PSHA, Site Response, and Site Spectra

Technical Presentation
Rockville, MD
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TOPIC 3: Site Hazard

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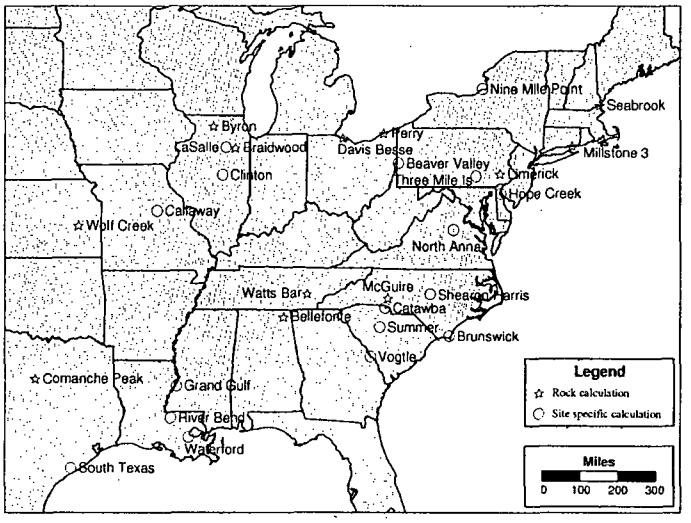
Boulder, Colorado

Topic 3: Site hazard

- Typical hazard curves, effect of revised σ and CAV
- Deaggregation for high and low frequencies
- Effect of site response: how to convert rock hazard to site hazard (Approaches 1, 2A, 2B, 3, 4)

28 sites used for hazard comparisons



Source: REI 2005 EPRI Report

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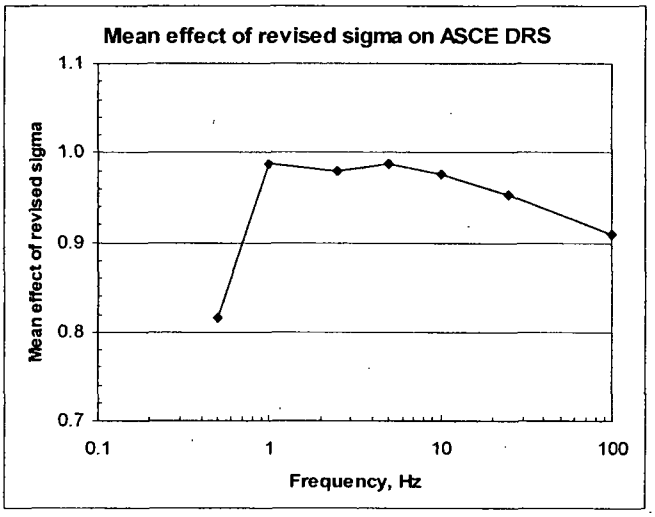
Mean effect of revised σ for 28 sites



Source: Risk Engineering, Inc. (2006)

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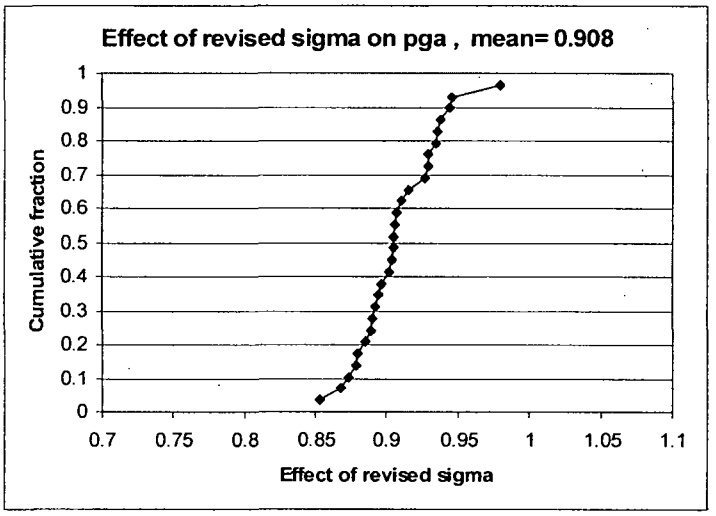
Range of effect of revised σ on PGA



Source: Risk Engineering, Inc. (2006)

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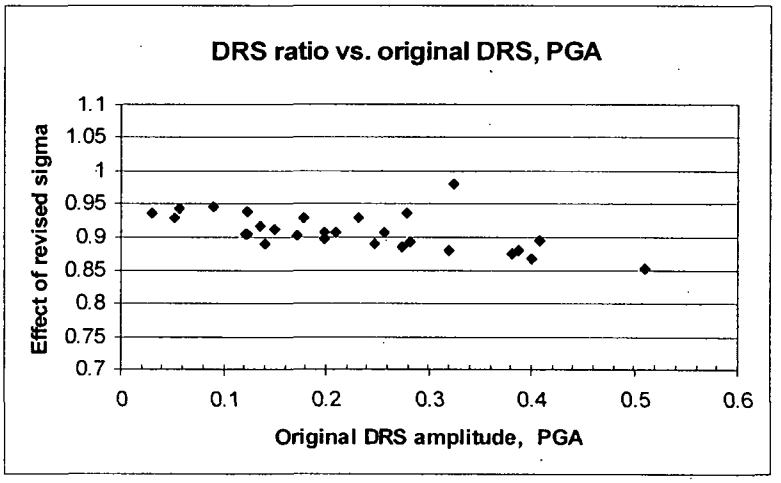
Effect of revised σ on PGA, vs PGA



