

PSHA, Site Response, and Site Spectra

Technical Presentation

Rockville, MD

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TOPIC 1: PSHA

Robin K. McGuire

Gabriel R. Toro

Risk Engineering, Inc.

Boulder, Colorado



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Topics of Discussion

- Topic 1 – Probabilistic seismic hazard analysis
- Topic 2 – Site response
- Topic 3 – Site hazard
- Topic 4 – Site spectra

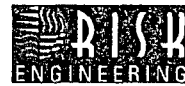


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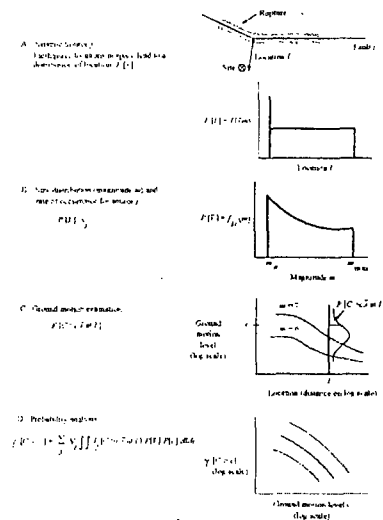
Topic 1: PSHA

- PSHA methodology
- Seismic sources (EPRI, New Madrid, Charleston)
- Ground motion models
- Revised σ 's
- CAV
- Calculations (rock, soil, deaggregation)

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Steps in seismic hazard analysis



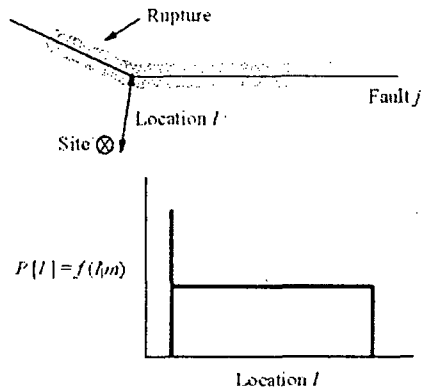
Source: McGuire (2004)

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Step A ~ Distribution of location

- A. Seismic Source j .
Earthquake locations in space lead to a
distribution of location: $P\{l\}$



Source: McGuire (2004)

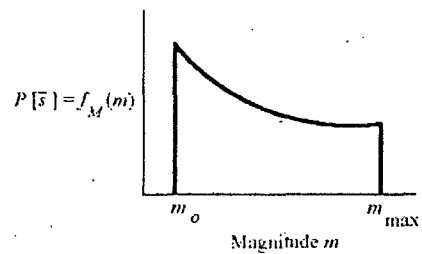
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Step B ~ Distribution of magnitude

- B. Size distribution (magnitude m) and
rate of occurrence for source j :

$$P\{X\}, \nu_j$$



Source: McGuire (2004)

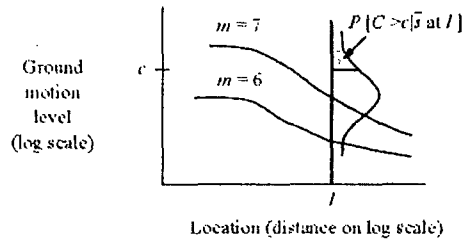
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Step C ~ Distribution of ground motion

C. Ground motion estimation:

$$P[C > c | \bar{s} \text{ at } l]$$



Source: McGuire (2004)

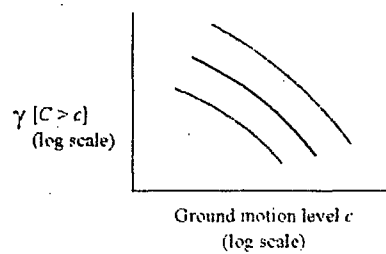
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Step D ~ Integration of hazard

D. Probability analysis:

$$\gamma[C > c] = \sum_j v_j \int \int P_j[C > c | \bar{s} \text{ at } l] P(\bar{s}) P(l) d\bar{s} dl$$

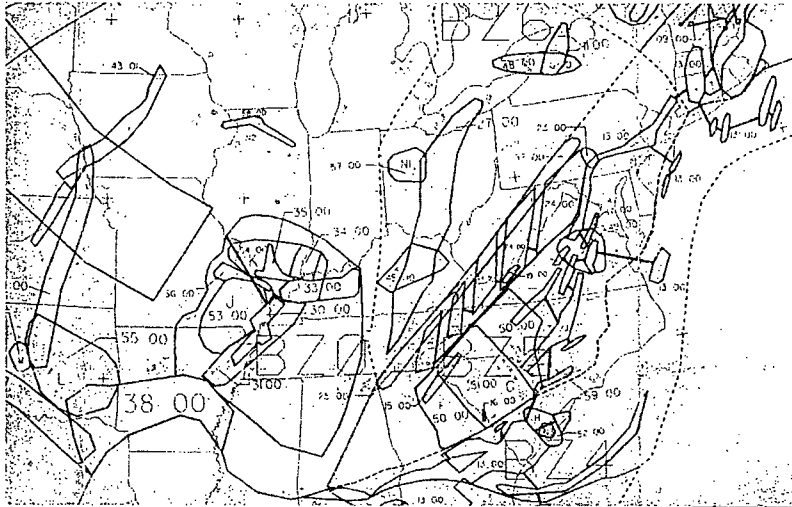


Source: McGuire (2004)

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EPRI-SOG sources for Bechtel team

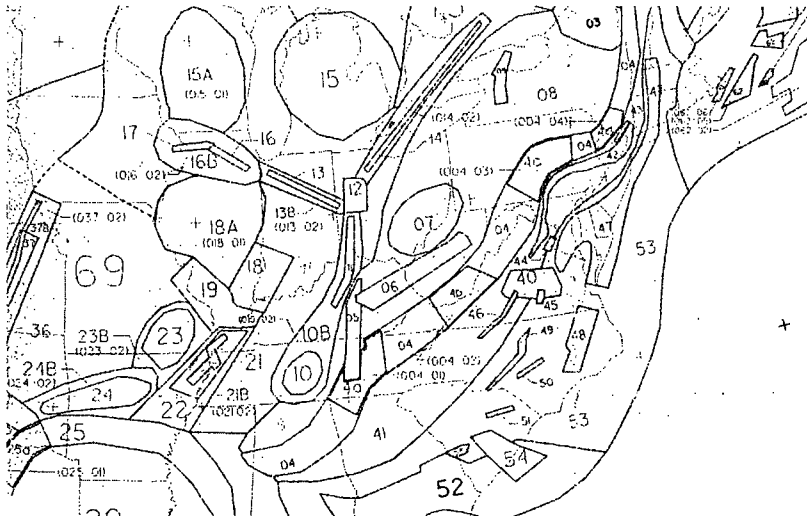


Source: EPRI-SOG (1989)

