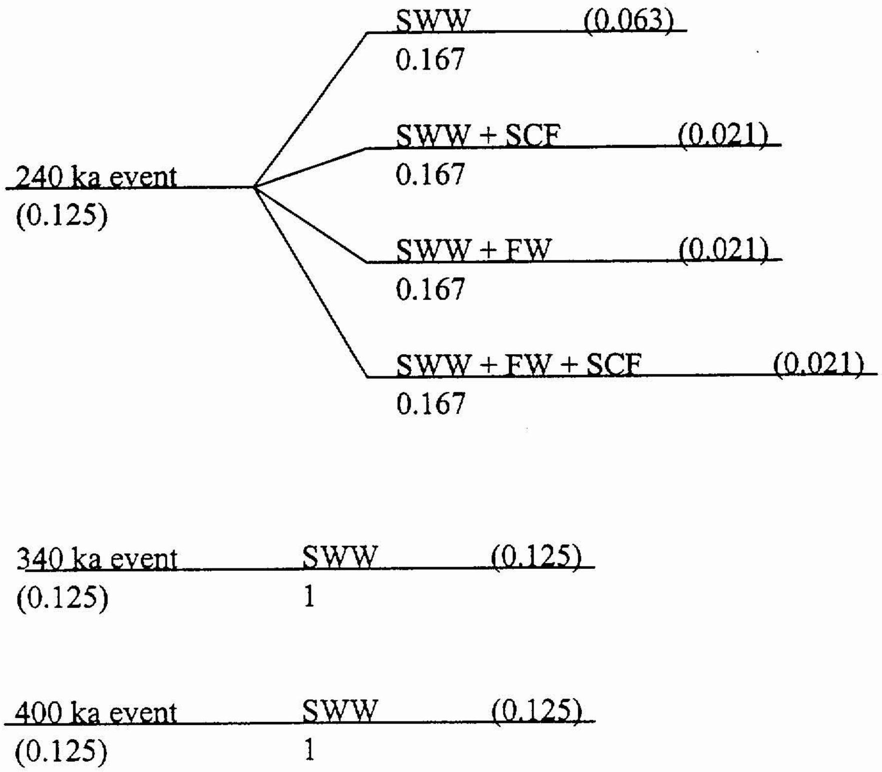
Interseismic intervals of the preferred values range from 30 kyr to 130 kyr, with an average of 62 kyr.

	Moment Rate Recurrence	Average Earthquake Recurrence	Preferred Interseismic Interval	Averaged Earthquake Recurrence	Maximum Earthquake Occurrence Rate (events/yr)
Min.	22 kyr	55 kyr	30 kyr	36 kyr	2.78×10^{-5}
Pref.	33 kyr	57 kyr	62 kyr	51 kyr	1.76×10^{-5}
Max.	37 kyr	64 kyr	130 kyr	77 kyr	1.3×10^{-5}

Relative Frequency	Nominal Age of the Event	Surface Displacement	Poss. Event Scenarios
(0.125)	2.7 ka	0.04/0.06/0.1 m	SWW + SCF + NCF or SWW + SCF or SWW
(0.125)	40 ka	0.14/0.20/0.45 m	SWW + FW + NWW or SWW + FW or SWW
(0.125)	75 ka	0.78/0.88/0.98 m	SWW + "ash event" or SWW
(0.125)	150 ka	0.38/0.42/0.52 m	SWW + CWW or SWW + SCF or SWW
(0.125)	200 ka	0.70/0.73/0.83 m	SWW + SC or SWW + CWW or SWW
(0.125)	240 ka	0.30/0.45/0.60 m	SWW + FW + SCF or SWW + FW or SWW + SCF or SWW
(0.125)	340-370 ka	0.55/0.60/0.78 m	SWW
(0.125)	400 ka	0.65/0.80?/1.00? m	SWW




40 ka event
(0.125)
SWW (0.063)
0.5
SWW + FW (0.031)
0.25
SWW + FW + NWW (0.031)
0.25
75 ka event
(0.125)
SWW (0.063)
0.5
SWW + "ash event" (0.063)
0.5
150 ka event
(0.125)
SWW (0.063)
0.5
SWW + SCF (0.031)
0.25
SWW + CWW (0.031)
0.25
200 ka event
(0.125)
SWW (0.063)
0.5
SWW + CWW (0.031)
0.25
SWW + SC (0.031)
0.25



Final Relative Weighting:

(0.625)	SWW
(0.083)	SWW + SCF
(0.052)	SWW + FW
(0.031)	SWW + SC
(0.063)	SWW + CWW
(0.031)	SWW + SCF + NCF
(0.031)	SWW + FW + NWW
(0.021)	SWW + FW + SCF
(0.063)	SWW + "ash event"

IRON RIDGE FAULT

Paleoseismic Information:

Three events have occurred along the Iron Ridge fault since 430 to 730 kyr (600 kyr pref.). The most recent event was at 5 to 10 ka and was small in offset (<0.1 m) with some question to its existence. Because of the lack of information, this event is assumed to occur for estimating corrected average earthquake recurrence intervals.

	Raw Average Earthquake Recurrence Intervals	Corrected Average Earthquake Recurrence Intervals Most Recent Event and Elapsed Time Removed
Min.	143 kyr	210 kyr
Pref.	200 kyr	295 kyr
Max.	243 kyr	360 kyr

Interseismic intervals are poorly constrained along the Iron Ridge fault.

	Moment Rate Recurrence	Average Earthquake Recurrence	Preferred Interseismic Interval	Averaged Earthquake Recurrence	Maximum Earthquake Occurrence Rate (events/yr)
Min.	76 kyr	210 kyr	none	143 kyr	6.99×10^{-6}
Pref.	106 kyr	295 kyr	none	201 kyr	4.98×10^{-6}
Max.	152 kyr	360 kyr	none	256 kyr	3.91×10^{-6}

Relative Frequency	Nominal Age of the Event	Surface Displacement	Poss. Event Scenarios
(0.333)	5-10 ka	0/0.05/0.1 m	IR
(0.333)	430-730 ka	0.5/0.7/1.0 m	IR or IR + AW or IR + AW + GD
(0.333)	430-730 ka	0.5/0.7/1.0 m	IR or IR + AW or IR + AW + GD

5-10 ka (0.333) — IR 1 — (0.333)

430-730 ka (0.667)
- IR 0.85 — (0.566)
- IR + AW 0.1 — (0.067)
- IR + AW + GD 0.05 — (0.33)

Final Relative Weighting:

(0.900)	IR
(0.067)	IR + AW
(0.033)	IR + AW + GD

PROBABILISTIC SEISMIC HAZARD ANALYSES FOR FAULT DISPLACEMENT AND VIBRATORY GROUND MOTION AT YUCCA MOUNTAIN, NEVADA

FINAL REPORT
VOLUME 3 APPENDICES

Prepared for the

U.S. Geological Survey

by the

Civilian Radioactive Waste Management System
Management & Operating Contractor

Ivan G. Wong and Carl Stepp
Report Coordinators

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23 September 1998

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APPENDIX F

GROUND MOTION
EXPERT ELICITATION SUMMARIES

The following ground motion expert interpretations have received review by PSHA Review Panel members in accordance with quality assurance approved PSHA Project Plan requirements, but have not been reviewed for conformity with Department of the Interior, U.S. Geological Survey standards.

APPENDIX F1

GROUND MOTIONS FOR THE YUCCA MOUNTAIN VICINITY, SOUTHERN NEVADA

John G. Anderson

APPENDIX F1
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APPENDIX F1

GROUND MOTIONS FOR THE YUCCA MOUNTAIN VICINITY, SOUTHERN NEVADA

John G. Anderson

F1-1 INTRODUCTION

In Fall, 1994, I was selected to be on a panel of "ground motion experts" with the responsibility to develop estimates of ground motions needed to prepare a licensing application for the proposed nuclear waste repository at Yucca Mountain, in southern Nevada. The panel met once in the spring of 1995, then due to funding and political considerations took a year off during FY 1996. The panel became active again early in 1997. Altogether, we met three times in Salt Lake City and twice in Oakland to compare approaches and share information. My stack of paper associated with this panel, if organized onto a single bookshelf, would take at least 1.3 meters of space, and the page count would be on the order of 6000 pages.

Ultimately, the panel was asked to prepare estimates of ground motions for 51 specified combinations of earthquake source and station location. The earthquake source was specified by moment magnitude, using Hanks and Kanamori (1979) as a definition to relate moment magnitude to seismic moment. The fault orientation and mechanism were given. The station location was also given. For each of these 51 combinations, each member of our panel was asked to provide his best estimate of nine ground motion parameters. These parameters were to be specified for both a random horizontal component and a vertical component. The ground motion parameters for each of these components were to be given together with three uncertainty values. To be specific, the mean estimate will be called 'mu', μ, the standard deviation of the data relative to this mean is 'sigma', σ, the uncertainty on the mean value is 'sigma-mu', σ_μ, and the uncertainty on the standard deviation is 'sigma-sigma', σ_σ. Thus the number of numbers to be specified by each expert is:

51 cases x 2 components/case x 9 parameters / component x 4 numbers / parameter
= 3672 numbers.

Information supplied to each expert included several "proponent models", in which people who have studied ground motions at Yucca Mountain provided the predictions of their model. Some of these models are empirical regressions, and some are physical models. To make the problem more tractable, I began by developing my estimates from weighted averages of some of these "proponent models". After the implications of these weighted averages were studied, I modified the input to some of the weighted averages, and then the point values themselves.

This report contains my personal evaluation of various proponent models, followed by my weighting scheme. I discuss reasons for modifying my weighting scheme and then my point estimates in some cases to produce my final point estimates.

F1-2 WEIGHTING SCHEME

The weighting scheme used to develop the preliminary point estimates is given in this section. I used the approach of first dividing the proponent models into model classes and then assigning weights to each class and to each model within a class consistent with the methodology described in Section 3.3.

F1-2.1 Model Classes

I divided the proponent models into two classes. My weighting scheme by class is as follows:

Synthetic models: 0.65
Empirical regressions: 0.35

My reasoning for this weighting is as follows:
First, I consider that the synthetic models are successful in fitting observations of ground motions where there are adequate data. Thus for these situations, it should make little difference whether one uses regressions or synthetic models. However, for some combinations of magnitudes and distances, we are using a regression or synthetic seismogram

model to extrapolate beyond the reaches of abundant data. In these situations, I trust the synthetics more for extrapolation than I trust regressions. While I recognize that the physical models for the synthetics are incomplete, there is no physical model at all behind the empirical regressions. Thus I have no reason at all to trust them for extrapolation.

Second, there is another type of extrapolation in our problem, and that is the extrapolation to a very specific site condition. For the regressions, it is necessary to make a very complicated set of adjustments to obtain those conditions. The regressions are dominantly developed for strike-slip and thrust earthquakes in a compressional environment, while the Yucca Mountain region has strike-slip and normal earthquakes in an extensional environment. The difference between a horizontal and vertical orientation for the maximum compressive stress is not explicitly taken into account in any of the models. However, our panel was presented with one study (Becker and Abrahamson 1997) indicating that on average the stress drop (defined in a special way) is smaller in extensional environments. Thus the panel was given the option to adjust regressions for this difference in average stress drops. There is a second adjustment to the regressions for the difference between the specific site condition in our project and the "average site condition" for the stations used to develop the regressions. This adjustment includes Q. Yet another adjustment for the regressions comes from the shortage of regressions for peak velocity or vertical components. One "fix" is to use ratios of these parameters to horizontal components, combined with a "trustworthy" horizontal regression. I am not aware of any documented studies which demonstrate that these adjustments are successful, although I do not see any major flaws in the physical reasoning behind them. Still, every time another adjustment is applied, more uncertainties are introduced. In contrast, the physical models do not require adjustments to calculate ground motions because the source and site condition can be input directly. Thus, the physical models are two or more steps more direct, a feature that I appreciate.

F1-2.2 Model Weights - Horizontal Component

I specified a weighting approach designed to include the full range of all of the models, and also put more emphasis on one or more preferred models. This approach is used for both the empirical regressions and the numerical simulation models.

To include the full range of the models, the probability distribution is considered to be a uniform distribution between the smallest (Ymin) and largest (Ymax) proponent model that I considered to be "qualified" as discussed below. (The uniform distribution is on the natural logarithm of the ground motion.) The median for this approach is given by the geometric mean of the largest and smallest proponent models. The epistemic uncertainty is computed from the standard deviation of the "boxcar" shaped probability distribution which is given by 0.29 ln(Ymax/Ymin). The second approach is based on my preferred model or models and is intended to give additional weight to the models that I believe to be most applicable.

The same weights are used for both the median (μ) and the aleatory uncertainty (σ).