Source: Risk Engineering, Inc. (2006)

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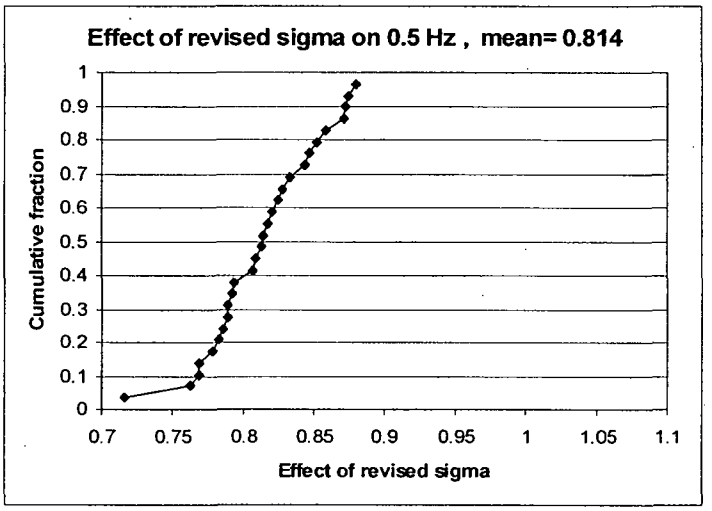
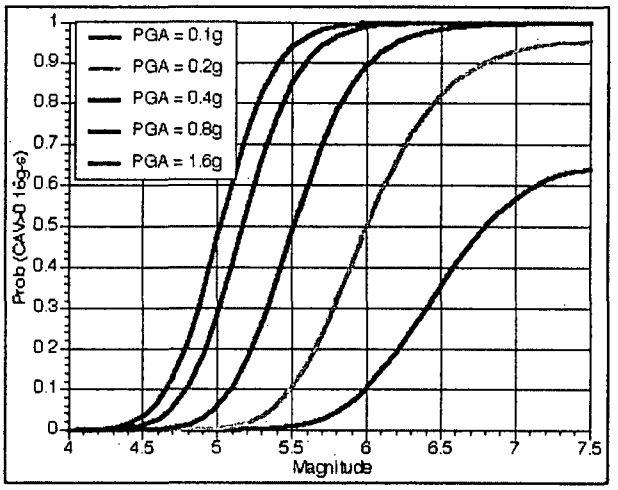
Range of effect of revised σ on 0.5 Hz



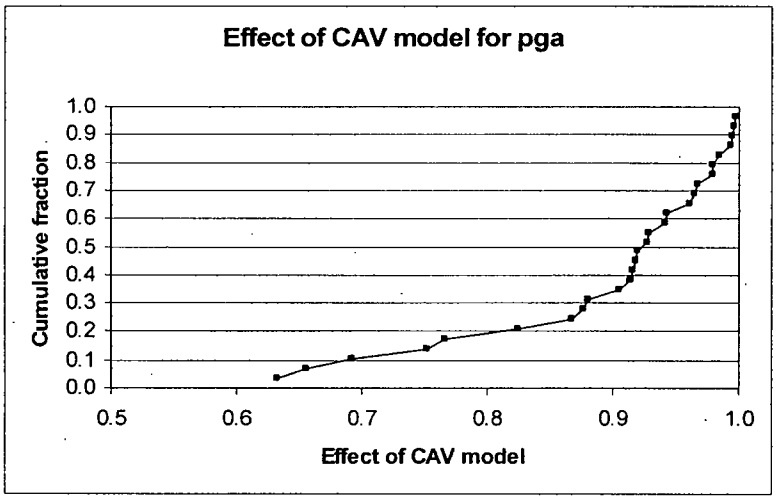
Source: Risk Engineering, Inc. (2006)

Probability of CAV > 0.16g-sec



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

Range of effect of CAV for PGA



Source: Risk Engineering, Inc. (2006)

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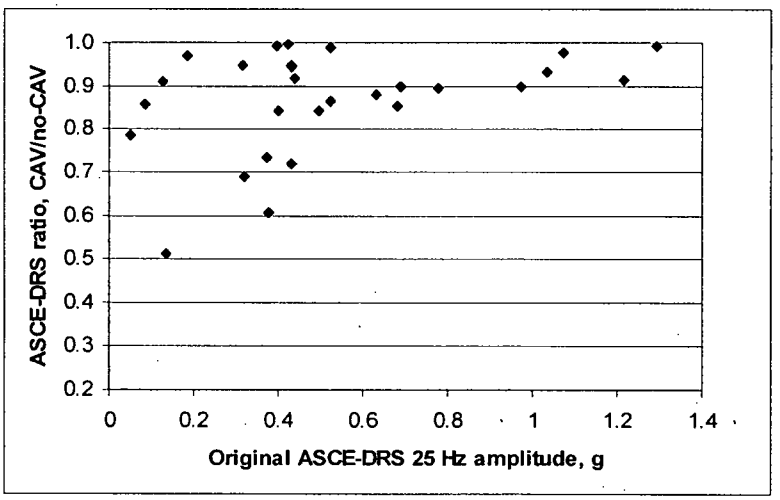
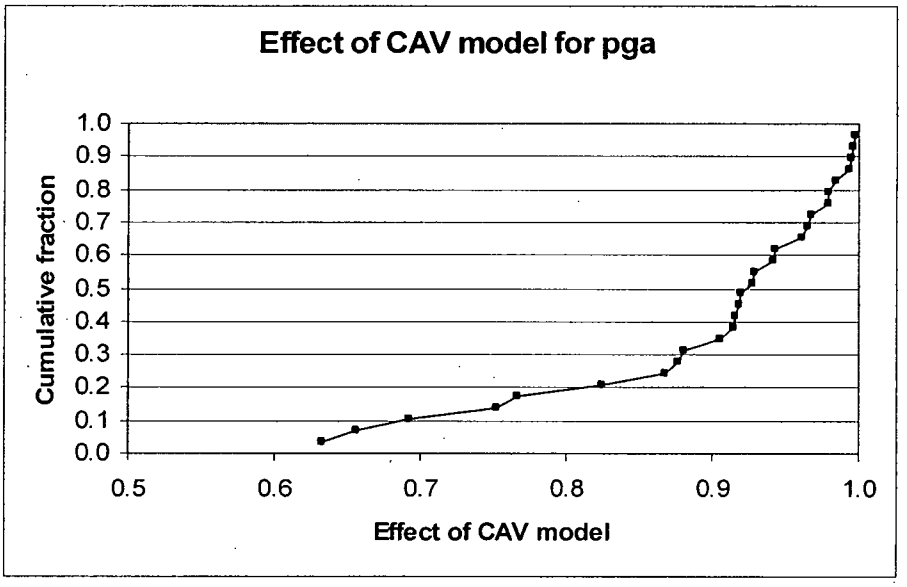
Effect of CAV vs 25 Hz SA