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EPRI-SOG sources for Dames & Moore team

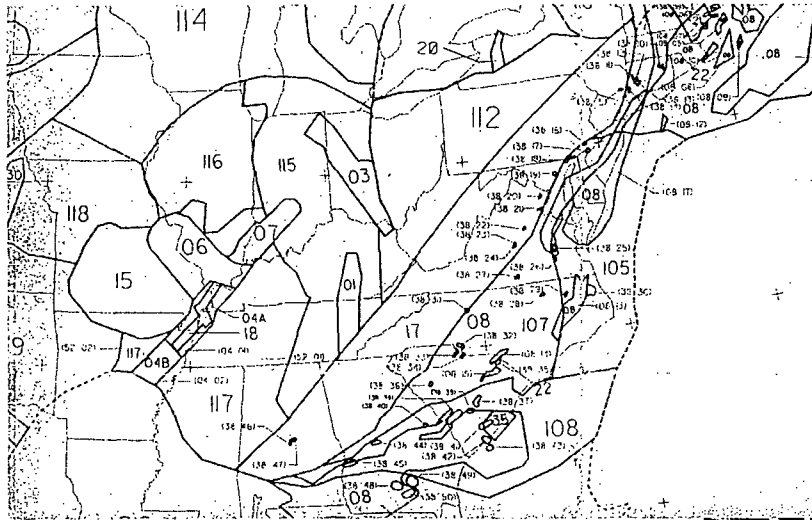


Source: EPRI-SOG (1989)

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EPRI-SOG sources for Law Engineering team

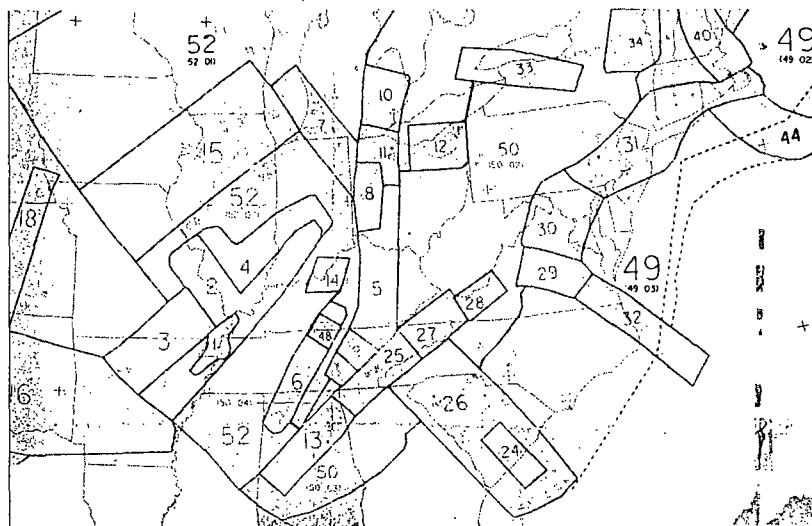


Source: EPRI-SOG (1989)

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EPRI-SOG sources for Rondout team

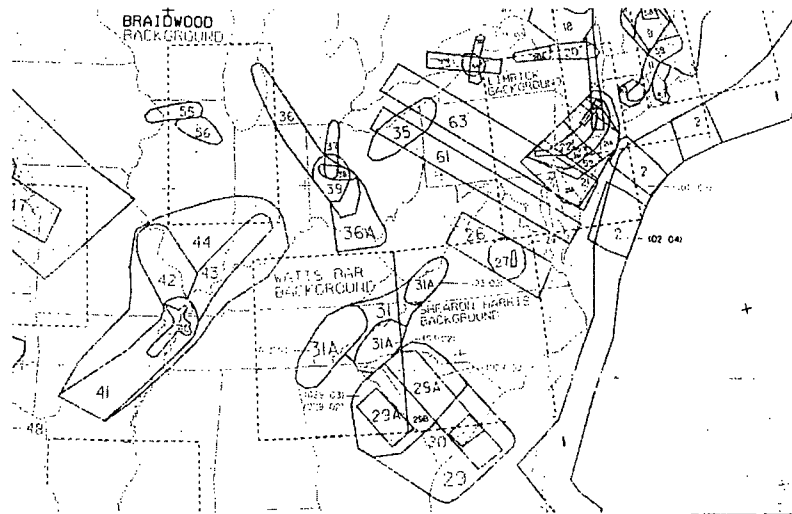


Source: EPRI-SOG (1989)

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EPRI-SOG sources for Woodward-Clyde team

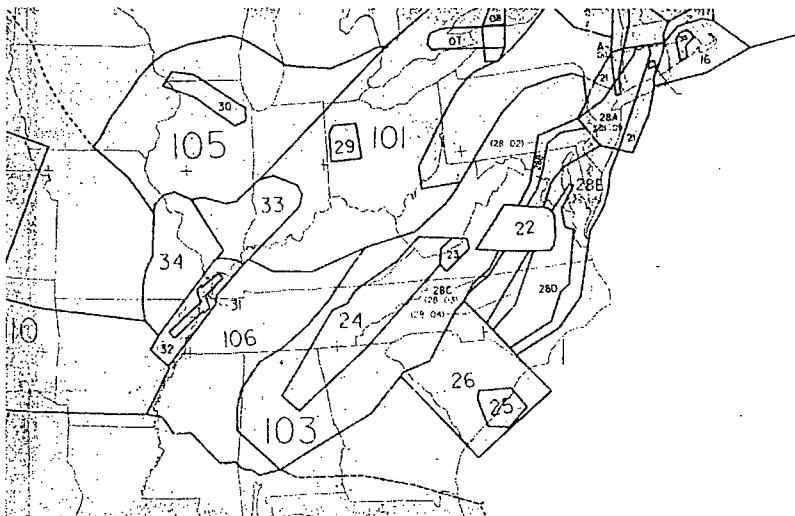


Source: EPRI-SOG (1989)

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EPRI-SOG sources for Weston Geophysical team



Source: EPRI-SOG (1989)

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Seismicity parameters in EPRI-SOG project

- EPRI-SOG seismicity parameters determined by statistical analysis of historical seismicity
- Seismicity parameters calculated for each source per degree cell using smoothing options specified by each team for each source
- Alternative sets of seismicity parameters were weighted using weights specified by each team