F1-2.2.1 Empirical Models. In evaluating the empirical regressions, I look for models that are as consistent as possible with the physics of earthquakes as I understand it. My own studies indicate that the shape of regression curves ought to change with magnitude: large events ought to have a less rapid decay with distance than small events. The interaction of fault size and duration, and complexity in the Green's function, can cause varying rates of decay with distance that defy any simplistic $R^{-\gamma}$ model. Saturation is expected at short distances as magnitude increases, but it is not expected at large distances. I also expect regressions to show some nonlinear behavior in their relationship between soil and rock ground motions, although I consider this to be a weaker constraint. We are predicting motions on rock. The way soil/rock behavior is built in, however, is of the highest consequence because the majority of the available data constraining these regressions is recorded on soft sites. Thus the regressions will tend to follow the available soil data more closely, and misfit on the few rock sites can be difficult to distinguish from natural variability.

Abrahamson and Silva (1997) regression. This regression model is generally consistent with my expectations, both for magnitude-distance behavior, and in its ratio of soil/rock motions. In our tests on southern California data, it performs very well at all periods, although at 1 sec and 3 sec, its fit to the data is not as impressive as for PGA and SA at 0.3 Hz. I consider this model to be qualified. It is also my preferred model for the second approach.

Boore, *et al.* (1997); Spudich *et al.* (1997) regressions. These "USGS class" regressions do a very good job of fitting the data also. However, they do not allow for a variable ratio between soil and rock, or for a magnitude-dependent shape. The unusual definition of distance may in part compensate for the lack of magnitude-dependent shape, but I do not see a physical justification for using it. Thus, although I consider that it is crucial to take their predictions into account within my range of uncertainties, I feel less confident in using any of these to extrapolate to situations where there are little data. I consider these models to be qualified but not as preferred models.

Campbell regressions (1990, 1993, 1994, 1997). These use a lot of data for short distances. Using the distance to "seismogenic rupture" instead of the fault is conceptually good, although I consider it a little ambiguous in its implementation. They are not constrained at larger distances which, although arguably less important, are distances for which we need to make estimates of motions. Thus, I feel I cannot assign the method as much weight as the other methods above. I consider these models to be qualified but not as preferred models.

Idriss (University of California, Davis, written communication, 1997), Sadigh *et al.* (1997), Sabetta and Pugliese (1996). I have a high respect for each of these regressions, and consider that they all have some merit. I consider these models to be qualified but not as preferred models.

McGarr (1984) regression: Only the peak velocity model is recommended by McGarr as a proponent model applicable to Yucca Mountain. I consider that the physical assumptions behind this model are a little overly simplified. Therefore, I do not consider this model to be "qualified" and it is not included in defining the range of model estimates.

Weights:

I specified a relative weight of 0.1 for the boxcar model and a relative weight of 0.25 for the preferred model. (This sums to the total weight of 0.35 for the empirical models)

I considered the following empirical models to be qualified: Abrahamson and Silva (1997) with the normal faulting factor included; Boore *et al.* (1997); Campbell (1997) for soft rock; Idriss (University of California, Davis, written communication, 1997) with Idriss (University of California, Davis, written communication, 1993) for spectral shape; Sadigh *et al.* (1997); Sabetta and Pugliese (1996); and Spudich *et al.* (1996). The preferred empirical model is Abrahamson and Silva (1997).

F1-2.2.2 Numerical Simulations.

Zeng and Anderson synthetics. This model has the least amount of empiricism of any of the synthetic approaches. The source is described in a way that has been shown to include a plausible amount of complexity. Wave propagation from source to station is computed for a layered medium, so it includes body and surface waves, and scattering is incorporated. The disadvantage of this approach would be related to sensitivity of the results to Q and velocity models, which are uncertain. Still, having an approach that is predominantly a model of the physical phenomena that are involved gives me confidence in its ability to extrapolate to situations where there are little or no data. In spite of the model's successes, I recognize that there is still some physics that is not modeled properly, so I cannot give it a full weight.

Silva synthetics. This approach has the greatest amount of empiricism and the least amount of physics of any of the synthetic approaches. The spectrum of a M=5 subevent is specified, the attenuation with distance is greatly simplified, and wave propagation is not thoroughly incorporated. The advantage of this approach is that vagaries of wave propagation are "averaged out", i.e. it is less sensitive to uncertainties in regional velocity models for instance because this information is not used.

Somerville synthetics. This model is between the Zeng and Anderson approach and the Silva approach. The source is described with an empirical time function. However, wave propagation is modeled for a layered medium.

Point source model:

The point source proponent model was provided with the median and uncertainties in the point source stress drop to be specified by each expert. The following values are used:

median stress drop = 40 bars
standard deviation of stress drop = 0.5 (natural log units)
standard error of the median stress drop = 0.2 (natural log units)
standard error of the standard deviation of stress drop = 0.05

These values of the standard deviation and epistemic uncertainties are based on Ann Becker's evaluations of the normal faulting data.

Weights:

I consider all four of the numerical simulation models to be qualified. The three finite-fault synthetics are all preferred models, but the point source model is not preferred. I assigned a relative weight of 0.15 to the boxcar model and a relative weight of 0.50 to the preferred models. (This sums to the total weight of 0.65 for the numerical simulations).

Due to the differences in the finite fault simulations discussed above, I have given the following relative weights to the preferred models:

Silva finite fault	0.10
Somerville	0.15
Zeng and Anderson	0.25

More weight is given to the models with less empiricism. In some of the cases, I elected to deviate from the above approach to weighing the various models. These special cases are described below with the explanations.

F1-2.2.3 Weighting Scheme for Uncertainties. There are three types of uncertainties that need to be estimated: sigma, sigma-mu, and sigma-sigma, as defined above.

To estimate sigma, I recommend a weighted average of the values of sigma from each of the proponent models as the starting point. The weighting scheme was to be exactly the same as the scheme used to estimate the median value.

To estimate sigma-mu, I specified values of sigma-mu that I believe are reasonable to apply to each of the regressions and the synthetics as given below: These values replace the proponent model estimates of sigma mu. The total sigma-mu is computed by combining this proponent model sigma-mu with the variability of the weighted median ground motions computed using the weights described earlier.

To estimate sigma-sigma, the statistical estimates from the weighted averages are used. The magnitude 5 cases produced lower estimates of sigma-sigma than for the other magnitudes. I do not think that there should be a lower value of sigma-sigma for the lower magnitudes, so I used a constant value for all magnitudes computed from the average for magnitudes greater or equal to 5.8.

F1-2.2.4 Blast Models. The source for a blast is so different from the source of an earthquake that, in spite of all adjustments, I did not have much confidence in these models. Therefore, I gave zero weight to this class of models.

F1-2.2.5 Horizontal Component Variability. he proponent models for the horizontal component all predict the average of the two horizontal components. This project is using the random horizontal component, so the component-to-component variability needs to be added to the aleatory uncertainty. The average component-to-component variability is well determined from empirical models. The two proponent models are Boore *et al.* (1997) and Spudich *et al.* (1997). These two models are very similar. I selected the horizontal component to component variability from the Boore *et al.* (1997) model.

F1-2.3 Model Weights - Vertical Component

The weighting scheme described for the horizontal component is also used for the vertical component. For models without a vertical component, a zero weight is used. No scaling based on vertical/horizontal ratios is used.

F1-3 ADJUSTMENTS TO WEIGHTED POINT ESTIMATES

The weighting scheme described in Section F1-2 is used to develop preliminary point estimates for each of the 918 required estimates of the median and aleatory uncertainty. I reviewed these point estimates and made some adjustments for particular cases for which the weighted estimates were not consistent with my judgments.

The changes to the point estimates are listed below: for cases 22, 23, and 24, Spudich *et al.* (1997), Boore *et al.* (1997), and Sabetta and Pugliese (1996) were excluded. I consider that the inflexible distance dependence and magnitude form used in these models will tend to cause these models to overestimate the ground motions for M=5 at 50 and 160 km distances.

F1-4 EPISTEMIC UNCERTAINTY

Based on my weighting scheme and proponent model sigma-mu (Table F1-1), the epistemic uncertainties (σ_μ and σ_σ) were computed by the facilitation team. I made the following modifications to these statistical estimates of the epistemic uncertainty:

I set a minimum value of 0.2 natural log units for the epistemic uncertainty to cover the cases in which the statistical estimate was low due to chance agreement of the various proponent models or few proponent models being available for some particular cases.

Table F1-1. Values of Sigma-Mu to be used for the Proponent Models

	X Distance			
M Range	**1,5 km**	**10 km**	**50 km**	**100,160 km**
5, 5.8	0.6	0.4	0.4	0.5
6.5	0.65	0.3	0.3	0.60
70, 7.5, 8.0	0.70	0.4	0.4	0.60

F1-5 FINAL POINT ESTIMATES

After making the adjustments to the weighted estimates as described above, my final point estimates of μ, σ, σ_μ, and σ_σ for the horizontal component for the 51 cases are given in Tables F1-2 to F1-10 for the nine ground motion parameters. The corresponding point estimates for the vertical component are given in Tables F1-11 to F1-19.

F1-6 EVALUATION OF REGRESSION MODELS

The facilitation team developed regression models to parameterize my point estimates in terms of the dependence on magnitude, distance, and style-of-faulting. I reviewed the final regression models given in Volume 11A of the data package. These regression models adequately model my point estimates of the median, aleatory uncertainty, epistemic uncertainty in the median, and epistemic uncertainty in the aleatory uncertainty.

F1-7 SPECIAL CASES

The ground motion models developed in this study are for " typical" events that cover the majority of the source models developed by the source experts. There are two source models that have geometries significantly different from those considered in developing the base models. These are simultaneous rupture of multiple parallel faults (local events) and a low angle fault. These two cases are discussed below.

F1-7.1 Multiple Parallel Faults

Some of the experts on describing sources have hypothesized that it is possible for more than one fault to rupture in a single earthquake. The question then is what the ground motion would be. What is needed is some approach that is simple to implement for a probabilistic seismic hazard assessment.

In order to discuss options, some terminology is needed. Suppose that there are J faults that are involved in a single earthquake. I characterize the moment, moment magnitude, and rupture distance to the j[th] fault as M_o^j, M_w^j, and R^j. The total moment and moment magnitude for the event are $M_o = \sum_{j=1}^{J} M_o^j$, and $M_w = \frac{2}{3}(\log(M_o - 16)$. Finally, let the ground motion parameter that we are seeking to predict be $Y = GM(M,R)$, and designate the ground motion from each of the subevents as Y_1, Y_2, ...

While any number of possibilities exist, I considered the following alternatives:

A1. Choose Y = max(Y_1, Y_2,...). This treats each subfault as an independent event, and acts as if the ruptures are sufficiently separated in time that the peak is controlled by the one causing the largest motions. However, having multiple ruptures on either side of the station could lead to multiple sources of energy that are all contributing at the same time. Thus, intuitively we might expect something larger than the prediction in this approach.

A2. Define $R^m = \min\{R^1,...,R^J\}$. Use $Y = GM(M_w, R^m)$. If we had any strong motion data, this is the way that it would be entered into the regression. It does not model the physics correctly, but the ground motion it predicts will be greater than the approach A1. Some preliminary calculations by Paul Somerville, supplied to our panel, suggested that the predictions using this approach are smaller than his model. However, it should be clear that we do not know what input to a physical rupture model is appropriate for this situation.

A3. Let R^e be an "effective distance" defined as $\frac{1}{R^e} = \sum_{j=1}^{J} \frac{1}{R^J}$. Use $Y = GM(M_w, R^e)$. This is strictly an "engineering fix" which adjusts to a closer distance, and thus predicts a larger ground motion than approach A1 or A2.

A4. Choose $Y = \{\sum_{j=1}^{J} Y_j^2\}^{1/2}$. This approach would rest on the physical assumption that the peak values of Y from all of the subfaults arrive at the same time, but interfere randomly.

A5. Choose $Y = \sum_{j=1}^{J} Y_j$. This approach would rest on the physical assumption that the peak values of Y from all of the subfaults arrive at the same time, and that they add constructively.

A6. Considering that subevent 1 causes the largest motions of any of the subevents, choose $Y = \{Y_1^2 + \sum_{j=2}^{J} (kY_j)^2\}^{1/2}$. This approach would rest on the physical assumption that the peak values of Y from all of the subfaults interfere randomly. It is modified from A4 with a judgmental assumption that ground motions from other subevents will be below their peak values at the time that the peak from the largest subevent arrives. The factor k is obviously arbitrary within the range $0 \le k \le 1$. Case A1 is the special case of this one in which *k=0.* Case 4 is a special case of this one where *k=1.* A value of *k=2/3* seems plausible to me.

Considering these six alternatives, I think A1, A3, and A5 are least likely since they do not match the physics of the situation. A2 may match the practice of regression analysis, but actual recordings for this situation may tend to have positive residuals because of the special geometry. I prefer approach A6 with $k=2/3$; however, if this gives values of ground motions that are smaller than A2, then replace those values with the estimate using method A2.