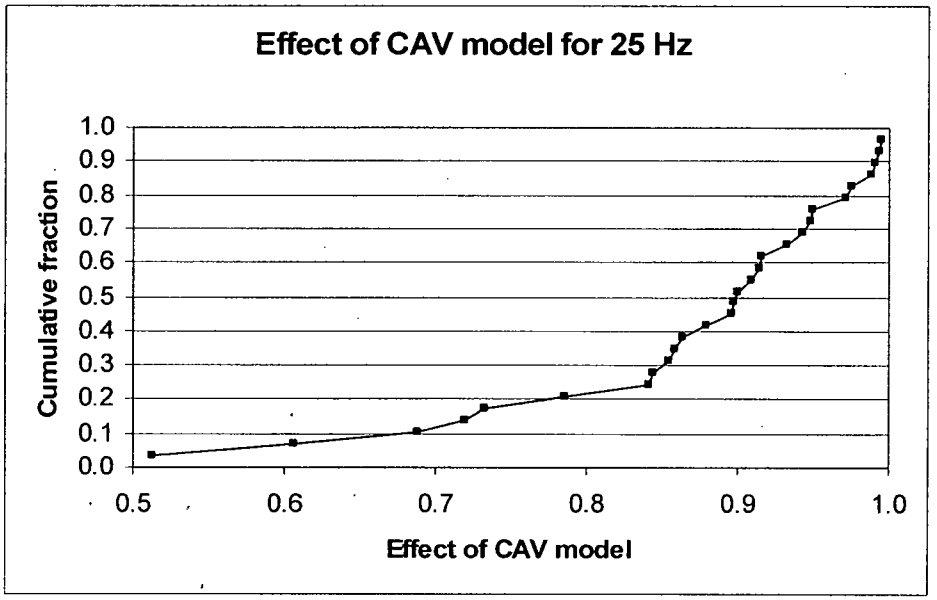
Source: Risk Engineering, Inc. (2006)