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Seismicity parameters for Bechtel source BZ5, constant a and b

INITIAL HOMOGENEOUS SOLUTION : -1.45 0.91

A-ESTIMATES

	87.00	86.00	85.00	84.00	83.00	82.00	81.00	80.00	79.00	78.00	77.00	76.00	75.00	74.00	73.00
87.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
86.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
85.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
84.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
83.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
82.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
81.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
80.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
79.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
78.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
77.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
76.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
75.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
74.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
73.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

B-ESTIMATES

	87.00	86.00	85.00	84.00	83.00	82.00	81.00	80.00	79.00	78.00	77.00	76.00	75.00	74.00	73.00
87.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
86.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
85.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
84.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
83.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
82.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
81.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
80.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
79.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
78.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
77.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
76.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
75.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
74.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
73.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

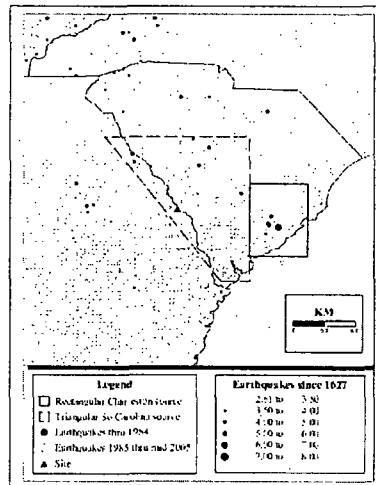
TOTAL AREA OF THIS ZONE: 43.74(1113.11)**2 KM-2

Source: REI 1989 EPRI Report

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PSHA requires evaluation of whether seismicity from 1985-now would change seismicity parameters



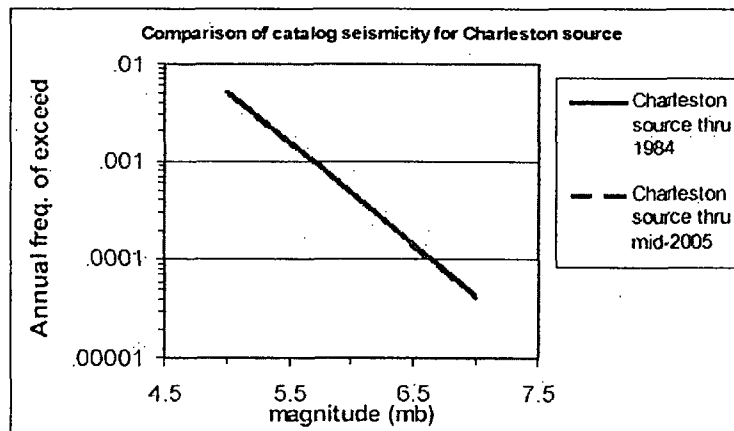
Seismicity, Local Source, & Charleston Source

Source: Vogtle 2006 ESP Application

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PSHA requires evaluation of whether seismicity from 1985-now would change seismicity parameters

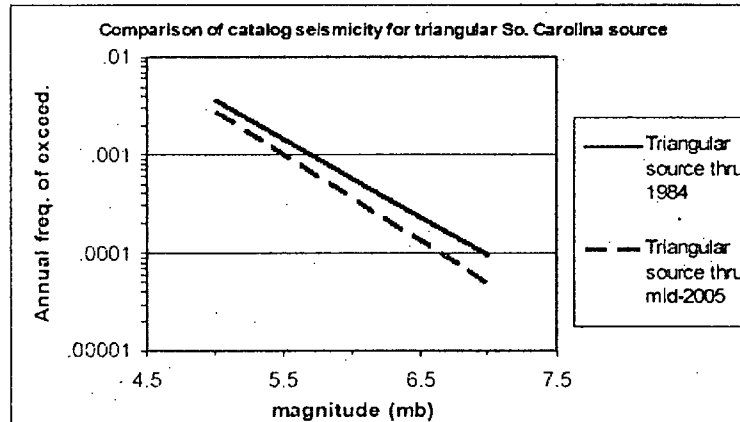


Source: Vogtle 2006 ESP Application

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PSHA requires evaluation of whether seismicity from 1985-now would change seismicity parameters

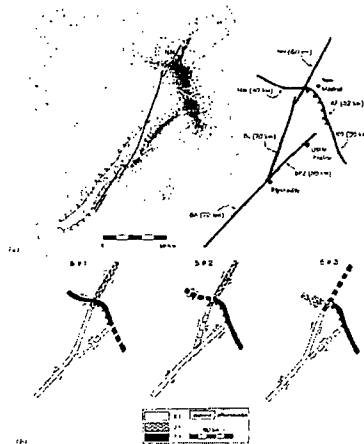


Source: Vogtle 2006 ESP Application

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Geometries of postulated faults and 1811-1812 rupture sequences in New Madrid seismic zone

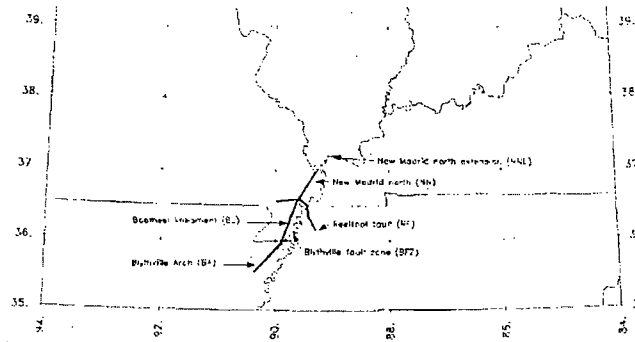


Source: Exelon (2003) Clinton ESP application

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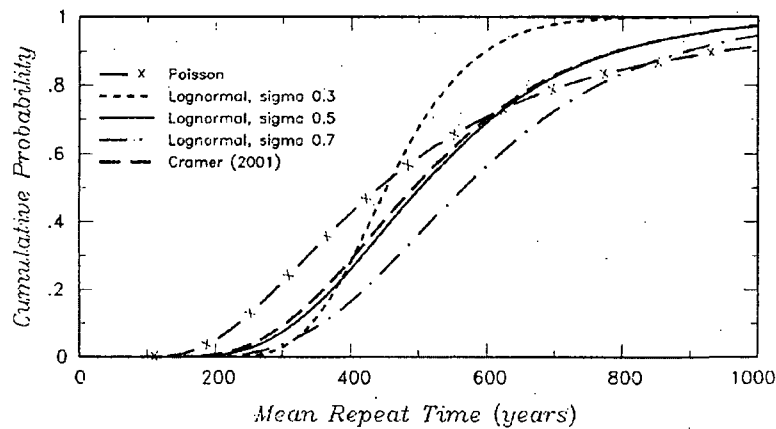
Geometries of faults in New Madrid seismic zone as modeled for PSHA