F1-7.2 Low Angle Fault

The second difficult case is one of a detachment fault beneath the site. The hypothesis is that there could be some "normal" faulting detachment, potentially large, on a very shallow dipping fault. There are no data available to predict how such a fault could behave. One physical hypothesis is that an event of this type would be much like any other event. A second hypothesis is that such an event could have a longer rise time, looking more like a creep event. Defense of this hypothesis would rest on the lack of observations of any well documented events of this type. The reasoning would be that the lack of observations is caused by these events mostly occurring by creep, but once in a while they accelerate more to be an actual earthquake. To my mind, the most reasonable approach for this case is to assume that if there should be such an event, the ground motions that it causes will be similar to the ground motions caused by other earthquakes in the region. It is plausible that there have been some detachment events, but they have not been recognized as such; failure to recognize them would be more likely if they are otherwise typical. Lacking any other better information, for this type of event, my recommendation is to use the regressions we have without modification.

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TABLE F1-2
J. G. ANDERSON: HORIZONTAL POINT ESTIMATES
PEAK GROUND ACCELERATION

CASE NO.	MAGNITUDE	DISTANCE (KM)	MU	SIGMA	SIGMA MU	SIGMA SIGMA
1	5.00	1	0.12411	0.65861	0.60000	0.09940
2	5.00	1	0.21635	0.66848	0.60000	0.09751
3	5.00	5	0.04459	0.66354	0.60000	0.09838
4	5.00	5	0.07861	0.66848	0.60000	0.09751
5	5.80	10	0.09918	0.60246	0.40000	0.11865
6	5.80	20	0.07996	0.60163	0.40000	0.11873
7	6.50	1	0.49138	0.57948	0.65000	0.11251
8	6.50	1	0.58235	0.58496	0.65000	0.11615
9	6.50	1	0.49031	0.58159	0.65000	0.11337
10	6.50	5	0.40357	0.57561	0.65000	0.11103
11	6.50	5	0.27324	0.58284	0.65000	0.11404
12	6.50	50	0.03178	0.57500	0.30000	0.11091
13	6.50	50	0.03063	0.57469	0.30000	0.11086
14	7.00	10	0.28433	0.54940	0.40000	0.12564
15	7.50	50	0.06512	0.55389	0.40000	0.13012
16	7.50	50	0.06628	0.55029	0.40000	0.12811
17	5.00	1	0.05417	0.67286	0.60000	0.05269
18	5.80	5	0.16911	0.60316	0.60000	0.11862
19	5.80	5	0.09635	0.60271	0.60000	0.11863
20	5.00	10	0.06634	0.66354	0.40000	0.09838
21	5.00	10	0.08545	0.65861	0.40000	0.09940
22	5.00	50	0.00580	0.65861	0.40000	0.09940
23	5.00	50	0.00555	0.65369	0.40000	0.10058
24	5.00	160	0.00076	0.64878	0.50000	0.10190
25	5.80	1	0.27500	0.60477	0.60000	0.11932
26	5.80	5	0.23217	0.60200	0.60000	0.11868
27	5.80	5	0.13897	0.60223	0.60000	0.11866
28	5.80	10	0.12399	0.61010	0.40000	0.12100
29	5.80	10	0.17957	0.60223	0.40000	0.11866
30	5.80	10	0.07494	0.60440	0.60000	0.11936
31	5.80	50	0.01290	0.60631	0.40000	0.06216
32	5.80	50	0.01273	0.61383	0.40000	0.06304
33	6.50	5	0.35218	0.57646	0.65000	0.11124
34	6.50	10	0.22425	0.57921	0.30000	0.11243
35	6.50	10	0.33871	0.57876	0.30000	0.11230
36	6.50	10	0.16640	0.57583	0.65000	0.11108
37	6.50	20	0.11192	0.57507	0.30000	0.11092
38	6.50	20	0.16599	0.57966	0.30000	0.11257
39	6.50	20	0.08065	0.57239	0.65000	0.10990
40	6.50	100	0.01559	0.57652	0.60000	0.11190
41	6.50	160	0.00544	0.59316	0.60000	0.12156
42	7.00	1	0.50377	0.55133	0.60000	0.12653
43	7.00	10	0.38880	0.55458	0.40000	0.12835
44	7.00	10	0.20551	0.54700	0.60000	0.12475
45	7.00	50	0.04945	0.54715	0.40000	0.12480
46	7.00	50	0.04857	0.54926	0.40000	0.12559
47	7.50	1	0.54649	0.57853	0.60000	0.14692
48	5.00	10	0.29788	0.56966	0.40000	0.14041
49	5.00	10	0.39649	0.55316	0.40000	0.12968
50	8.00	50	0.07505	0.58503	0.40000	0.07992
51	8.00	160	0.02345	0.57622	0.60000	0.07396

TABLE F1-3
J. G. ANDERSON: HORIZONTAL POINT ESTIMATES SPECTRAL ACCELERATION AT 0.05 SEC PERIOD

CASE NO.	MAGNITUDE	DISTANCE (KM)	MU	SIGMA	SIGMA MU	SIGMA SIGMA
1	5.00	1	0.21962	0.66700	0.60000	0.07622
2	5.00	1	0.36309	0.67199	0.60000	0.07449
3	5.00	5	0.08181	0.67199	0.60000	0.07449
4	5.00	5	0.12701	0.67699	0.60000	0.07296
5	5.80	10	0.16346	0.61190	0.40000	0.11023
6	5.80	20	0.12482	0.60578	0.40000	0.10898
7	6.50	1	0.78883	0.58479	0.65000	0.10645
8	6.50	1	0.89820	0.58975	0.65000	0.11012
9	6.50	1	0.76665	0.58320	0.65000	0.10570
10	6.50	5	0.67474	0.58136	0.65000	0.10581
11	6.50	5	0.45286	0.58163	0.65000	0.10514
12	6.50	50	0.04361	0.57927	0.30000	0.10469
13	6.50	50	0.04262	0.57887	0.30000	0.10466
14	7.00	10	0.44758	0.54791	0.40000	0.12662
15	7.50	50	0.09058	0.55293	0.40000	0.13241
16	7.50	50	0.09298	0.54901	0.40000	0.13032
17	5.00	1	0.10922	0.67982	0.60000	0.04674
18	5.80	5	0.26202	0.60503	0.60000	0.10813
19	5.80	5	0.15036	0.60649	0.60000	0.10881
20	5.00	10	0.12213	0.69203	0.40000	0.06961
21	5.00	10	0.16206	0.67199	0.40000	0.07449
22	5.00	50	0.00921	0.66711	0.40000	0.05695
23	5.00	50	0.00869	0.66711	0.40000	0.05695
24	5.00	160	0.00109	0.65221	0.50000	0.06686
25	5.80	1	0.47736	0.60699	0.60000	0.10872
26	5.80	5	0.40567	0.61356	0.60000	0.11139
27	5.80	5	0.23371	0.61142	0.60000	0.11033
28	5.80	10	0.20626	0.61684	0.40000	0.11236
29	5.80	10	0.29213	0.60651	0.40000	0.10881
30	5.80	10	0.12417	0.60413	0.60000	0.10826
31	5.80	50	0.01881	0.61804	0.40000	0.03868
32	5.80	50	0.01822	0.62182	0.40000	0.03960
33	6.50	5	0.57701	0.57538	0.65000	0.10302
34	6.50	10	0.37664	0.58812	0.30000	0.10868
35	6.50	10	0.56006	0.58070	0.30000	0.10490
36	6.50	10	0.27161	0.58483	0.65000	0.10717
37	6.50	20	0.17553	0.58611	0.30000	0.10852
38	6.50	20	0.25800	0.58596	0.30000	0.10735
39	6.50	20	0.12533	0.57872	0.65000	0.10465
40	6.50	100	0.01850	0.57817	0.60000	0.10465
41	6.50	160	0.00726	0.57862	0.60000	0.10465
42	7.00	1	0.85798	0.55091	0.60000	0.12790
43	7.00	10	0.65565	0.55480	0.40000	0.13006
44	7.00	10	0.33873	0.54622	0.60000	0.12607
45	7.00	50	0.07000	0.54543	0.40000	0.12584
46	7.00	50	0.06948	0.54814	0.40000	0.12671
47	7.50	1	0.89060	0.57994	0.60000	0.15113
48	5.00	10	0.48541	0.57051	0.40000	0.14410
49	5.00	10	0.63775	0.55230	0.40000	0.13204
50	8.00	50	0.10072	0.58885	0.40000	0.08569
51	8.00	160	0.02545	0.57608	0.60000	0.07834

TABLE F1-4
J. G. ANDERSON: HORIZONTAL POINT ESTIMATES
SPECTRAL ACCELERATION AT 0.10 SEC PERIOD

CASE NO.	MAGNITUDE	DISTANCE (KM)	MU	SIGMA	SIGMA MU	SIGMA SIGMA
1	5.00	1	0.27826	0.72629	0.60000	0.09707
2	5.00	1	0.48422	0.71610	0.60000	0.09652
3	5.00	5	0.10119	0.72629	0.60000	0.09707
4	5.00	5	0.18575	0.72119	0.60000	0.09671
5	5.80	10	0.20065	0.63353	0.40000	0.12796
6	5.80	20	0.16039	0.63396	0.40000	0.12801
7	6.50	1	1.01411	0.61305	0.65000	0.12920
8	6.50	1	1.25153	0.61461	0.65000	0.13042
9	6.50	1	1.03999	0.61199	0.65000	0.12864
10	6.50	5	0.81889	0.60378	0.65000	0.12470
11	6.50	5	0.57148	0.60757	0.65000	0.12634
12	6.50	50	0.05993	0.60472	0.30000	0.12501
13	6.50	50	0.05698	0.60203	0.30000	0.12366
14	7.00	10	0.56552	0.56009	0.40000	0.13217
15	7.50	50	0.11973	0.57033	0.40000	0.14153
16	7.50	50	0.12691	0.56279	0.40000	0.13713
17	5.00	1	0.12606	0.68511	0.60000	0.05783
18	5.80	5	0.35628	0.63468	0.60000	0.12811
19	5.80	5	0.19970	0.63161	0.60000	0.12695
20	5.00	10	0.14936	0.72629	0.40000	0.09707
21	5.00	10	0.19680	0.70592	0.40000	0.09670
22	5.00	50	0.01241	0.71610	0.40000	0.09652
23	5.00	50	0.01174	0.70592	0.40000	0.09670
24	5.00	160	0.00140	0.69069	0.50000	0.09831
25	5.80	1	0.55892	0.63821	0.60000	0.12947
26	5.80	5	0.50366	0.63422	0.60000	0.12804
27	5.80	5	0.28199	0.63986	0.60000	0.13073
28	5.80	10	0.23985	0.63929	0.40000	0.13071
29	5.80	10	0.35203	0.63389	0.40000	0.12800
30	5.80	10	0.15166	0.62657	0.60000	0.12560
31	5.80	50	0.02490	0.65456	0.40000	0.07141
32	5.80	50	0.02364	0.65835	0.40000	0.07331
33	6.50	5	0.72848	0.60678	0.65000	0.12591
34	6.50	10	0.46044	0.60837	0.30000	0.12684
35	6.50	10	0.70615	0.60734	0.30000	0.12650
36	6.50	10	0.34014	0.60774	0.65000	0.12662
37	6.50	20	0.22633	0.60070	0.30000	0.12316
38	6.50	20	0.31735	0.60326	0.30000	0.12424
39	6.50	20	0.15737	0.60418	0.65000	0.12483
40	6.50	100	0.02506	0.60004	0.60000	0.12296
41	6.50	160	0.00918	0.60035	0.60000	0.12305
42	7.00	1	1.05676	0.56497	0.60000	0.13511
43	7.00	10	0.79509	0.57010	0.40000	0.13808
44	7.00	10	0.41749	0.56023	0.60000	0.13192
45	7.00	50	0.09343	0.55857	0.40000	0.13120
46	7.00	50	0.09229	0.56109	0.40000	0.13286
47	7.50	1	1.07643	0.59466	0.60000	0.15928
48	5.00	10	0.59081	0.58555	0.40000	0.15206
49	5.00	10	0.77500	0.56822	0.40000	0.14024
50	8.00	50	0.13350	0.63443	0.40000	0.10837
51	8.00	160	0.02994	0.61071	0.60000	0.09424