RISK ENGINEERING



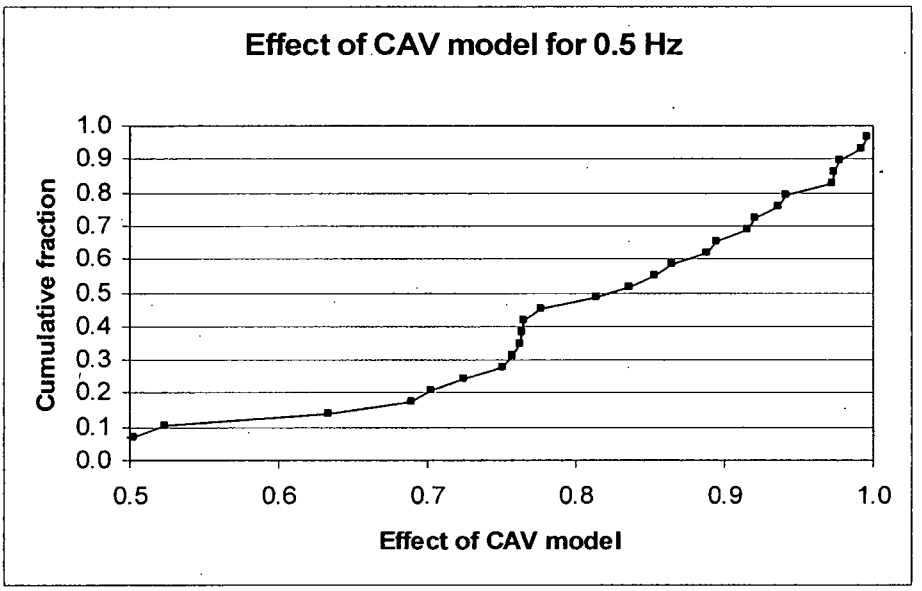
Source: 2006 EPRI Report

RISK ENGINEERING



Source: 2006 EPRI Report

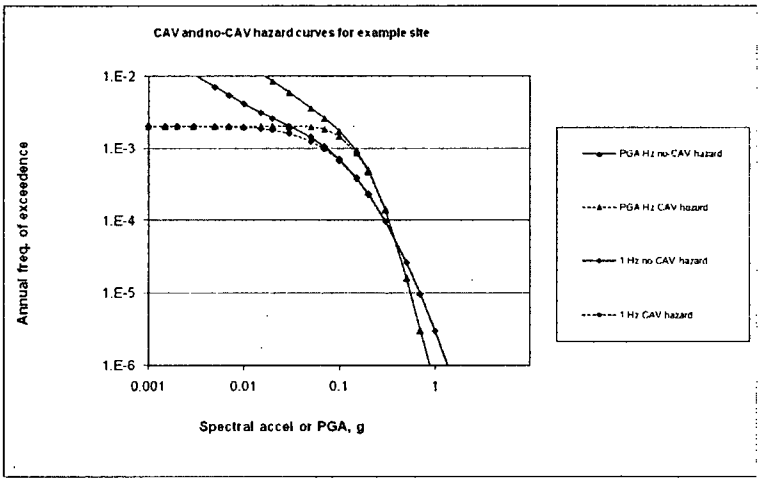
RISK ENGINEERING



Source: 2006 EPRI Report

RISK ENGINEERING

Example of CAV and no-CAV hazard curves for PGA and 1 Hz



Source: Risk Engineering, Inc. (2006)

RISK ENGINEERING

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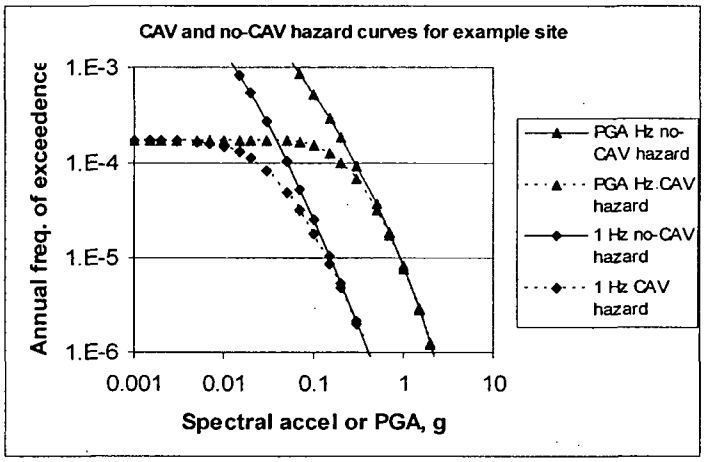

Source: Risk Engineering, Inc. (2006)

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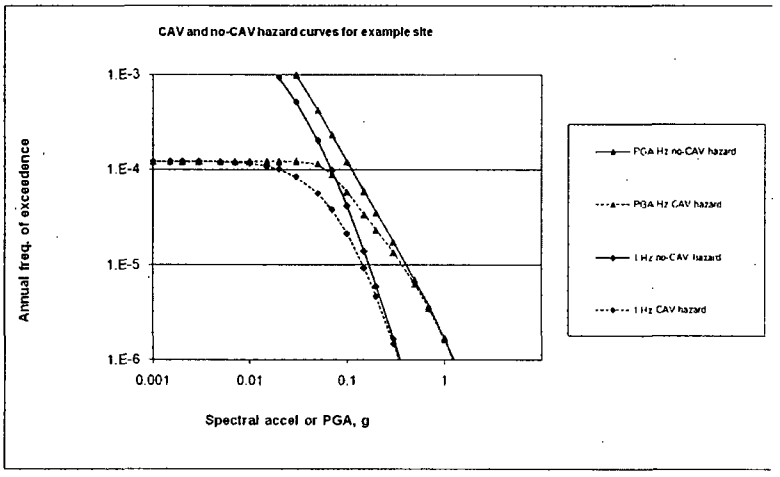
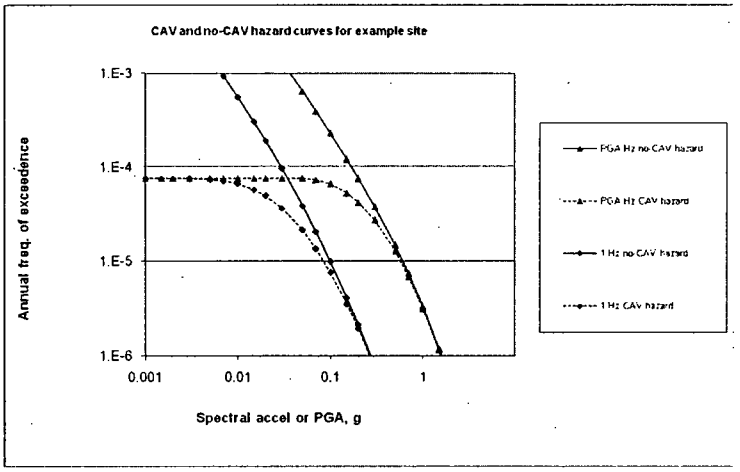


Source: Risk Engineering, Inc. (2006)

Example of CAV and no-CAV hazard curves for PGA and 1 Hz



Source: Risk Engineering, Inc. (2006)

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Mean and Median Reductions in ASCE DRS from CAV Filter at Each Structural Frequency

Frequency, Hz	Mean Reduction	Median Reduction
PGA (100)	10.4%	7.7%
25	13.2%	10.1%
10	12.2%	9.6%
5	12.6%	10.3%
2.5	15.0%	11.9%
1	18.0%	15.1%
0.5	19.8%	17.4%

Source: 2006 EPRI Report

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Observations about CAV

- Affects 10^{-4} ground motion more than 10^{-5} ground motion
- Little effect for sites dominated by Charleston & New Madrid sources
- Large effect for sites where hazard is low
- Major effect at sites with hazard dominated by frequent, small earthquakes