Source: Exelon (2003) Clinton Report
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Distribution of mean repeat times for New Madrid earthquakes



Source: Exelon (2003) Clinton Report
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Maximum magnitude and recurrence interval distributions for Charleston source

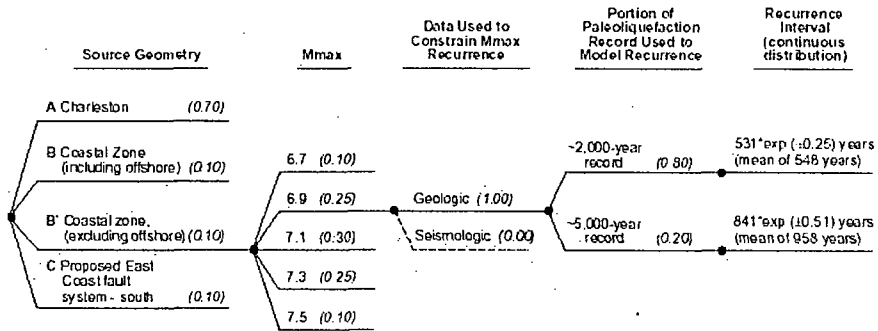


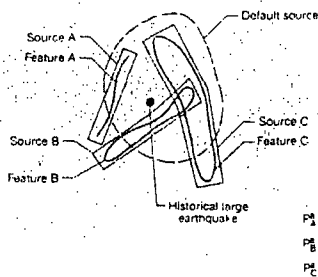
Figure 11. Updated Charleston seismic source (USGS) logic tree with weights for each branch shown in italics

Source: WLA UCSS

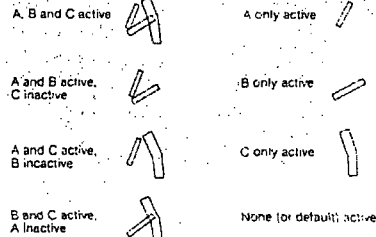
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Example of treatment of alternative source geometries



POSSIBLE STATES OF JOINT SOURCE ACTIVITY

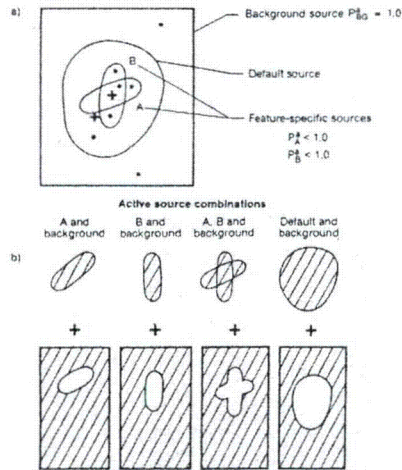


Source: REI (1989) EPRI Report

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Example of “donut” sources representing regions surrounding alternative source geometries

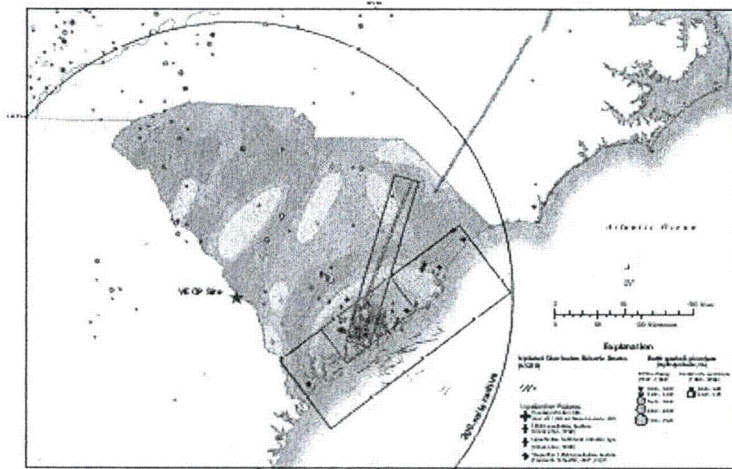


Source: REI 1989 EPRI Report

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Four alternative geometries for Charleston source

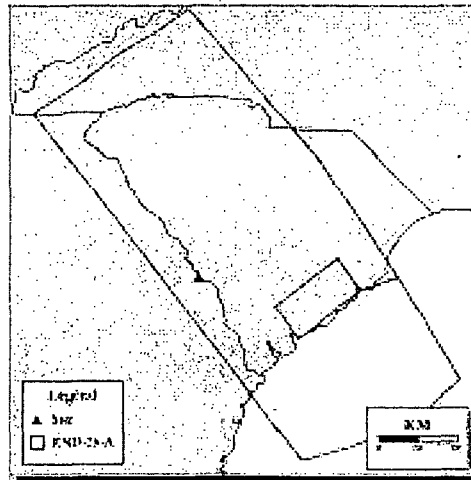


Source: Southern ESP Application Rev 0

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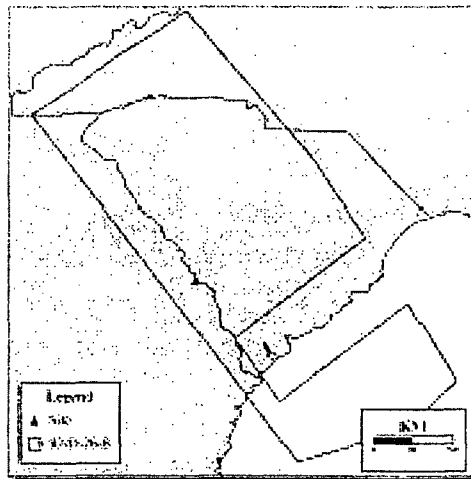
Example: Rondout source 26-A