TABLE F1-5
J. G. ANDERSON: HORIZONTAL POINT ESTIMATES
SPECTRAL ACCELERATION AT 0.20 SEC PERIOD

CASE NO.	MAGNITUDE	DISTANCE (KM)	MU	SIGMA	SIGMA MU	SIGMA SIGMA
1	5.00	1	0.21253	0.75048	0.60000	0.08726
2	5.00	1	0.36713	0.76045	0.60000	0.08706
3	5.00	5	0.07666	0.74055	0.60000	0.08821
4	5.00	5	0.13967	0.73559	0.60000	0.08897
5	5.80	10	0.19290	0.67167	0.40000	0.12614
6	5.80	20	0.16291	0.65818	0.40000	0.12219
7	6.50	1	0.97252	0.63718	0.65000	0.12026
8	6.50	1	1.17980	0.65105	0.65000	0.12674
9	6.50	1	1.02196	0.65803	0.65000	0.13015
10	6.50	5	0.80188	0.64246	0.65000	0.12287
11	6.50	5	0.56675	0.63835	0.65000	0.12050
12	6.50	50	0.06656	0.63731	0.30000	0.12030
13	6.50	50	0.06494	0.63044	0.30000	0.11766
14	7.00	10	0.56999	0.59392	0.40000	0.13309
15	7.50	50	0.15030	0.59980	0.40000	0.13938
16	7.50	50	0.15874	0.59278	0.40000	0.13557
17	5.00	1	0.09982	0.71644	0.60000	0.05958
18	5.80	5	0.31328	0.66445	0.60000	0.12392
19	5.80	5	0.20028	0.66170	0.60000	0.12302
20	5.00	10	0.11445	0.74055	0.40000	0.08821
21	5.00	10	0.14818	0.73559	0.40000	0.08897
22	5.00	50	0.01303	0.75048	0.40000	0.08726
23	5.00	50	0.01051	0.72570	0.40000	0.09100
24	5.00	160	0.00201	0.73559	0.50000	0.08897
25	5.80	1	0.50600	0.66414	0.60000	0.12391
26	5.80	5	0.43848	0.66353	0.60000	0.12392
27	5.80	5	0.25975	0.66463	0.60000	0.12392
28	5.80	10	0.22186	0.66860	0.40000	0.12500
29	5.80	10	0.32185	0.65864	0.40000	0.12223
30	5.80	10	0.15099	0.67076	0.60000	0.12612
31	5.80	50	0.02556	0.68556	0.40000	0.06030
32	5.80	50	0.02720	0.68514	0.40000	0.06040
33	6.50	5	0.70065	0.63179	0.65000	0.11813
34	6.50	10	0.42825	0.64154	0.30000	0.12203
35	6.50	10	0.65041	0.63582	0.30000	0.11971
36	6.50	10	0.34349	0.62979	0.65000	0.11725
37	6.50	20	0.22125	0.63987	0.30000	0.12151
38	6.50	20	0.33881	0.63629	0.30000	0.12002
39	6.50	20	0.17088	0.63492	0.65000	0.11933
40	6.50	100	0.03070	0.63597	0.60000	0.11994
41	6.50	160	0.01278	0.64211	0.60000	0.12281
42	7.00	1	1.02238	0.59574	0.60000	0.13386
43	7.00	10	0.80487	0.59900	0.40000	0.13591
44	7.00	10	0.44746	0.59163	0.60000	0.13176
45	7.00	50	0.11076	0.59190	0.40000	0.13190
46	7.00	50	0.11222	0.59254	0.40000	0.13227
47	7.50	1	1.17143	0.62217	0.60000	0.15375
48	5.00	10	0.65887	0.61950	0.40000	0.15180
49	5.00	10	0.83377	0.59386	0.40000	0.13627
50	8.00	50	0.16681	0.65700	0.40000	0.09999
51	8.00	160	0.04360	0.64045	0.60000	0.09158

TABLE F1-6
J. G. ANDERSON: HORIZONTAL POINT ESTIMATES
SPECTRAL ACCELERATION AT 0.50 SEC PERIOD

CASE No.	MAGNITUDE	DISTANCE (KM)	MU	SIGMA	SIGMA MU	SIGMA SIGMA
1	5.00	1	0.09182	0.81772	0.60000	0.07969
2	5.00	1	0.17663	0.79323	0.60000	0.08046
3	5.00	5	0.03461	0.81281	0.60000	0.07943
4	5.00	5	0.06542	0.79811	0.60000	0.07990
5	5.80	10	0.10844	0.72136	0.40000	0.13195
6	5.80	20	0.10151	0.72685	0.40000	0.13418
7	6.50	1	0.62512	0.69297	0.65000	0.13291
8	6.50	1	0.72492	0.69748	0.65000	0.13511
9	6.50	1	0.62977	0.70147	0.65000	0.13678
10	6.50	5	0.50364	0.69308	0.65000	0.13277
11	6.50	5	0.34712	0.69310	0.65000	0.13297
12	6.50	50	0.05285	0.69814	0.30000	0.13484
13	6.50	50	0.05828	0.69137	0.30000	0.13230
14	7.00	10	0.42692	0.64534	0.40000	0.14039
15	7.50	50	0.13294	0.65082	0.40000	0.14673
16	7.50	50	0.13968	0.64518	0.40000	0.14279
17	5.00	1	0.04782	0.76695	0.60000	0.06060
18	5.80	5	0.18569	0.72762	0.60000	0.13448
19	5.80	5	0.10197	0.72540	0.60000	0.13321
20	5.00	10	0.04771	0.79323	0.40000	0.08046
21	5.00	10	0.06542	0.78350	0.40000	0.08216
22	5.00	50	0.00671	0.79064	0.40000	0.06722
23	5.00	50	0.00796	0.79552	0.40000	0.06614
24	5.00	160	0.00163	0.78092	0.50000	0.07001
25	5.80	1	0.29543	0.71784	0.60000	0.13144
26	5.80	5	0.26108	0.72073	0.60000	0.13230
27	5.80	5	0.14513	0.71364	0.60000	0.13035
28	5.80	10	0.14499	0.72699	0.40000	0.13423
29	5.80	10	0.21267	0.72216	0.40000	0.13265
30	5.80	10	0.08279	0.72160	0.60000	0.13250
31	5.80	50	0.01904	0.74592	0.40000	0.06706
32	5.80	50	0.01898	0.75642	0.40000	0.06982
33	6.50	5	0.46682	0.69192	0.65000	0.13249
34	6.50	10	0.31615	0.69644	0.30000	0.13441
35	6.50	10	0.46655	0.69592	0.30000	0.13419
36	6.50	10	0.21889	0.69184	0.65000	0.13246
37	6.50	20	0.15813	0.69313	0.30000	0.13298
38	6.50	20	0.24457	0.70130	0.30000	0.13668
39	6.50	20	0.12575	0.69227	0.65000	0.13262
40	6.50	100	0.03114	0.69300	0.60000	0.13292
41	6.50	160	0.01463	0.70174	0.60000	0.13703
42	7.00	1	0.73935	0.64696	0.60000	0.14155
43	7.00	10	0.62325	0.64772	0.40000	0.14220
44	7.00	10	0.30515	0.64527	0.60000	0.14035
45	7.00	50	0.09002	0.64567	0.40000	0.14069
46	7.00	50	0.09322	0.64853	0.40000	0.14275
47	7.50	1	0.83194	0.67418	0.60000	0.16209
48	5.00	10	0.47527	0.66602	0.40000	0.15619
49	5.00	10	0.60988	0.64994	0.40000	0.14625
50	8.00	50	0.15882	0.71713	0.40000	0.10679
51	8.00	160	0.05723	0.70921	0.60000	0.10354

TABLE F1-7
J. G. ANDERSON: HORIZONTAL POINT ESTIMATES
SPECTRAL ACCELERATION AT 1.00 SEC PERIOD

CASE NO.	MAGNITUDE	DISTANCE (KM)	MU	SIGMA	SIGMA MU	SIGMA SIGMA
1	5.00	1	0.03848	0.83470	0.60000	0.07295
2	5.00	1	0.07157	0.82983	0.60000	0.07357
3	5.00	5	0.01459	0.82497	0.60000	0.07440
4	5.00	5	0.02649	0.82497	0.60000	0.07440
5	5.80	10	0.05332	0.78390	0.40000	0.12761
6	5.80	20	0.04668	0.77780	0.40000	0.13073
7	6.50	1	0.32531	0.75929	0.65000	0.13322
8	6.50	1	0.33897	0.75905	0.65000	0.13728
9	6.50	1	0.29366	0.75099	0.65000	0.13450
10	6.50	5	0.26459	0.75485	0.65000	0.13543
11	6.50	5	0.16689	0.74962	0.65000	0.13387
12	6.50	50	0.03369	0.75189	0.30000	0.13086
13	6.50	50	0.03060	0.74996	0.30000	0.13399
14	7.00	10	0.22092	0.72545	0.40000	0.14131
15	7.50	50	0.08143	0.73839	0.40000	0.13724
16	7.50	50	0.08248	0.73188	0.40000	0.13754
17	5.00	1	0.01923	0.80619	0.60000	0.04866
18	5.80	5	0.08099	0.79699	0.60000	0.13633
19	5.80	5	0.04612	0.79288	0.60000	0.13484
20	5.00	10	0.01851	0.82013	0.40000	0.07543
21	5.00	10	0.02390	0.82013	0.40000	0.07543
22	5.00	50	0.00251	0.81501	0.40000	0.07523
23	5.00	50	0.00272	0.82955	0.40000	0.07216
24	5.00	160	0.00087	0.82469	0.50000	0.07298
25	5.80	1	0.13518	0.79064	0.60000	0.12931
26	5.80	5	0.11623	0.77322	0.60000	0.12975
27	5.80	5	0.06390	0.78821	0.60000	0.13368
28	5.80	10	0.06662	0.78645	0.40000	0.12831
29	5.80	10	0.10017	0.77485	0.40000	0.12996
30	5.80	10	0.04015	0.78745	0.60000	0.13335
31	5.80	50	0.01000	0.78801	0.40000	0.08169
32	5.80	50	0.01057	0.79829	0.40000	0.08448
33	6.50	5	0.22618	0.76405	0.65000	0.13487
34	6.50	10	0.16864	0.75653	0.30000	0.13220
35	6.50	10	0.25515	0.75155	0.30000	0.13453
36	6.50	10	0.11253	0.74926	0.65000	0.13376
37	6.50	20	0.08329	0.75034	0.30000	0.13031
38	6.50	20	0.12713	0.75584	0.30000	0.13575
39	6.50	20	0.06423	0.75055	0.65000	0.13420
40	6.50	100	0.02102	0.75253	0.60000	0.13101
41	6.50	160	0.01007	0.75449	0.60000	0.13177
42	7.00	1	0.34756	0.72444	0.60000	0.14096
43	7.00	10	0.30195	0.72178	0.40000	0.14501
44	7.00	10	0.17011	0.71521	0.60000	0.14153
45	7.00	50	0.04970	0.72526	0.40000	0.14124
46	7.00	50	0.04579	0.71639	0.40000	0.14205
47	7.50	1	0.43714	0.74001	0.60000	0.15057
48	5.00	10	0.27341	0.73851	0.40000	0.14979
49	5.00	10	0.33899	0.72074	0.40000	0.14591
50	8.00	50	0.10819	0.75977	0.40000	0.12039
51	8.00	160	0.04934	0.76032	0.60000	0.12097