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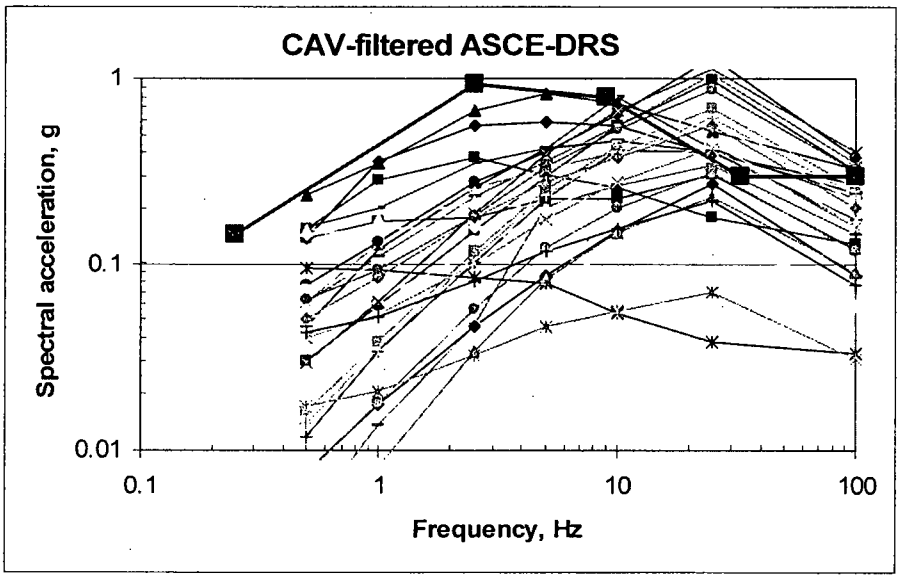

Source: 2006 EPRI Report

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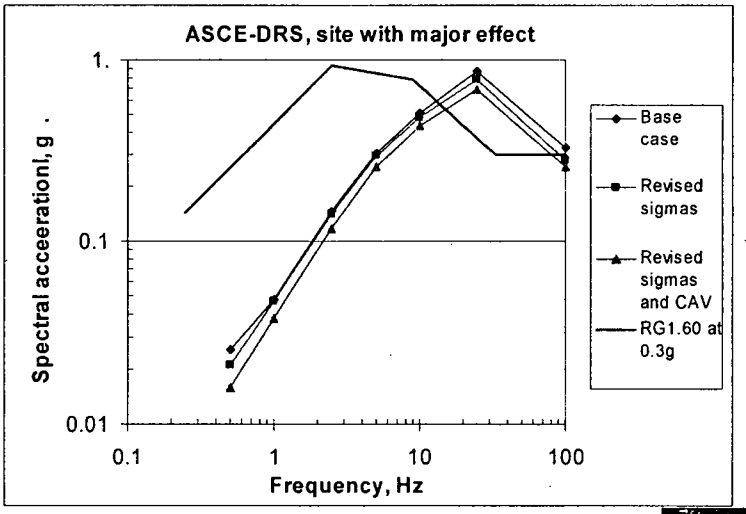
Example of CAV and σ effect



Source: Risk Engineering, Inc. (2006)

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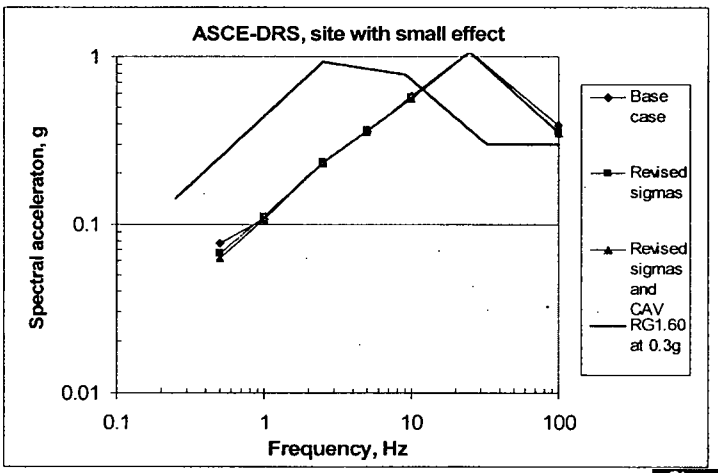

Source: 2006 EPRI Report

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Hard Rock UHS and Deaggregation

- Deaggregation shows what earthquakes (M and R) contribute to high- and low-frequency parts of the design spectrum
- Two earthquakes required in RG 1.165
- Use of broad-banded spectrum may be unconservative for site response
- Should calculate site response with HF input motion and LF input motion, and envelop response