Source: Southern ESP Application Rev 0
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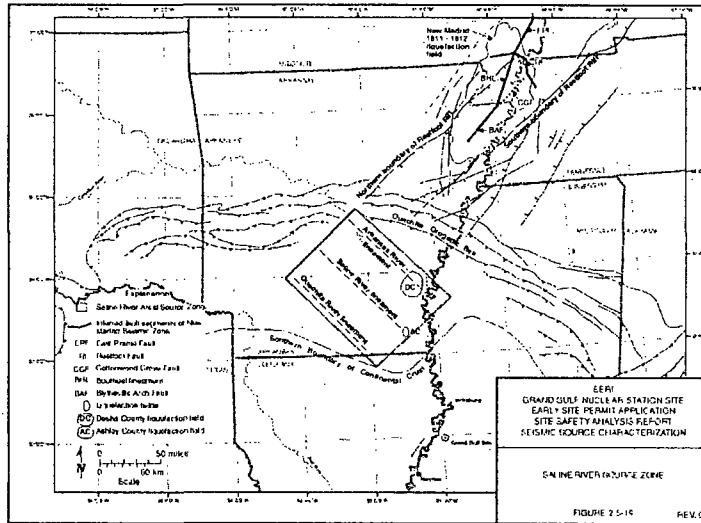
Example: Rondout source 26-B



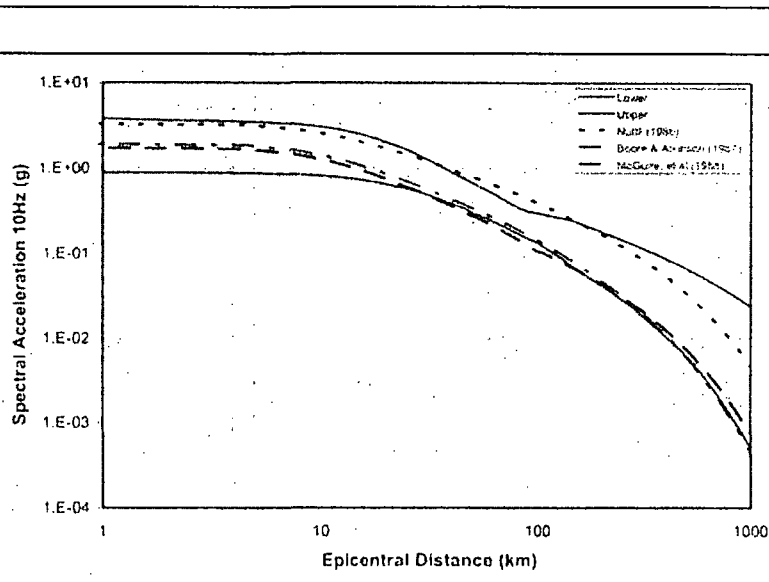
Source: Southern ESP Application Rev 0
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Saline River source



Source: Entergy (2003) Grand Gulf ESP application
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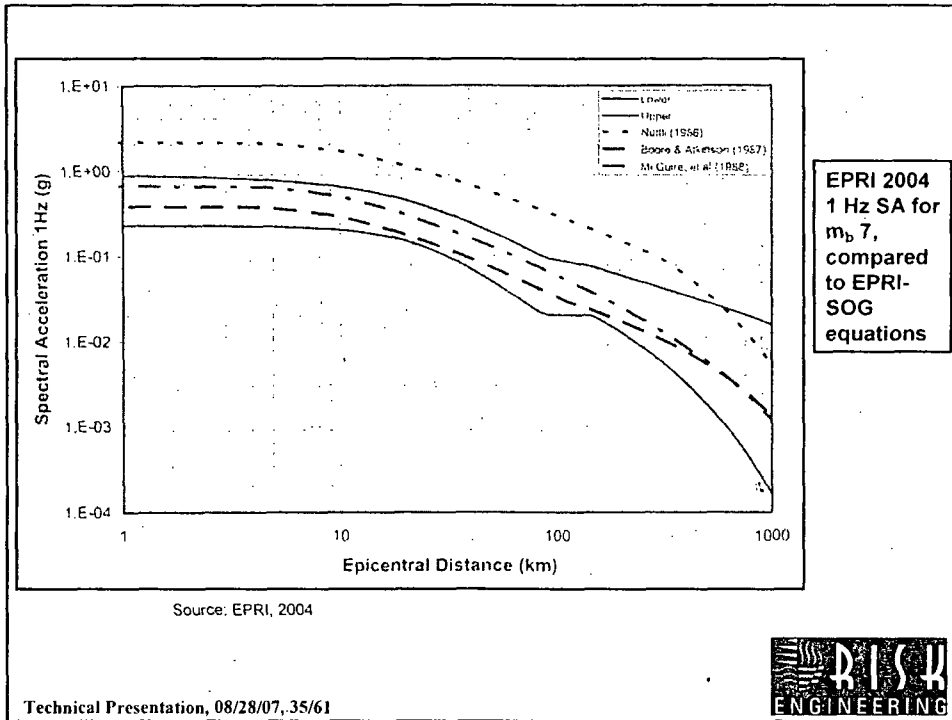


EPRI 2004
 10 Hz SA
 for $m_b 7$,
 compared
 to EPRI-
 SOG
 equations

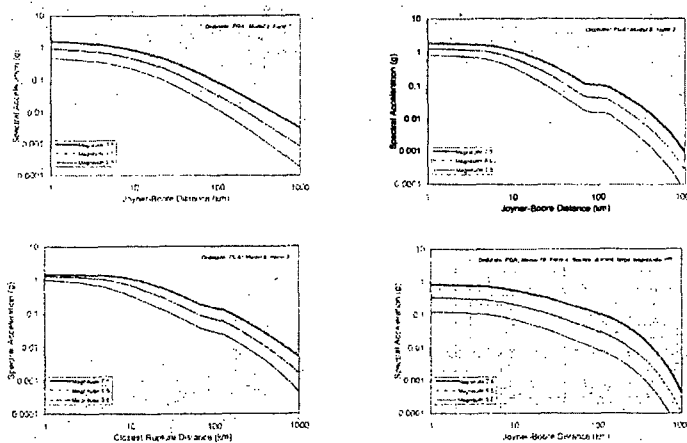
Source: EPRI, 2004

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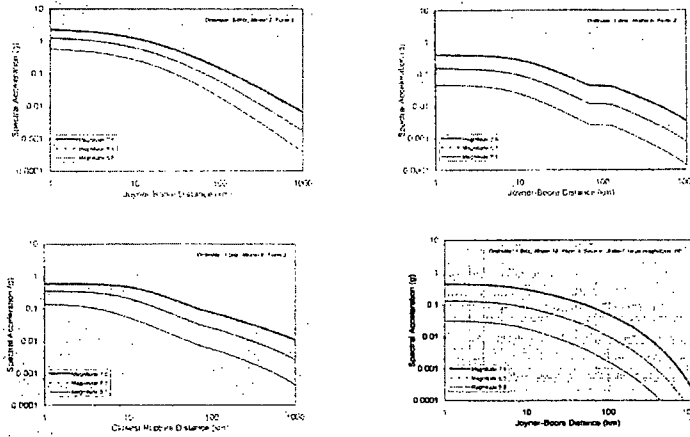
EPRI (2004): Four PGA models (M=5.5, 6.5, 7.5)