TABLE F1-8
J. G. ANDERSON: HORIZONTAL POINT ESTIMATES
SPECTRAL ACCELERATION AT 2.00 SEC PERIOD

CASE NO.	MAGNITUDE	DISTANCE (KM)	MU	SIGMA	SIGMA MU	SIGMA SIGMA
1	5.00	1	0.00967	0.91473	0.60000	0.09834
2	5.00	1	0.01766	0.90503	0.60000	0.09833
3	5.00	5	0.00429	0.89054	0.60000	0.09949
4	5.00	5	0.00722	0.89054	0.60000	0.09949
5	5.80	10	0.01764	0.86291	0.40000	0.14263
6	5.80	20	0.01324	0.85159	0.40000	0.15310
7	6.50	1	0.14955	0.84202	0.65000	0.15042
8	6.50	1	0.14694	0.83226	0.65000	0.15898
9	6.50	1	0.12619	0.83308	0.65000	0.15927
10	6.50	5	0.10994	0.83285	0.65000	0.15946
11	6.50	5	0.08031	0.83409	0.65000	0.15992
12	6.50	50	0.01482	0.84269	0.30000	0.15107
13	6.50	50	0.01245	0.82926	0.30000	0.15709
14	7.00	10	0.09530	0.81592	0.40000	0.15893
15	7.50	50	0.04246	0.84784	0.40000	0.15496
16	7.50	50	0.03945	0.82720	0.40000	0.14887
17	5.00	1	0.00529	0.93024	0.60000	0.03541
18	5.80	5	0.03223	0.84236	0.60000	0.14847
19	5.80	5	0.01781	0.84938	0.60000	0.15168
20	5.00	10	0.00620	0.89054	0.40000	0.09949
21	5.00	10	0.00689	0.89536	0.40000	0.09894
22	5.00	50	0.00097	0.88665	0.40000	0.07855
23	5.00	50	0.00079	0.88665	0.40000	0.07855
24	5.00	160	0.00051	0.88665	0.50000	0.07855
25	5.80	1	0.05348	0.87420	0.60000	0.14729
26	5.80	5	0.04402	0.84245	0.60000	0.14833
27	5.80	5	0.02789	0.84705	0.60000	0.15045
28	5.80	10	0.02181	0.86939	0.40000	0.14679
29	5.80	10	0.02737	0.85828	0.40000	0.15678
30	5.80	10	0.01554	0.84433	0.60000	0.14919
31	5.80	50	0.00377	0.87408	0.40000	0.11319
32	5.80	50	0.00355	0.87403	0.40000	0.11837
33	6.50	5	0.10674	0.84274	0.65000	0.15044
34	6.50	10	0.06854	0.84455	0.30000	0.15122
35	6.50	10	0.08816	0.83175	0.30000	0.15931
36	6.50	10	0.04899	0.82984	0.65000	0.15742
37	6.50	20	0.03960	0.84732	0.30000	0.15266
38	6.50	20	0.04725	0.82660	0.30000	0.15579
39	6.50	20	0.02678	0.82769	0.65000	0.15634
40	6.50	100	0.01006	0.84426	0.60000	0.15142
41	6.50	160	0.00501	0.85388	0.60000	0.15625
42	7.00	1	0.21678	0.81592	0.60000	0.15893
43	7.00	10	0.12529	0.79484	0.40000	0.16543
44	7.00	10	0.07081	0.79876	0.60000	0.16891
45	7.00	50	0.02427	0.81633	0.40000	0.15916
46	7.00	50	0.02062	0.79152	0.40000	0.16282
47	7.50	1	0.24029	0.82688	0.60000	0.16830
48	5.00	10	0.11234	0.81701	0.40000	0.16160
49	5.00	10	0.13137	0.78776	0.40000	0.16196
50	8.00	50	0.06787	0.86100	0.40000	0.16242
51	8.00	160	0.03689	0.86532	0.60000	0.16370

TABLE F1-9
J. G. ANDERSON: HORIZONTAL POINT ESTIMATES SPECTRAL ACCELERATION AT 3.33 SEC PERIOD

CASE NO.	MAGNITUDE	DISTANCE (KM)	MU	SIGMA	SIGMA MU	SIGMA SIGMA
1	5.00	1	0.00348	0.98219	0.60000	0.10129
2	5.00	1	0.00584	0.96740	0.60000	0.09676
3	5.00	5	0.00152	0.96740	0.60000	0.09676
4	5.00	5	0.00264	0.96740	0.60000	0.09676
5	5.80	10	0.00826	0.89185	0.40000	0.14181
6	5.80	20	0.00526	0.87786	0.40000	0.15200
7	6.50	1	0.07200	0.88468	0.65000	0.16220
8	6.50	1	0.06817	0.85442	0.65000	0.15369
9	6.50	1	0.05983	0.86099	0.65000	0.15885
10	6.50	5	0.05654	0.86581	0.65000	0.16260
11	6.50	5	0.04285	0.86895	0.65000	0.16557
12	6.50	50	0.00737	0.88514	0.30000	0.15858
13	6.50	50	0.00550	0.86360	0.30000	0.16081
14	7.00	10	0.04539	0.84914	0.40000	0.17006
15	7.50	50	0.02694	0.88919	0.40000	0.12968
16	7.50	50	0.02115	0.87418	0.40000	0.12221
17	5.00	1	0.00155	0.97729	0.60000	0.06387
18	5.80	5	0.01386	0.88358	0.60000	0.15653
19	5.80	5	0.00702	0.88264	0.60000	0.15561
20	5.00	10	0.00233	0.95757	0.40000	0.09449
21	5.00	10	0.00238	0.96248	0.40000	0.09555
22	5.00	50	0.00050	0.95267	0.40000	0.09359
23	5.00	50	0.00041	0.95267	0.40000	0.09359
24	5.00	160	0.00015	0.95267	0.50000	0.09359
25	5.80	1	0.02297	0.89964	0.60000	0.14690
26	5.80	5	0.02023	0.88146	0.60000	0.15537
27	5.80	5	0.01397	0.87741	0.60000	0.15163
28	5.80	10	0.01126	0.89500	0.40000	0.14368
29	5.80	10	0.01062	0.87660	0.40000	0.15088
30	5.80	10	0.00667	0.88068	0.60000	0.15386
31	5.80	50	0.00189	0.92592	0.40000	0.09874
32	5.80	50	0.00145	0.91665	0.40000	0.09830
33	6.50	5	0.05655	0.88682	0.65000	0.16167
34	6.50	10	0.03491	0.88393	0.30000	0.15842
35	6.50	10	0.03733	0.86239	0.30000	0.16017
36	6.50	10	0.02277	0.86639	0.65000	0.16356
37	6.50	20	0.01790	0.87865	0.30000	0.15357
38	6.50	20	0.01737	0.86969	0.30000	0.16634
39	6.50	20	0.01238	0.85816	0.65000	0.15649
40	6.50	100	0.00363	0.87205	0.60000	0.14893
41	6.50	160	0.00257	0.88894	0.60000	0.16201
42	7.00	1	0.12545	0.84476	0.60000	0.16560
43	7.00	10	0.06112	0.82039	0.40000	0.17091
44	7.00	10	0.03272	0.81881	0.60000	0.16914
45	7.00	50	0.01213	0.84134	0.40000	0.16246
46	7.00	50	0.00978	0.82097	0.40000	0.17157
47	7.50	1	0.15876	0.85261	0.60000	0.17609
48	5.00	10	0.05928	0.84187	0.40000	0.16559
49	5.00	10	0.07190	0.81800	0.40000	0.17039
50	8.00	50	0.04513	0.92864	0.40000	0.15902
51	8.00	160	0.02424	0.93020	0.60000	0.15859

TABLE F1-10
J. G. ANDERSON: HORIZONTAL POINT ESTIMATES
PEAK GROUND VELOCITY

CASE NO.	MAGNITUDE	DISTANCE (KM)	MU	SIGMA	SIGMA MU	SIGMA SIGMA
1	5.00	1	5.95368	0.77651	0.60000	0.09377
2	5.00	1	11.94466	0.77651	0.60000	0.09377
3	5.00	5	2.33973	0.77651	0.60000	0.09377
4	5.00	5	4.82999	0.76681	0.60000	0.08963
5	5.80	10	6.58281	0.73789	0.40000	0.10574
6	5.80	20	5.77092	0.73518	0.40000	0.10859
7	6.50	1	37.87487	0.73826	0.65000	0.12078
8	6.50	1	42.64674	0.73784	0.65000	0.12504
9	6.50	1	36.03432	0.73784	0.65000	0.12504
10	6.50	5	33.90291	0.73015	0.65000	0.12098
11	6.50	5	21.35413	0.72875	0.65000	0.12033
12	6.50	50	2.66481	0.72948	0.30000	0.11687
13	6.50	50	2.62790	0.72653	0.30000	0.11911
14	7.00	10	25.61209	0.71950	0.40000	0.13054
15	7.50	50	6.65118	0.71862	0.40000	0.13758
16	7.50	50	7.08289	0.70574	0.40000	0.13552
17	5.00	1	2.88039	0.75041	0.60000	0.04856
18	5.80	5	12.21397	0.73389	0.60000	0.10805
19	5.80	5	6.47582	0.73304	0.60000	0.10765
20	5.00	10	2.98180	0.76197	0.40000	0.08776
21	5.00	10	4.17823	0.76681	0.40000	0.08963
22	5.00	50	0.32234	0.75714	0.40000	0.08604
23	5.00	50	0.35921	0.76197	0.40000	0.08776
24	5.00	160	0.06889	0.74751	0.50000	0.08307
25	5.80	1	17.18409	0.74141	0.60000	0.10711
26	5.80	5	16.05410	0.72978	0.60000	0.10614
27	5.80	5	9.52540	0.73245	0.60000	0.10741
28	5.80	10	7.80374	0.74290	0.40000	0.10765
29	5.80	10	12.21401	0.73521	0.40000	0.10860
30	5.80	10	5.11692	0.73209	0.60000	0.10727
31	5.80	50	0.92102	0.74839	0.40000	0.08574
32	5.80	50	0.95812	0.75016	0.40000	0.08729
33	6.50	5	26.39163	0.73692	0.65000	0.12027
34	6.50	10	17.90324	0.73584	0.30000	0.11974
35	6.50	10	26.67163	0.73044	0.30000	0.12114
36	6.50	10	12.92577	0.72822	0.65000	0.12012
37	6.50	20	8.97351	0.73337	0.30000	0.11854
38	6.50	20	12.96219	0.73093	0.30000	0.12141
39	6.50	20	6.85566	0.72373	0.65000	0.11777
40	6.50	100	1.47121	0.73356	0.60000	0.11890
41	6.50	160	0.53372	0.74577	0.60000	0.12519
42	7.00	1	50.85425	0.71709	0.60000	0.12918
43	7.00	10	36.90607	0.71115	0.40000	0.13164
44	7.00	10	18.94126	0.70719	0.60000	0.12915
45	7.00	50	4.43288	0.71535	0.40000	0.12848
46	7.00	50	4.50998	0.70723	0.40000	0.12917
47	7.50	1	61.70474	0.73257	0.60000	0.14612
48	5.00	10	32.23119	0.72249	0.40000	0.14002
49	5.00	10	39.51812	0.70725	0.40000	0.13646
50	8.00	50	11.39069	0.74528	0.40000	0.12715
51	8.00	160	4.17337	0.75030	0.60000	0.12935

TABLE F1-11
J. G. ANDERSON: VERTICAL POINT ESTIMATES
PEAK GROUND ACCELERATION

CASE NO.	MAGNITUDE	DISTANCE (KM)	MU	SIGMA	SIGMA MU	SIGMA SIGMA
1	5.00	1	0.06378	0.65949	0.60000	0.12094
2	5.00	1	0.09231	0.66794	0.60000	0.12009
3	5.00	5	0.02423	0.65949	0.60000	0.12094
4	5.00	5	0.03063	0.66530	0.60000	0.12031
5	5.80	10	0.05316	0.65523	0.40000	0.14238
6	5.80	20	0.06651	0.63641	0.40000	0.13725
7	6.50	1	0.29684	0.62878	0.65000	0.12843
8	6.50	1	0.34868	0.63915	0.65000	0.13192
9	6.50	1	0.35225	0.62724	0.65000	0.12800
10	6.50	5	0.30597	0.62302	0.65000	0.12693
11	6.50	5	0.22112	0.62724	0.65000	0.12800
12	6.50	50	0.01982	0.62417	0.30000	0.12720
13	6.50	50	0.02435	0.62148	0.30000	0.12658
14	7.00	10	0.18926	0.62894	0.40000	0.13031
15	7.50	50	0.04332	0.63855	0.40000	0.13414
16	7.50	50	0.05311	0.63778	0.40000	0.13381
17	5.00	1	0.02533	0.64999	0.60000	0.12236
18	5.80	5	0.07798	0.63372	0.60000	0.13678
19	5.80	5	0.06272	0.64448	0.60000	0.13907
20	5.00	10	0.03258	0.67375	0.40000	0.11974
21	5.00	10	0.06918	0.64312	0.40000	0.12368
22	5.00	50	0.00410	0.65474	0.40000	0.12159
23	5.00	50	0.00365	0.64101	0.40000	0.12413
24	5.00	160	0.00045	0.65738	0.50000	0.12121
25	5.80	1	0.14869	0.63948	0.60000	0.13787
26	5.80	5	0.16475	0.63372	0.60000	0.13678
27	5.80	5	0.09909	0.63948	0.60000	0.13787
28	5.80	10	0.06674	0.64601	0.40000	0.13948
29	5.80	10	0.12768	0.63795	0.40000	0.13755
30	5.80	10	0.05887	0.64102	0.60000	0.13822
31	5.80	50	0.00621	0.63641	0.40000	0.13725
32	5.80	50	0.00755	0.64255	0.40000	0.13858
33	6.50	5	0.24213	0.62148	0.65000	0.12658
34	6.50	10	0.14657	0.63031	0.30000	0.12888
35	6.50	10	0.28602	0.63531	0.30000	0.13051
36	6.50	10	0.13342	0.62417	0.65000	0.12720
37	6.50	20	0.07673	0.62724	0.30000	0.12800
38	6.50	20	0.14856	0.63723	0.30000	0.13120
39	6.50	20	0.06182	0.62148	0.65000	0.12658
40	6.50	100	0.00823	0.63185	0.60000	0.12936
41	6.50	160	0.00205	0.62417	0.60000	0.12720
42	7.00	1	0.37990	0.63663	0.60000	0.13331
43	7.00	10	0.34283	0.63778	0.40000	0.13381
44	7.00	10	0.16806	0.63317	0.60000	0.13190
45	7.00	50	0.02878	0.63240	0.40000	0.13160
46	7.00	50	0.03869	0.63240	0.40000	0.13160
47	7.50	1	0.69730	0.65737	0.60000	0.14381
48	5.00	10	0.23206	0.63855	0.40000	0.13414
49	5.00	10	0.39478	0.64738	0.40000	0.13835
50	8.00	50	0.06157	0.63912	0.40000	0.09000
51	8.00	160	0.01270	0.64124	0.60000	0.09134