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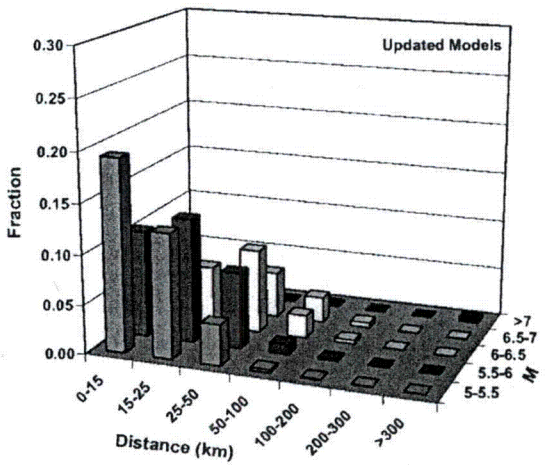
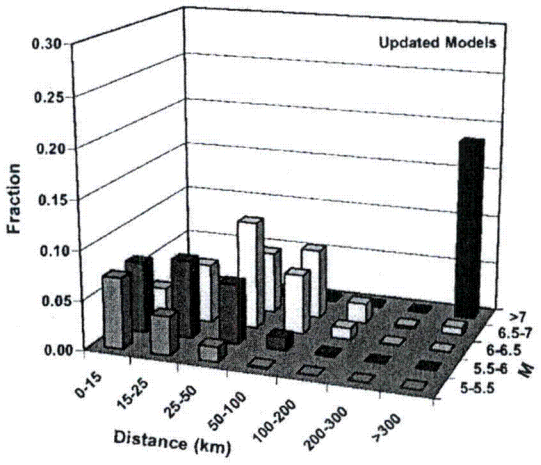
HF deaggregation at mean $5x10^{-5}$



Source: NA ESP (2004)

RISK ENGINEERING

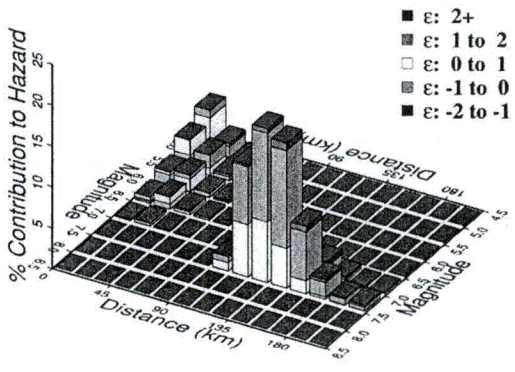
LF deaggregation at mean $5x10^{-5}$



Source: NA ESP (2004)

RISK ENGINEERING

High Frequency, 1.0e-4



Source: Vogtle ESP (2006)

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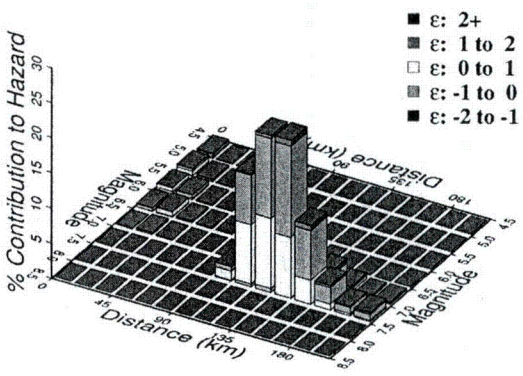
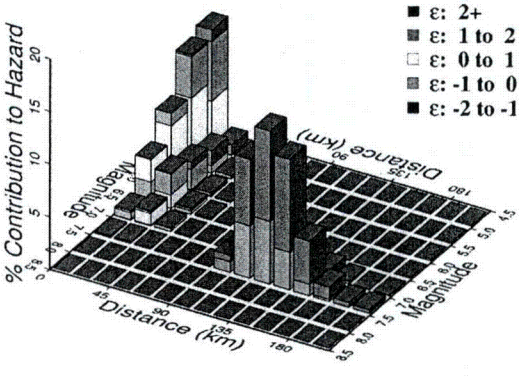
Low Frequency, 1.0e-4



Source: Vogtle ESP (2006)

RISK ENGINEERING

High Frequency, 1.0e-5



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RISK ENGINEERING

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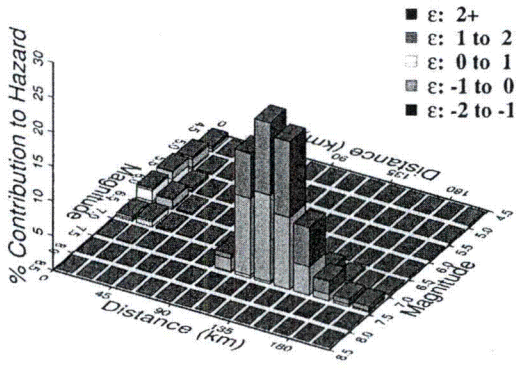
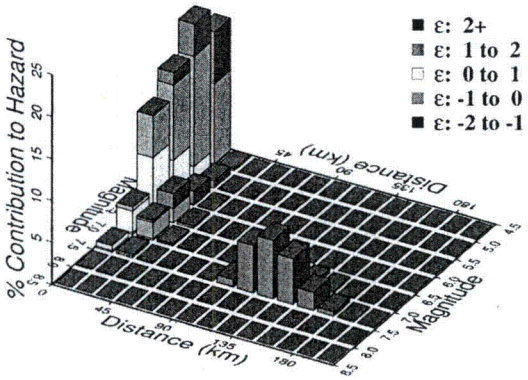


Source: Vogtle ESP (2006)

RISK ENGINEERING

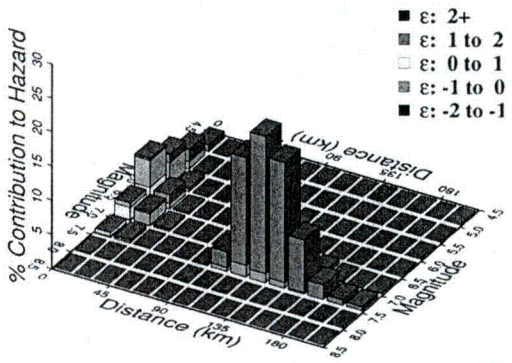
High Frequency, 1.0e-6



Source: Vogtle ESP (2006)

RISK ENGINEERING

Low Frequency, 1.0e-6



Source: Vogtle ESP (2006)