Source: EPRI (2004) Ground Motion Report
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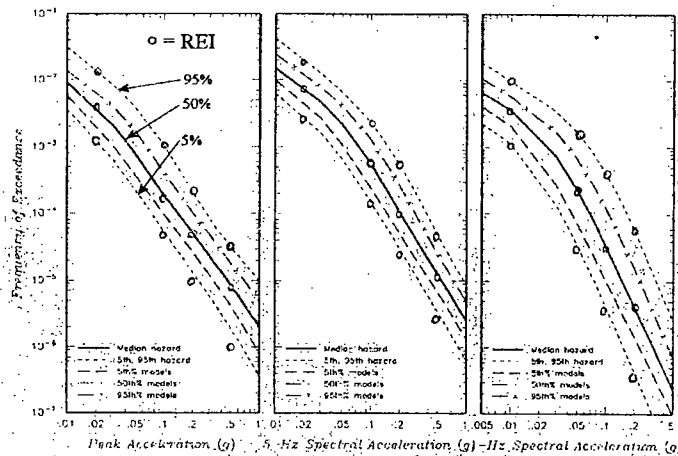
EPRI (2004): Four 1 Hz models (M=5.5, 6.5, 7.5)



Source: CEUS Ground Motion Project 2003
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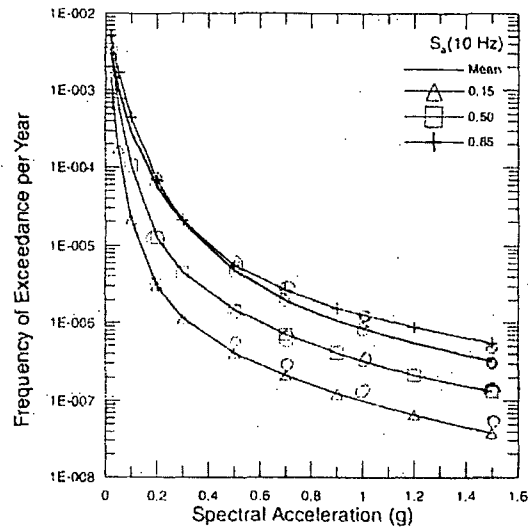
Comparison of rock hazard curves for Clinton



Source: 2005 EPRI Report
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Comparison of rock hazard curves for Grand Gulf



Source: 2005 EPRI Report

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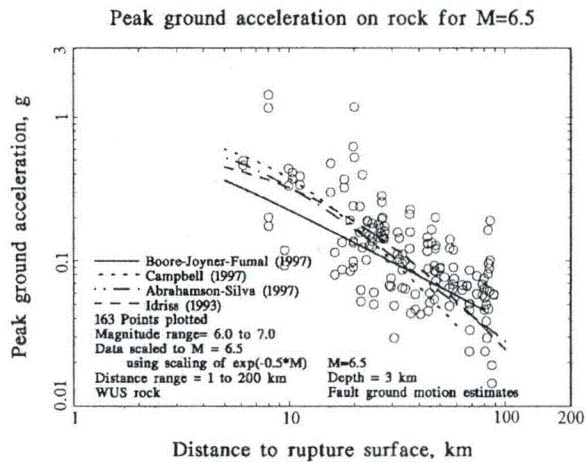
EPRI revised σ 's

- σ is standard deviation of \ln (ground motion amplitude)
- σ represents aleatory uncertainty
- Multiple σ 's represent epistemic uncertainty
- In California we get σ 's from data

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California data vs distance

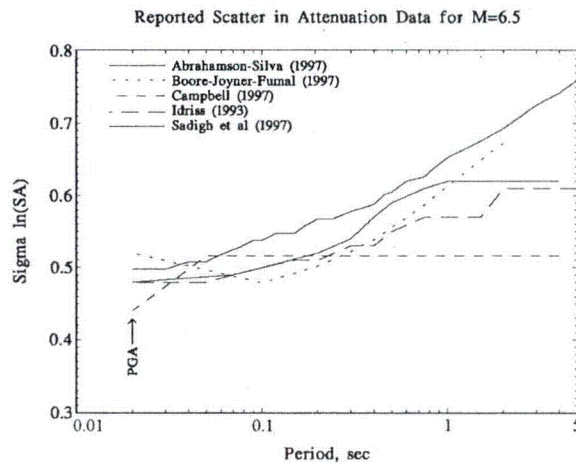


Source: McGuire (2004)

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California σ 's vs period

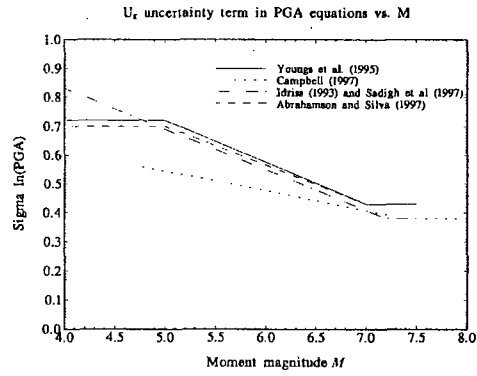


Source: McGuire (2004)

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California σ 's vs magnitude



Source: McGuire (2004)

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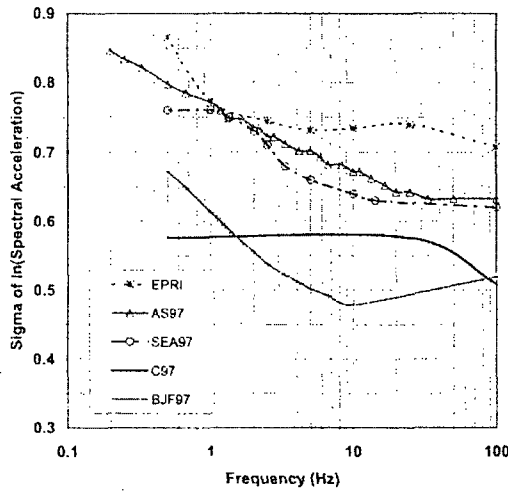
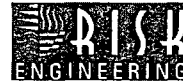


Figure 2.5-54C Comparison of Aleatory Sigmas Reported for California with Weighted Average Aleatory Sigma from EPRI Ground Motion 2003 Models for M = 5.5, R_{CD} = 20 km