TABLE F1-12
J. G. ANDERSON: VERTICAL POINT ESTIMATES
SPECTRAL ACCELERATION AT 0.05 SEC PERIOD

Case No.	Magnitude	Distance (km)	Mu	Sigma	Sigma Mu	Sigma Sigma
1	5.00	1	0.13347	0.67393	0.60000	0.06680
2	5.00	1	0.18731	0.67393	0.60000	0.06680
3	5.00	5	0.04507	0.67129	0.60000	0.06812
4	5.00	5	0.05963	0.68343	0.60000	0.06245
5	5.80	10	0.09997	0.67209	0.40000	0.12087
6	5.80	20	0.11158	0.65903	0.40000	0.11773
7	6.50	1	0.60196	0.64703	0.65000	0.11350
8	6.50	1	0.69029	0.65202	0.65000	0.11562
9	6.50	1	0.71534	0.64396	0.65000	0.11232
10	6.50	5	0.61004	0.64396	0.65000	0.11232
11	6.50	5	0.42481	0.64089	0.65000	0.11124
12	6.50	50	0.02887	0.64549	0.30000	0.11290
13	6.50	50	0.03687	0.64703	0.30000	0.11350
14	7.00	10	0.33989	0.64818	0.40000	0.11581
15	7.50	50	0.06402	0.65467	0.40000	0.11847
16	7.50	50	0.07822	0.65543	0.40000	0.11889
17	5.00	1	0.04883	0.67604	0.60000	0.06578
18	5.80	5	0.14738	0.66709	0.60000	0.11946
19	5.80	5	0.11678	0.67593	0.60000	0.12212
20	5.00	10	0.06320	0.70297	0.40000	0.05591
21	5.00	10	0.13313	0.67393	0.40000	0.06680
22	5.00	50	0.00682	0.67129	0.40000	0.06812
23	5.00	50	0.00696	0.68343	0.40000	0,06245
24	5.00	160	0.00058	0.67604	0.50000	0.06578
25	5.80	1	0.30288	0.67593	0.60000	0.12212
26	5.80	5	0.30355	0.66517	0.60000	0.11898
27	5.80	5	0.19563	0.66517	0.60000	0.11898
28	5.80	10	0.12937	0.67785	0.40000	0.12280
29	5.80	10	0.22267	0.66364	0.40000	0.11863
30	5.80	10	0.10612	0.66210	0.60000	0.11831
31	5.80	50	0.00987	0.66210	0.40000	0.11831
32	5.80	50	0.01181	0.67401	0.40000	0.12147
33	6.50	5	0.48935	0.64549	0.65000	0.11290
34	6.50	10	0.27891	0.65740	0.30000	0.11817
35	6.50	10	0.52724	0.65049	0.30000	0.11495
36	6.50	10	0.25454	0.64857	0.65000	0.11413
37	6.50	20	0.13869	0.64857	0.30000	0.11413
38	6.50	20	0.26216	0.65740	0.30000	0.11817
39	6.50	20	0.10770	0.64242	0.65000	0.11177
40	6.50	100	0.01080	0.64857	0.60000	0.11413
41	6.50	160	0.00316	0.63973	0.60000	0.11086
42	7.00	1	0.79242	0.65855	0.60000	0.12113
43	7.00	10	0.63653	0.66239	0.40000	0.12333
44	7.00	10	0.31664	0.65356	0.60000	0.11845
45	7.00	50	0.04579	0.65125	0.40000	0.11729
46	7.00	50	0.05981	0.65010	0.40000	0.11672
47	7.50	1	1.35242	0.67925	0.60000	0.13410
48	5.00	10	0.42535	0.65390	0.40000	0.11806
49	5.00	10	0.74040	0.66465	0.40000	0.12430
50	8.00	50	0.09158	0.66378	0.40000	0.07215
51	8.00	160	0.01473	0.65955	0.60000	0.06882

TABLE F1-13
J. G. ANDERSON: VERTICAL POINT ESTIMATES
SPECTRAL ACCELERATION AT 0.10 SEC PERIOD

CASE NO.	MAGNITUDE	DISTANCE (KM)	MU	SIGMA	SIGMA MU	SIGMA SIGMA
1	5.00	1	0.14358	0.72387	0.60000	0.08768
2	5.00	1	0.21911	0.73443	0.60000	0.08924
3	5.00	5	0.05581	0.73443	0.60000	0.08924
4	5.00	5	0.07690	0.74605	0.60000	0.09187
5	5.80	10	0.12015	0.68991	0.40000	0.15612
6	5.80	20	0.14451	0.67802	0.40000	0.14957
7	6.50	1	0.69039	0.66357	0.65000	0.13438
8	6.50	1	0.84340	0.66972	0.65000	0.13824
9	6.50	1	0.87979	0.66972	0.65000	0.13824
10	6.50	5	0.69046	0.66357	0.65000	0.13438
11	6.50	5	0.52342	0.66664	0.65000	0.13628
12	6.50	50	0.03783	0.66357	0.30000	0.13438
13	6.50	50	0.04730	0.66511	0.30000	0.13532
14	7.00	10	0.39644	0.67336	0.40000	0.14211
15	7.50	50	0.08229	0.68253	0.40000	0.14900
16	7.50	50	0.09791	0.67793	0.40000	0.14547
17	5.00	1	0.05885	0.72387	0.60000	0.08768
18	5.80	5	0.18801	0.67954	0.60000	0.15036
19	5.80	5	0.15102	0.67954	0.60000	0.15036
20	5.00	10	0.07559	0.74288	0.40000	0.09106
21	5.00	10	0.16114	0.71648	0.40000	0.08709
22	5.00	50	0.00825	0.74024	0.40000	0.09044
23	5.00	50	0.00797	0.72123	0.40000	0.08742
24	5.00	160	0.00081	0.72915	0.50000	0.08836
25	5.80	1	0.35533	0.67493	0.60000	0.14804
26	5.80	5	0.37619	0.67954	0.60000	0.15036
27	5.80	5	0.22244	0.67340	0.60000	0.14730
28	5.80	10	0.14317	0.68607	0.40000	0.15391
29	5.80	10	0.29315	0.68607	0.40000	0.15391
30	5.80	10	0.12861	0.67493	0.60000	0.14804
31	5.80	50	0.01286	0.68801	0.40000	0.15500
32	5.80	50	0.01375	0.68607	0.40000	0.15391
33	6.50	5	0.54287	0.66664	0.65000	0.13628
34	6.50	10	0.33094	0.66818	0.30000	0.13725
35	6.50	10	0.63894	0.66818	0.30000	0.13725
36	6.50	10	0.31466	0.66511	0.65000	0.13532
37	6.50	20	0.15833	0.66511	0.30000	0.13532
38	6.50	20	0.31703	0.67471	0.30000	0.14156
39	6.50	20	0.13572	0.66088	0.65000	0.13277
40	6.50	100	0.01408	0.65743	0.60000	0.13078
41	6.50	160	0.00427	0.66242	0.60000	0.13368
42	7.00	1	0.90562	0.67950	0.60000	0.14663
43	7.00	10	0.74908	0.68911	0.40000	0.15405
44	7.00	10	0.37997	0.67336	0.60000	0.14211
45	7.00	50	0.05691	0.67067	0.40000	0.14020
46	7.00	50	0.07430	0.67413	0.40000	0.14267
47	7.50	1	1.54266	0.69406	0.60000	0.15826
48	5.00	10	0.49762	0.67985	0.40000	0.14693
49	5.00	10	0.89378	0.68791	0.40000	0.15325
50	8.00	50	0.11464	0.70386	0.40000	0.10366
51	8.00	160	0.01686	0.70492	0.60000	0.10448

TABLE F1-14
J. G. ANDERSON: VERTICAL POINT ESTIMATES
SPECTRAL ACCELERATION AT 0.20 SEC PERIOD

CASE NO.	MAGNITUDE	DISTANCE (KM)	MU	SIGMA	SIGMA MU	SIGMA SIGMA
1	5.00	1	0.09530	0.68923	0.60000	0.06986
2	5.00	1	0.12766	0.71035	0.60000	0.07419
3	5.00	5	0.04435	0.70718	0.60000	0.07330
4	5.00	5	0.05031	0.70190	0.60000	0.07199
5	5.80	10	0.09233	0.65049	0.40000	0.15539
6	5.80	20	0.12191	0.64396	0.40000	0.15180
7	6.50	1	0.53242	0.65116	0.65000	0.14171
8	6.50	1	0.55432	0.64770	0.65000	0.13937
9	6.50	1	0.58307	0.64616	0.65000	0.13835
10	6.50	5	0.55121	0.64271	0.65000	0.13613
11	6.50	5	0.38906	0.63964	0.65000	0.13421
12	6.50	50	0.03658	0.63272	0.30000	0.13015
13	6.50	50	0.04760	0.64271	0.30000	0.13613
14	7.00	10	0.34350	0.65794	0.40000	0.13770
15	7.50	50	0.08702	0.65982	0.40000	0.13890
16	7.50	50	0.10808	0.66328	0.40000	0.14150
17	5.00	1	0.04324	0.70718	0.60000	0.07330
18	5.80	5	0.13677	0.63897	0.60000	0.14924
19	5.80	5	0.11382	0.64550	0.60000	0.15262
20	5.00	10	0.04595	0.71299	0.40000	0.07500
21	5.00	10	0.12379	0.70190	0.40000	0.07199
22	5.00	50	0.00883	0.70892	0.40000	0.06851
23	5.00	50	0.00750	0.67723	0.40000	0.06238
24	5.00	160	0.00100	0.69783	0.50000	0.06526
25	5.80	1	0.24693	0.64051	0.60000	0.15001
26	5.80	5	0.28649	0.65241	0.60000	0.15650
27	5.80	5	0.17210	0.64550	0.60000	0.15262
28	5.80	10	0.11572	0.66009	0.40000	0.16115
29	5.80	10	0.23704	0.65625	0.40000	0.15878
30	5.80	10	0.10260	0.64051	0.60000	0.15001
31	5.80	50	0.01217	0.65049	0.40000	0.15539
32	5.80	50	0.01658	0.65049	0.40000	0.15539
33	6.50	5	0.41027	0.63964	0.65000	0.13421
34	6.50	10	0.25199	0.63272	0.30000	0.13015
35	6.50	10	0.49643	0.64616	0.30000	0.13835
36	6.50	10	0.25521	0.63964	0.65000	0.13421
37	6.50	20	0.13948	0.64271	0.30000	0.13613
38	6.50	20	0.28301	0.65846	0.30000	0.14687
39	6.50	20	0.13011	0.64117	0.65000	0.13516
40	6.50	100	0.01762	0.64924	0.60000	0.14040
41	6.50	160	0.00601	0.64424	0.60000	0.13711
42	7.00	1	0.65462	0.65794	0.60000	0.13770
43	7.00	10	0.64684	0.67100	0.40000	0.14753
44	7.00	10	0.33569	0.66024	0.60000	0.13937
45	7.00	50	0.05831	0.65371	0.40000	0.13472
46	7.00	50	0.08283	0.65487	0.40000	0.13552
47	7.50	1	1.10802	0.67518	0.60000	0.15089
48	5.00	10	0.45521	0.66750	0.40000	0.14476
49	5.00	10	0.73504	0.67134	0.40000	0.14779
50	8.00	50	0.11738	0.70993	0.40000	0.09915
51	8.00	160	0.02268	0.69937	0.60000	0.09117