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Method 2

Critical step: use appropriate M and R

	Overall		R < 100 km		R > 100 km	
	M	R	M	R	M	R
10^{-4} HF	7.0	260	5.6	22	7.7	360
10^{-4} LF	7.5	330	5.9	23	7.7	360
10^{-5} HF	6.0	90	5.6	14	7.7	360
10^{-5} LF	7.4	290	6.0	18	7.7	360
10^{-6} HF	5.8	31	5.7	12	8.1	320
10^{-6} LF	7.1	220	6.2	15	7.8	360

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Method 2 (cont'd)

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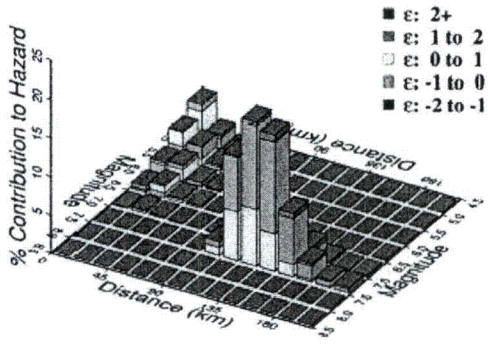

Source: Southern ESP Application Rev 0

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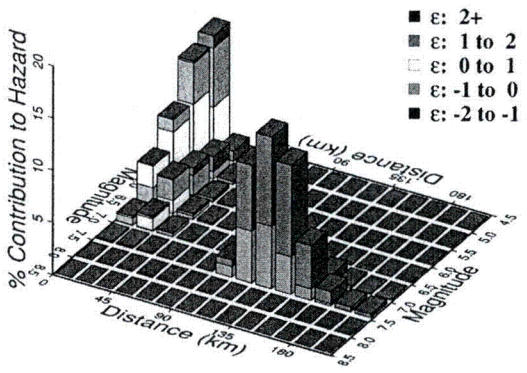
High Frequency, 1.0e-5



Source: Vogtle ESP (2006)

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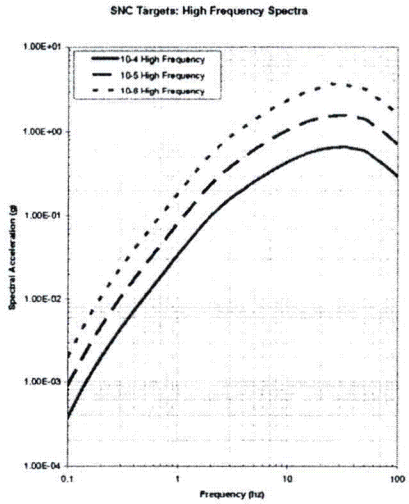
HF rock spectra



Source: Vogtle ESP (2006)

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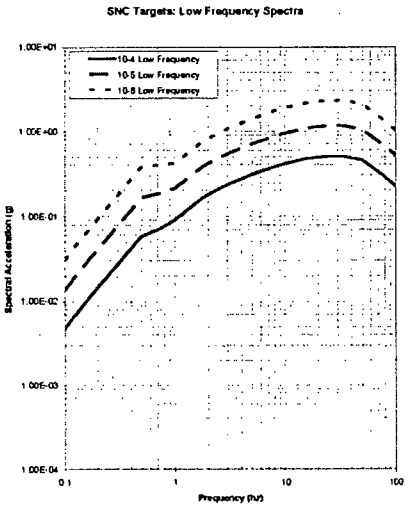
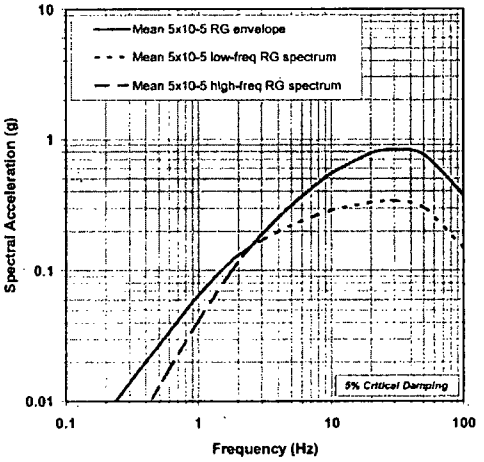
LF rock spectra



Source: Vogtle ESP (2006)

North Anna HF and LF rock spectra

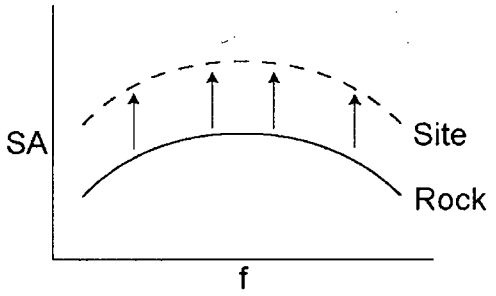


Source: NA ESP (2004)

How to estimate site hazard

Method 1

Use broadbanded rock USH, multiply by mean AF(f) to get broadbanded site UHS



Source: Risk Engineering, Inc. (2006)

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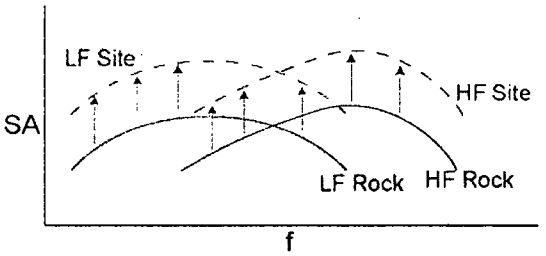
Method 2

Use high-frequency (HF) and low-frequency (LF) rock spectra, multiply by mean AF (f) calculated from HF and LF input, to get 2 site spectra, envelop.