Source: North Anna 2003 ESP Application

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EPRI revised σ 's (*continued*)

- In Central and Eastern US we have to estimate σ from models

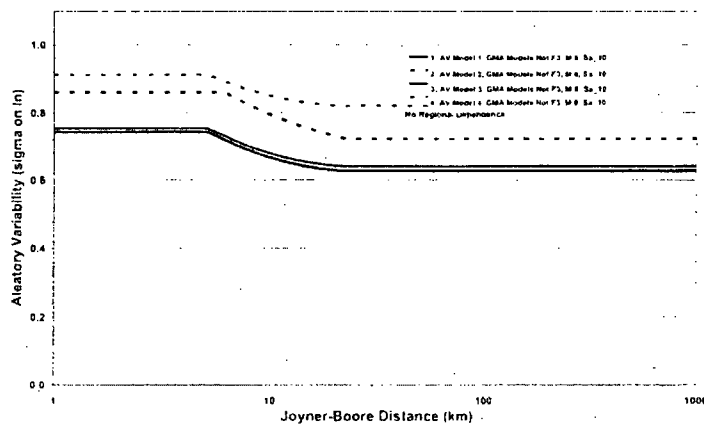
Why would σ (CEUS) > σ (WUS)?

- Earthquake energy release more variable (stress drop)
- Crustal path conditions more variable

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σ 's for 10 Hz SA, $M = 6$

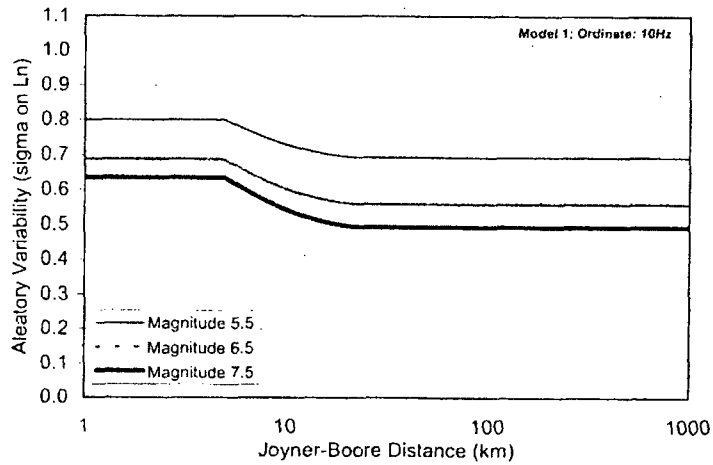


Source: EPRI (2004)

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EPRI (2004) sigmas, model 1, 10 Hz

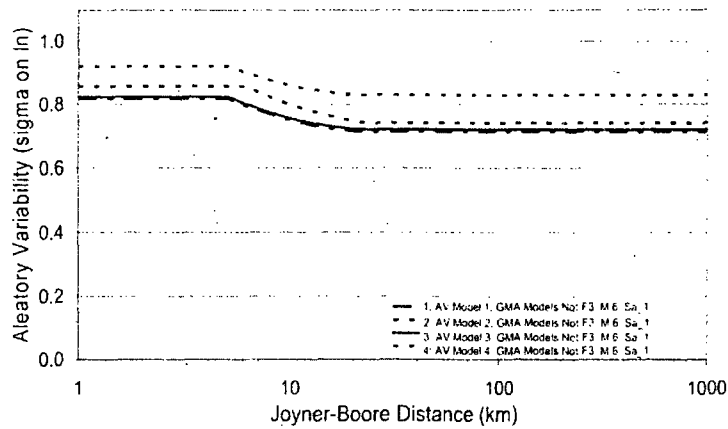


Source: EPRI (2004)

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σ 's for 1 Hz SA, M = 6



Source: EPRI (2004)

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EPRI revised σ 's

Recommended Standard Deviation, σ , for the CEUS. Values are in Ln units

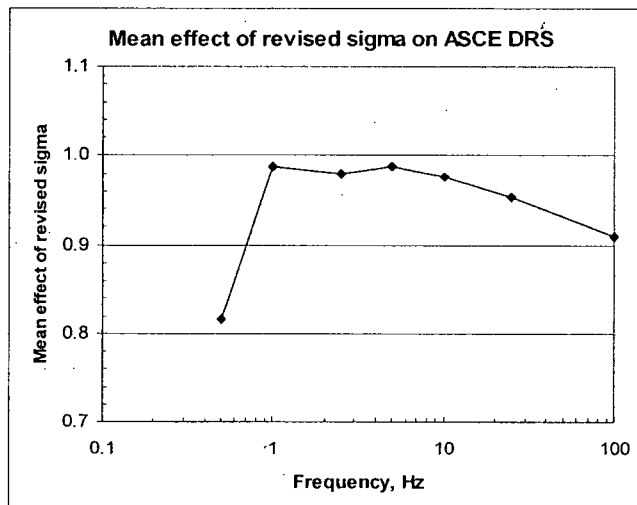
Frequency (Hz)	Model 1A			Model 1B		
	WUS Inter-event			WUS Inter-event		
	WUS Intra-event			WUS Intra-event Reduced for homogeneous crustal structure		
	wt = 0.7			wt = 0.3		
	Intra- event	Inter- Event	Total	Intra- event	Inter- event	Total
PGA	0.51	0.37	0.63	0.48	0.37	0.61
25	0.56	0.43	0.71	0.53	0.43	0.68
10	0.56	0.43	0.71	0.53	0.43	0.68
5	0.56	0.43	0.71	0.53	0.43	0.68
2	0.56	0.43	0.71	0.53	0.43	0.68
1	0.60	0.43	0.74	0.57	0.43	0.71
0.5	0.62	0.43	0.75	0.59	0.43	0.73

Source: Abrahamson and Bommer (2005)

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Mean effect of revised σ for 28 sites



Source: Risk Engineering, Inc. (2006)

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Observations about revised σ

- Affects 10^{-5} ground motion more than 10^{-4} ground motion
- Little effect for sites dominated by Charleston & New Madrid sources

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EPRI CAV Model

CAV = Cumulative Absolute Velocity

Really: Cumulative Absolute Acceleration x Time

Units are g-sec (velocity)

$$CAV = \sum_{i=1}^N H(pga_i - 0.025) \int_{t=t_i}^{t_{i+1}} |a(t)| dt$$

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EPRI CAV model (*continued*)

- Fraction of ground motions with $CAV \leq 0.16$ g-sec are eliminated from hazard calculations
- Estimate of $CAV = f(M, \text{amplitude, duration, } V_{S30})$
- CAV for spectral acceleration is linked to PGA through correlation
- CAV depends on amplitude, M, duration, and V_{S30} (site conditions!)