TABLE F1-15
J. G. ANDERSON: VERTICAL POINT ESTIMATES
SPECTRAL ACCELERATION AT 0.50 SEC PERIOD

CASE NO.	MAGNITUDE	DISTANCE (KM)	MU	SIGMA	SIGMA MU	SIGMA SIGMA
1	5.00	1	0.03461	0.70674	0.60000	0.05557
2	5.00	1	0.05549	0.70938	0.60000	0.05658
3	5.00	5	0.01312	0.72258	0.60000	0.06250
4	5.00	5	0.02005	0.70674	0.60000	0.05557
5	5.80	10	0.05091	0.64925	0.40000	0.15674
6	5.80	20	0.07600	0.65269	0.40000	0.15880
7	6.50	1	0.28059	0.65246	0.65000	0.14631
8	6.50	1	0.35104	0.64900	0.65000	0.14379
9	6.50	1	0.34972	0.65054	0.65000	0.14490
10	6.50	5	0.30222	0.64132	0.65000	0.13846
11	6.50	5	0.24210	0.64593	0.65000	0.14162
12	6.50	50	0.02860	0.63863	0.30000	0.13667
13	6.50	50	0.03920	0.63748	0.30000	0.13592
14	7.00	10	0.23688	0.65572	0.40000	0.14267
15	7.50	50	0.07639	0.66105	0.40000	0.14682
16	7.50	50	0.08323	0.65644	0.40000	0.14308
17	5.00	1	0.01561	0.74899	0.60000	0.07761
18	5.80	5	0.07051	0.65768	0.60000	0.16189
19	5.80	5	0.05091	0.64348	0.60000	0.15347
20	5.00	10	0.02033	0.70198	0.40000	0.05393
21	5.00	10	0.04626	0.69776	0.40000	0.05268
22	5.00	50	0.00385	0.72115	0.40000	0.05793
23	5.00	50	0.00435	0.70055	0.40000	0.04796
24	5.00	160	0.00063	0.71059	0.50000	0.05237
25	5.80	1	0.10383	0.65076	0.60000	0.15764
26	5.80	5	0.14270	0.67268	0.60000	0.17197
27	5.80	5	0.09774	0.64769	0.60000	0.15585
28	5.80	10	0.06844	0.66115	0.40000	0.16411
29	5.80	10	0.13211	0.66459	0.40000	0.16640
30	5.80	10	0.05844	0.66651	0.60000	0.16770
31	5.80	50	0.00723	0.64769	0.40000	0.15585
32	5.80	50	0.01101	0.65576	0.40000	0.16068
33	6.50	5	0.24617	0.65745	0.65000	0.15004
34	6.50	10	0.17192	0.65400	0.30000	0.14744
35	6.50	10	0.32681	0.65246	0.30000	0.14631
36	6.50	10	0.17436	0.64593	0.65000	0.14162
37	6.50	20	0.09853	0.65246	0.30000	0.14631
38	6.50	20	0.19322	0.65937	0.30000	0.15151
39	6.50	20	0.08057	0.64593	0.65000	0.14162
40	6.50	100	0.01513	0.64747	0.60000	0.14270
41	6.50	160	0.00603	0.64593	0.60000	0.14162
42	7.00	1	0.41676	0.67339	0.60000	0.15720
43	7.00	10	0.43246	0.66726	0.40000	0.15200
44	7.00	10	0.22559	0.65917	0.60000	0.14541
45	7.00	50	0.04310	0.65572	0.40000	0.14267
46	7.00	50	0.06536	0.65687	0.40000	0.14358
47	7.50	1	0.57789	0.67488	0.60000	0.15856
48	5.00	10	0.28605	0.65915	0.40000	0.14525
49	5.00	10	0.45321	0.66414	0.40000	0.14936
50	8.00	50	0.11083	0.70875	0.40000	0.09052
51	8.00	160	0.02744	0.71245	0.60000	0.09346

TABLE F1-16
J. G. ANDERSON: VERTICAL POINT ESTIMATES
SPECTRAL ACCELERATION AT 1.00 SEC PERIOD

CASE NO.	MAGNITUDE	DISTANCE (KM)	MU	SIGMA	SIGMA MU	SIGMA SIGMA
1	5.00	1	0.01569	0.71898	0.60000	0.02452
2	5.00	1	0.02295	0.74274	0.60000	0.03950
3	5.00	5	0.00552	0.72795	0.60000	0.02956
4	5.00	5	0.00828	0.71528	0.60000	0.02282
5	5.80	10	0.02151	0.68143	0.40000	0.13285
6	5.80	20	0.02740	0.67595	0.40000	0.13874
7	6.50	1	0.13121	0.68518	0.65000	0.13981
8	6.50	1	0.16387	0.67576	0.65000	0.14189
9	6.50	1	0.14674	0.67230	0.65000	0.13950
10	6.50	5	0.15014	0.67422	0.65000	0.14082
11	6.50	5	0.11533	0.66347	0.65000	0.13372
12	6.50	50	0.01272	0.67980	0.30000	0.13613
13	6.50	50	0.02246	0.66078	0.30000	0.13206
14	7.00	10	0.10488	0.69653	0.40000	0.14760
15	7.50	50	0.04057	0.68614	0.40000	0.14004
16	7.50	50	0.05275	0.68017	0.40000	0.14371
17	5.00	1	0.00531	0.71686	0.60000	0.02351
18	5.80	5	0.03241	0.67902	0.60000	0.14061
19	5.80	5	0.02735	0.68401	0.60000	0.14378
20	5.00	10	0.00597	0.70789	0.40000	0.02036
21	5.00	10	0.01285	0.71528	0.40000	0.02282
22	5.00	50	0.00121	0.71543	0.40000	0.01850
23	5.00	50	0.00195	0.71755	0.40000	0.01992
24	5.00	160	0.00029	0.72230	0.50000	0.02326
25	5.80	1	0.05133	0.70985	0.60000	0.15191
26	5.80	5	0.06535	0.68747	0.60000	0.14606
27	5.80	5	0.04567	0.67441	0.60000	0.13783
28	5.80	10	0.02959	0.68758	0.40000	0.13654
29	5.80	10	0.05575	0.67172	0.40000	0.13628
30	5.80	10	0.03640	0.68555	0.60000	0.14478
31	5.80	50	0.00359	0.69795	0.40000	0.14334
32	5.80	50	0.00655	0.67441	0.40000	0.13783
33	6.50	5	0.10873	0.68326	0.65000	0.13847
34	6.50	10	0.08182	0.68172	0.30000	0.13742
35	6.50	10	0.11766	0.65809	0.30000	0.13046
36	6.50	10	0.09168	0.66462	0.65000	0.13444
37	6.50	20	0.03949	0.68326	0.30000	0.13847
38	6.50	20	0.07980	0.66078	0.30000	0.13206
39	6.50	20	0.04988	0.65809	0.65000	0.13046
40	6.50	100	0.00766	0.67097	0.60000	0.13048
41	6.50	160	0.00315	0.68172	0.60000	0.13742
42	7.00	1	0.17045	0.70613	0.60000	0.15506
43	7.00	10	0.19912	0.68401	0.40000	0.14655
44	7.00	10	0.12073	0.68401	0.60000	0.14655
45	7.00	50	0.02385	0.68424	0.40000	0.13871
46	7.00	50	0.03566	0.67518	0.40000	0.14014
47	7.50	1	0.26612	0.73763	0.60000	0.18206
48	5.00	10	0.13927	0.68808	0.40000	0.14140
49	5.00	10	0.22823	0.68209	0.40000	0.14512
50	8.00	50	0.05822	0.73901	0.40000	0.10757
51	8.00	160	0.02017	0.72950	0.60000	0.10109

TABLE F1-17
J. G. ANDERSON: VERTICAL POINT ESTIMATES SPECTRAL ACCELERATION AT 2.00 SEC PERIOD

CASE NO.	MAGNITUDE	DISTANCE (KM)	MU	SIGMA	SIGMA MU	SIGMA SIGMA
1	5.00	1	0.00535	0.74083	0.60000	0.05673
2	5.00	1	0.00814	0.73027	0.60000	0.05138
3	5.00	5	0.00162	0.73766	0.60000	0.05504
4	5.00	5	0.00244	0.73133	0.60000	0.05188
5	5.80	10	0.00814	0.72890	0.40000	0.15389
6	5.80	20	0.00863	0.72174	0.40000	0.17478
7	6.50	1	0.07747	0.73163	0.65000	0.17064
8	6.50	1	0.10304	0.69927	0.65000	0.16982
9	6.50	1	0.08477	0.69503	0.65000	0.16666
10	6.50	5	0.09284	0.70386	0.65000	0.17335
11	6.50	5	0.06191	0.69503	0.65000	0.16666
12	6.50	50	0.00630	0.71818	0.30000	0.16036
13	6.50	50	0.01372	0.69773	0.30000	0.16866
14	7.00	10	0.04800	0.72129	0.40000	0.16589
15	7.50	50	0.01992	0.73051	0.40000	0.17307
16	7.50	50	0.03657	0.70863	0.40000	0.17920
17	5.00	1	0.00130	0.73502	0.60000	0.05368
18	5.80	5	0.01722	0.70023	0.60000	0.15884
19	5.80	5	0.00893	0.70638	0.60000	0.16317
20	5.00	10	0.00160	0.73027	0.40000	0.05138
21	5.00	10	0.00484	0.72710	0.40000	0.04996
22	5.00	50	0.00029	0.73238	0.40000	0.05238
23	5.00	50	0.00102	0.72710	0.40000	0.04996
24	5.00	160	0.00004	0.75351	0.50000	0.06411
25	5.80	1	0.02833	0.75847	0.60000	0.17745
26	5.80	5	0.03583	0.71521	0.60000	0.16972
27	5.80	5	0.02316	0.72174	0.60000	0.17478
28	5.80	10	0.00982	0.72736	0.40000	0.15277
29	5.80	10	0.01829	0.72673	0.40000	0.17875
30	5.80	10	0.01544	0.71675	0.60000	0.17089
31	5.80	50	0.00126	0.71622	0.40000	0.14503
32	5.80	50	0.00350	0.71982	0.40000	0.17327
33	6.50	5	0.05427	0.72471	0.65000	0.16525
34	6.50	10	0.03856	0.72779	0.30000	0.16762
35	6.50	10	0.06147	0.71617	0.30000	0.18318
36	6.50	10	0.04818	0.71425	0.65000	0.18161
37	6.50	20	0.01914	0.72471	0.30000	0.16525
38	6.50	20	0.03821	0.70580	0.30000	0.17485
39	6.50	20	0.02393	0.69773	0.65000	0.16866
40	6.50	100	0.00282	0.72279	0.60000	0.16379
41	6.50	160	0.00163	0.72779	0.60000	0.16762
42	7.00	1	0.08861	0.72705	0.60000	0.17033
43	7.00	10	0.09911	0.71439	0.40000	0.18395
44	7.00	10	0.05745	0.71286	0.60000	0.18267
45	7.00	50	0.01144	0.72052	0.40000	0.16530
46	7.00	50	0.02570	0.70172	0.40000	0.17365
47	7.50	1	0.11571	0.75240	0.60000	0.19136
48	5.00	10	0.06462	0.74741	0.40000	0.18705
49	5.00	10	0.13770	0.74128	0.40000	0.20746
50	8.00	50	0.04427	0.78063	0.40000	0.14388
51	8.00	160	0.01940	0.78538	0.60000	0.14718

TABLE F1-18
J. G. ANDERSON: VERTICAL POINT ESTIMATES
SPECTRAL ACCELERATION AT 3.33 SEC PERIOD

CASE NO.	MAGNITUDE	DISTANCE (KM)	MU	SIGMA	SIGMA MU	SIGMA SIGMA
1	5.00	1	0.00172	0.79952	0.60000	0.07516
2	5.00	1	0.00294	0.78790	0.60000	0.06615
3	5.00	5	0.00057	0.79212	0.60000	0.06941
4	5.00	5	0.00117	0.78473	0.60000	0.06372
5	5.80	10	0.00441	0.76674	0.40000	0.16974
6	5.80	20	0.00479	0.74345	0.40000	0.17920
7	6.50	1	0.04079	0.77565	0.65000	0.19693
8	6.50	1	0.06270	0.74021	0.65000	0.19293
9	6.50	1	0.05420	0.73521	0.65000	0.18854
10	6.50	5	0.06335	0.74136	0.65000	0.19395
11	6.50	5	0.03295	0.73293	0.65000	0.18654
12	6.50	50	0.00330	0.77222	0.30000	0.19376
13	6.50	50	0.00665	0.75672	0.30000	0.20789
14	7.00	10	0.03026	0.79220	0.40000	0.21535
15	7.50	50	0.01281	0.78183	0.40000	0.20546
16	7.50	50	0.01975	0.75343	0.40000	0.20678
17	5.00	1	0.00043	0.79793	0.60000	0.07392
18	5.80	5	0.01097	0.74461	0.60000	0.18017
19	5.80	5	0.00580	0.74038	0.60000	0.17662
20	5.00	10	0.00053	0.79582	0.40000	0.07228
21	5.00	10	0.00197	0.78473	0.40000	0.06372
22	5.00	50	0.00011	0.79793	0.40000	0.07392
23	5.00	50	0.00050	0.78526	0.40000	0.06412
24	5.00	160	0.00003	0.81959	0.50000	0.09098
25	5.80	1	0.01266	0.77135	0.60000	0.17377
26	5.80	5	0.02133	0.74729	0.60000	0.18247
27	5.80	5	0.01036	0.74115	0.60000	0.17726
28	5.80	10	0.00466	0.76290	0.40000	0.16642
29	5.80	10	0.00880	0.74845	0.40000	0.18345
30	5.80	10	0.00739	0.75459	0.60000	0.18880
31	5.80	50	0.00061	0.76175	0.40000	0.16544
32	5.80	50	0.00177	0.75690	0.40000	0.19083
33	6.50	5	0.03717	0.76453	0.65000	0.18681
34	6.50	10	0.01879	0.75071	0.30000	0.17472
35	6.50	10	0.03036	0.75175	0.30000	0.20330
36	6.50	10	0.02208	0.74291	0.65000	0.19532
37	6.50	20	0.01017	0.77913	0.30000	0.20013
38	6.50	20	0.01555	0.74405	0.30000	0.19635
39	6.50	20	0.01502	0.75019	0.65000	0.20189
40	6.50	100	0.00121	0.76453	0.60000	0.18681
41	6.50	160	0.00086	0.76453	0.60000	0.18681
42	7.00	1	0.05217	0.77645	0.60000	0.20042
43	7.00	10	0.05235	0.76649	0.40000	0.21916
44	7.00	10	0.03337	0.75573	0.60000	0.20894
45	7.00	50	0.00745	0.78452	0.40000	0.20801
46	7.00	50	0.01359	0.76649	0.40000	0.21916
47	7.50	1	0.08370	0.80411	0.60000	0.22692
48	5.00	10	0.03555	0.77837	0.40000	0.20222
49	5.00	10	0.07235	0.77378	0.40000	0.22620
50	8.00	50	0.03412	0.84048	0.40000	0.16943
51	8.00	160	0.01277	0.84418	0.60000	0.17227