2A: use 1 magnitude

2B: use multiple magnitudes



Source: Risk Engineering, Inc. (2006)

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Method 3

Convolve rock hazard with site AF to get site hazard.

$$P[A_S > a] = \int P[A_R = x] P\left[AF > \frac{a}{x}\right] dx$$

Effect of $\sigma_{\ln(AF)}$ on site UHS amplitudes

$$a_{rp}^{s} = a_{rp}\,\overline{AF_{rp}}\exp\left[0.5K_H\sigma_\delta^2/(1-K_{AF})\right]$$

Method 4

Put site response in the seismic hazard software, calculate site hazard directly

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Comparison of methods

Method:	**Direct Site Calculation**	**Rock Calculation Amplified**
Ground Motion Equation	Site-specific	Rock
Hazard Integral	Site-specific	Rock
Hazard Curve	Site-specific	Rock
Post-process	N/A	Amplify rock
Advantages	"Truth"	Traditional
Disadvantages	Changing site parameters → rerun everything	Approximate site effects (**M**, R effects approximated)
Approach	4	1, 2A, 2B, 3

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Comparison of methods (cont'd)

Method:	Direct Site Calculation	Rock Calculation Amplified
Site Amplification	For all M and R	For critical M and R only
Epistemic uncertainties	Use multiple models	Use multiple models
Aleatory uncertainties	Handle with each M and R	Can treat accurately

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"Results showed that once the (response spectral) value of a record at the bedrock is known, the additional knowledge of **M** and R, which implicitly define its average response spectrum shape, do not appreciably improve the estimate of AF(*f*) at the same frequency *f*.

In other words, AF(*f*), conditioned on (rock spectral level), is virtually independent of **M** and R."

--Bazzurro and Cornell, 2004, BSSA

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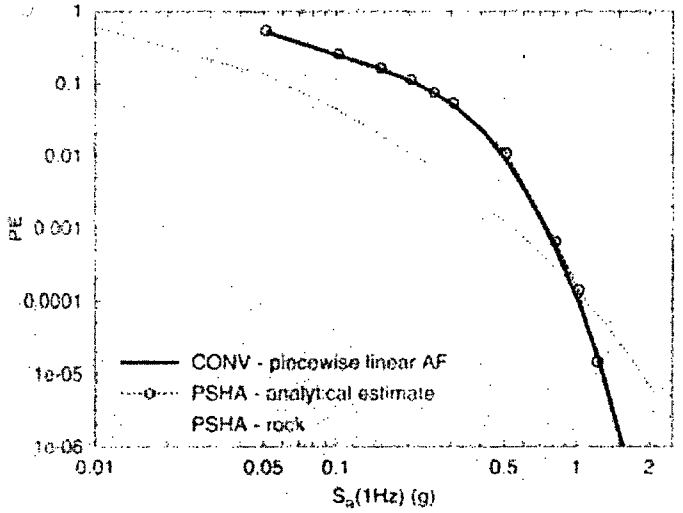
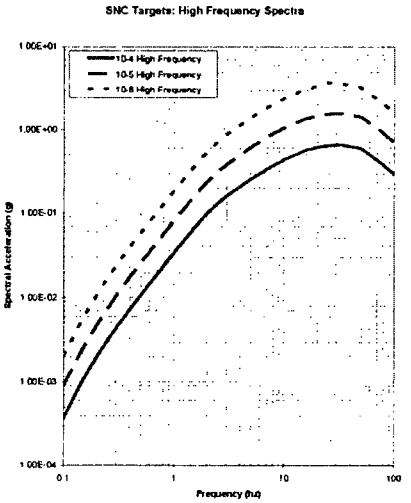
Comparison of Approach 3 and 4



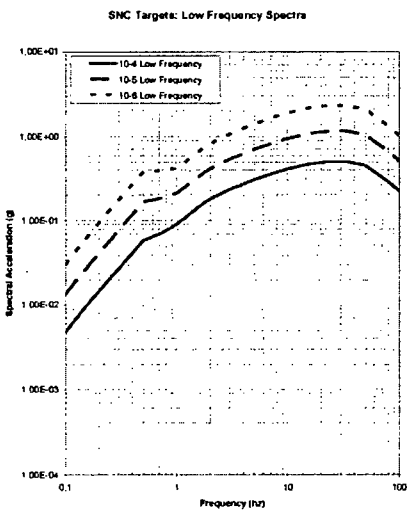
Source: Bazzurro and Cornell (2004)

HF rock spectra



Source: Vogtle ESP (2006)

LF rock spectra



Source: Vogtle ESP (2006)

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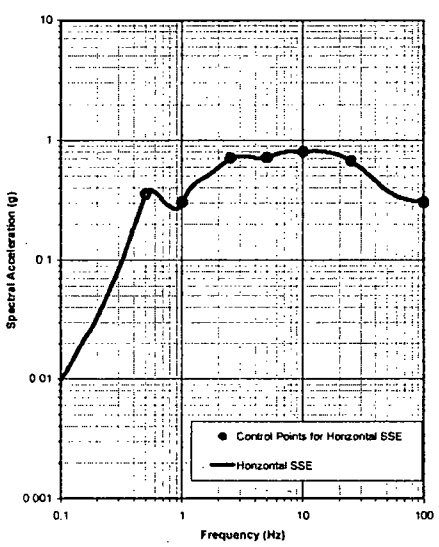
GMRS for deep soil site



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