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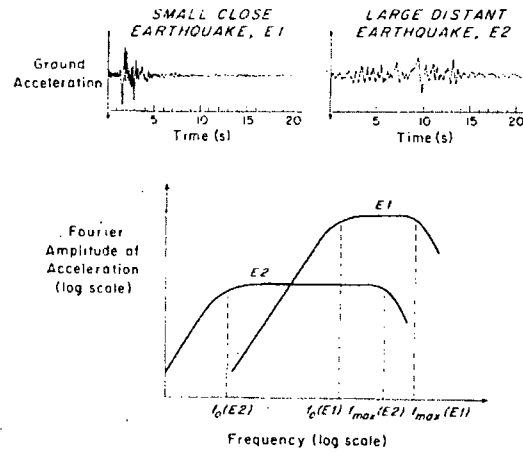
Ground motion correlation with PGA (of logarithmic deviation above & below logarithmic mean)

PGA	25 Hz	10Hz	5 Hz	2.5 Hz	1 Hz	0.5 Hz
1	0.91	0.88	0.75	0.60	0.55	0.50

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Spectra from small and large earthquakes

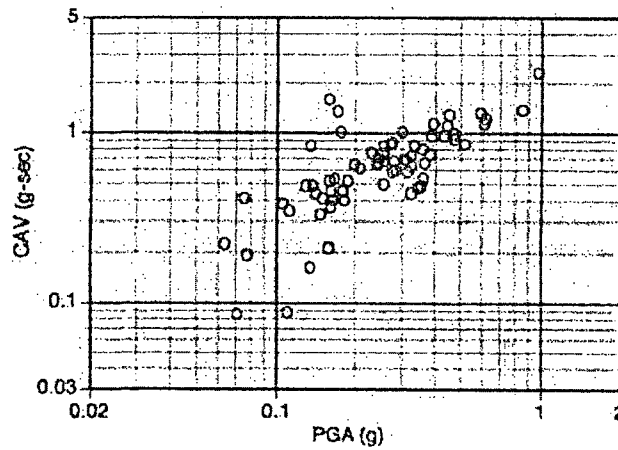


Source: McGuire and Arabasz, (1990)

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Dependence of CAV on PGA amplitude

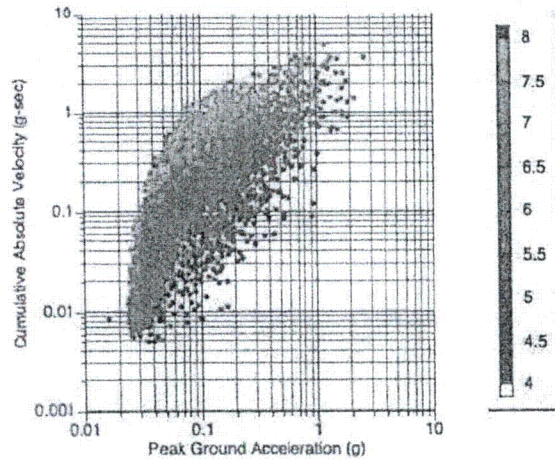


Source: Abrahamson and Watson-Lamprey (2005) EPRI report

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Dependence of CAV on PGA amplitude and magnitude

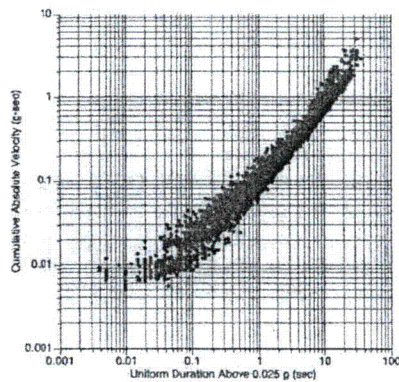


Source: Abrahamson and Watson-Lamprey (2005) EPRI report

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Dependence of CAV on strong motion duration

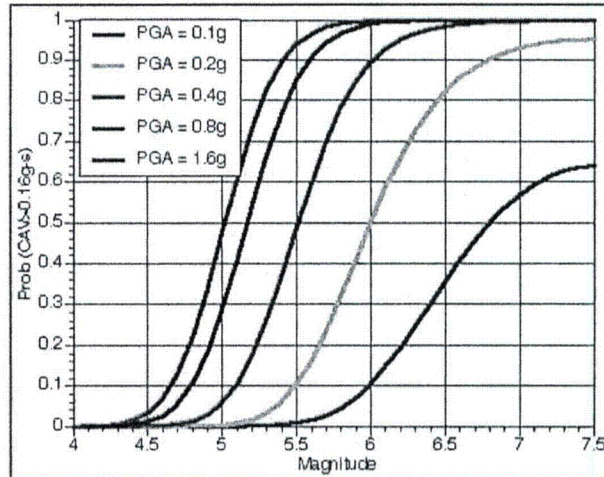


Source: Abrahamson and Watson-Lamprey (2005) EPRI report

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Probability of CAV > 0.16g-sec



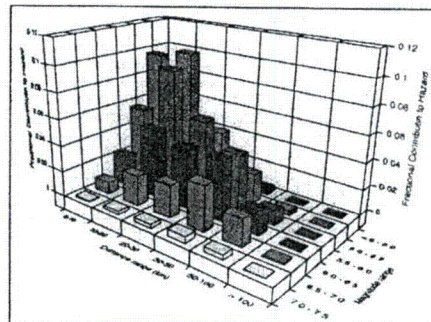
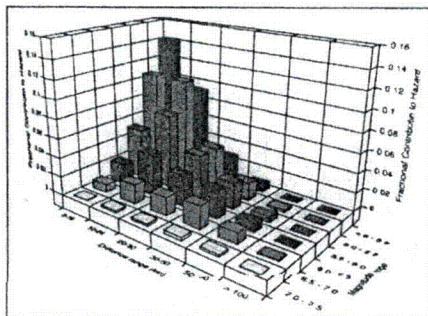
Source: Abrahamson and Watson-Lamprey (2005) EPRI report

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Effect of CAV on contribution to hazard

20 Hz 10^{-4} deaggregation, no CAV (left) and CAV (right)



Source: Abrahamson and Watson-Lamprey (2005) EPRI report

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Summary of PSHA applications

- Hazard based on EPRI-SOG updated by New Madrid and Charleston models (+ others)
- EPRI (2004) ground motions with revised σ
- CAV filter applied to account for damageability of small-magnitude earthquakes