TABLE F1-19
J. G. ANDERSON: VERTICAL POINT ESTIMATES
PEAK GROUND VELOCITY

CASE NO.	MAGNITUDE	DISTANCE (KM)	MU	SIGMA	SIGMA MU	SIGMA SIGMA
1	5.00	1	2.80810	0.65924	0.60000	0.08546
2	5.00	1	4.29556	0.66083	0.60000	0.08648
3	5.00	5	0.90284	0.66083	0.60000	0.08648
4	5.00	5	1.48331	0.65924	0.60000	0.08546
5	5.80	10	2.94654	0.63290	0.40000	0.12525
6	5.80	20	3.73412	0.61474	0.40000	0.11732
7	6.50	1	17.20402	0.63012	0.65000	0.11997
8	6.50	1	25.50247	0.62147	0.65000	0.11992
9	6.50	1	21.73553	0.62415	0.65000	0.12255
10	6.50	5	24.66848	0.61595	0.65000	0.11400
11	6.50	5	14.60814	0.61993	0.65000	0.11843
12	6.50	50	1.22950	0.61990	0.30000	0.10950
13	6.50	50	2.44010	0.61772	0.30000	0.11600
14	7.00	10	13.23987	0.64282	0.40000	0.13144
15	7.50	50	4.39409	0.63815	0.40000	0.13276
16	7.50	50	7.06752	0.63410	0.40000	0.13639
17	5.00	1	0.99430	0.65924	0.60000	0.08546
18	5.80	5	5.57618	0.61282	0.60000	0.11554
19	5.80	5	3.61064	0.61743	0.60000	0.11985
20	5.00	10	1.07860	0.66716	0.40000	0.09061
21	5.00	10	2.89521	0.65343	0.40000	0.08181
22	5.00	50	0.17204	0.66294	0.40000	0.08784
23	5.00	50	0.23777	0.63548	0.40000	0.07137
24	5.00	160	0.02367	0.67667	0.50000	0.09700
25	5.80	1	7.57530	0.62714	0.60000	0.11978
26	5.80	5	10.35665	0.61474	0.60000	0.11732
27	5.80	5	5.78659	0.61013	0.60000	0.11279
28	5.80	10	3.55716	0.62982	0.40000	0.12232
29	5.80	10	7.32232	0.61627	0.40000	0.11876
30	5.80	10	3.82405	0.61743	0.60000	0.11985
31	5.80	50	0.34628	0.62829	0.40000	0.12086
32	5.80	50	0.68701	0.61743	0.40000	0.11985
33	6.50	5	14.87275	0.63165	0.65000	0.12144
34	6.50	10	9.29801	0.62345	0.30000	0.11320
35	6.50	10	16.00772	0.62569	0.30000	0.12406
36	6.50	10	10.05691	0.61329	0.65000	0.11105
37	6.50	20	4.60363	0.61931	0.30000	0.10890
38	6.50	20	8.79620	0.61772	0.30000	0.11600
39	6.50	20	5.39304	0.61595	0.65000	0.11400
40	6.50	100	0.59426	0.62743	0.60000	0.11743
41	6.50	160	0.18813	0.62167	0.60000	0.11133
42	7.00	1	22.74919	0.64512	0.60000	0.13366
43	7.00	10	25.58826	0.63837	0.40000	0.13490
44	7.00	10	14.56536	0.63299	0.60000	0.12954
45	7.00	50	2.53180	0.63706	0.40000	0.12596
46	7.00	50	4.69880	0.63299	0.40000	0.12954
47	7.50	1	38.22290	0.66313	0.60000	0.15761
48	5.00	10	17.87472	0.64124	0.40000	0.13575
49	5.00	10	32.33877	0.64370	0.40000	0.14617
50	8.00	50	9.00461	0.68372	0.40000	0.14362
51	8.00	160	2.67731	0.70749	0.60000	0.16129

APPENDIX F2

MY RULES (FOR COMPUTING GROUND MOTIONS FOR PSHA OF YUCCA MOUNTAIN WASTE REPOSITORY)

David M. Boore

APPENDIX F2
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APPENDIX F2

MY RULES (FOR COMPUTING GROUND MOTIONS FOR PSHA OF YUCCA MOUNTAIN WASTE REPOSITORY)

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F2-1 INTRODUCTION

Because of the huge number of ground motion values that I am to provide (Tables F2-1 to F2-18), I have decided that the only practical way to provide the numbers is to first specify weights used in combining the proponent estimates and then review the resulting weighted ground motions. These weights are specified in this documentation. Included are very brief discussions of the reasons for the various weights. It should be understood that the actual weights are based on my judgment; my comments regarding the weights will not attempt to justify the precise numerical values, but rather will dwell more on the relative weights of the various proponent models.

F2-2 WEIGHTING SCHEME

F2-2.1 Distances

The distances are computed assuming Wells & Coppersmith (1994) width as a function of M, centered at the depth (shallow) or with bottom edge at greatest depth (deep). The point source calculations should use a distance as per Walt Silva's suggestion (rps = sqrt(rjb**2 + h**2), where rps = equivalent point source distance, rjb = "Joyner-Boore" distance, and h = depth to midpoint of rupture surface on fault).

F2-2.2 Classes Of Proponent Models

I divide the proponent models into three classes: 1) empirical, 2) point source simulations, and 3) finite fault simulations.

F2-2.3 Between-Class Weights

When combining the various proponent models, the weights should be normalized so that various classes have the following relative weights:

Type of Motion	Class	Weight
Horizontal	Empirical	2
Horizontal	Pt. Source	1
Horizontal	Finite Fault	1
Vertical	Empirical	4
Vertical	Pt. Source	1
Vertical	Finite Fault	1

For the horizontal component motions I decided that the empirical and the simulated motions should be given equal weight. I further decided that the point source and finite simulations should be given equal weight. The point source is a well-established model that has been well tested; in particular, it has been shown to provide good predictions of ground motions close to large earthquakes, where it would seem that the point source approximation is not valid. The use of some variant of closest distance to the fault in applying the point source model may overcome the apparent deficiency of the point source model at close distance to faults. The finite fault models are not as well validated and require the estimation of a number of parameters. The motions can be sensitive to such things as radiation pattern if adequate randomization is not included. The computation of motions at high frequencies using the finite source models must be done with care if a propagating rupture is to be properly modeled. On the other hand, what is needed may not be the proper mathematical modeling of the idealized rupture; randomness probably should be included to account for the complexities of the real world. In this sense the finite-fault models take on the flavor of the point source stochastic model.

For vertical motions it is my opinion that the numerical simulations have not been adequately validated, and for this reason I have downweighted them relative to the empirical models (giving them 1/2 the weight of the empirical models).

F2-2.4 Within-Class Weights

F2-2.4.1 Empirical Model Weights. Fourteen empirical models were considered. Six models were given zero weight (see below). The remaining eight models were separated into two categories based on the distance measure used, those using the Joyner-Boore" distance and those using any other distance measure.

For spectral acceleration, the weights were evenly balanced between these two distance groups. For the relations using a distance measure different from Joyner-Boore, I gave most weight to AS97 as I feel that it is the most current and complete study. With respect to peak velocity, few proponent models are available; I gave equal weight to all models providing peak velocity, with the exception of those proponent models receiving no weight for any ground motion estimates. The weights applied to the empirical models are summarized below.

Models used in analysis:

- BJF 97: weight = 1 except weight = 0.5 for M = 5 and weight = 0 for pga
- SEA97: weight = 1
- AS97: weight = 1
- Campbell 97 (soft rock): weight = 0.6
- Idriss 97 (University of California, Davis, written communication): weight = 0.2
- JB88: weight = 0 except for pgv, for which weight = 1
- Sadigh 97: weight = 0.2
- McGarr 84: weight = 1 (this is for pgv only)

Models given zero weight:

- BJF94, site class A and B: more recent relations in terms of shear-wave velocity are available.

- Blast-Based Models: I expect that the attenuation from a surface source differs from an earthquake source.
- Campbell's early models: more recent models are available
- Campbell's hard rock model: other relations are for "soft" rock; few hard rock data are available.
- Idriss, University of California, Davis, written communicaiton, 93 (pga): more recent relation is available
- Sabetta & Pugliese 96: not up-to-date; uses S triggered data

	Proponent Model	Model Weight	
		Spectral Acceleration, PGA	PGV
Joyner-Boore Distance	BJF94	1.0 (0.5 for M=5); 0 for PGA	–
	SEA96	1.0	–
	JB88	0.0	1.0
All Other Distance Measures	AS97	1.0	–
	C97	0.6	1.0
	Idriss 97	0.2	–
	Sadigh 97	0.2	–
	McGarr 84	0.0	1.0

F2-2.4.2 Point Source Weights. The validations for the point source model show that there is a significant bias (over prediction) for this model at long periods (T ≥ 2 sec). Since no correction was made for this bias, I gave the point source model zero weight for periods greater than or equal to 2 sec. At periods less than 1 sec, there is not a significant bias so I gave the point source model full weight for short periods.

- T ≥ 2.0 sec: weight = 0.0 (because of uncorrected bias)
- T = 1.0 sec: weight = 0.5 (transition to periods with no bias)
- T < 1.0 sec: weight = 1.0

F2-2.4.3 Finite Fault Weights. I consider all three finite fault models to be equally credible so I gave equal weight to all three. Only Zeng and Anderson provided estimates at M = 5. To avoid giving much larger weight to this model for magnitude 5 events, I gave it zero weight. This ensures that all models have equal impact on the estimates.

- Zeng and Anderson: weight = 1, except = 0 for M = 5 (the only finite fault model for M = 5)
- Silva: weight = 1
- Somerville: weight = 1

F2-2.5 Conversions

Use same source and path corrections for horizontal and vertical motions.

F2-2.5.1 Empirical Models.

- Source differences: all empirical except Abrahamson & Silva (1997) and SEA96 need corrections for differences in source. Use Silva's corrections.
- Site differences: Campbell CA-->YM300
- pgv: For those proponent models lacking pgv use pgv/Sa(T=1.0s) from the point source model to scale the Sa(T=1.0s) estimates. Apply the conversion to the Sa(T=1.0s) AFTER conversions to YM300 and normal fault source.
- Sa(T=0.05s): For those proponent models lacking Sa at T = 0.05 s (20 Hz), use the following factor: Sa(T=0.05s)/Sa(T=0.10s) = 0.7 See the Appendix F2-A for the derivation of this factor. Apply the conversion factor to the Sa(T=0.1s) results before applying the source and YM300 conversion factors.
- Point source model: use stress = 45 bars, sigma(lnStress) = 0.5 (these numbers will probably be updated after receiving the new Becker results).

F2-2.5.2 Finite Fault Models.

- Source differences: apply the source correction, as in the empirical proponent models.
- Site differences: the simulations accounted for the YM site condition, so no corrections are needed.

F2-3 SIGMAS

F2-3.1 Aleatory

Find the average of the sigma from the empirical proponent models, using the same in-class weights used for finding the median ground motions. Include component-to-component