Recent Activities Concerning PSHA at the USNRC

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IAEA Consultancy Meeting
on Probabilistic Seismic Hazard Analysis (PSHA)
of Nuclear Facilities
Vienna, Austria
November 12-14, 2007

Outline

- Background
  - Use of Deterministic Seismic Hazard Analysis (DSHA) for Currently Operating NPPs
- Regulatory Framework for Probabilistic Seismic Hazard Analysis (PSHA)
  - Regulation
    - 10 CFR 100.23
  - Regulatory Guidance
    - RG 1.165 (1997)
      - Development of Reference Probability (1×10^{-5} median, ~ 1×10^{-4} mean)
    - RG 1.208 (2007)
      - Implemented - PSHA and Risk Consistency in a Performance-Based Framework
- Use of PSHA for Early Site Permits (ESPs) and First Combined Licenses (COLs)
  - Clinton
  - Grand Gulf
  - North Anna
  - Vogtle
  - South Texas Project

Background

- Over 100 NPPs Safely Licensed Using DSHA
- Use of DSHA
  - Before Appendix A to 10 CFR Part 100
  - Since Appendix A to 10 CFR Part 100 (November 1973)
    - Defined Safe-Shutdown Earthquake (SSE) and Operating-Basis Earthquake (OBE)
    - Very Prescriptive and Detailed
    - Controversial and Conflicting Interpretations Often Led to Delays

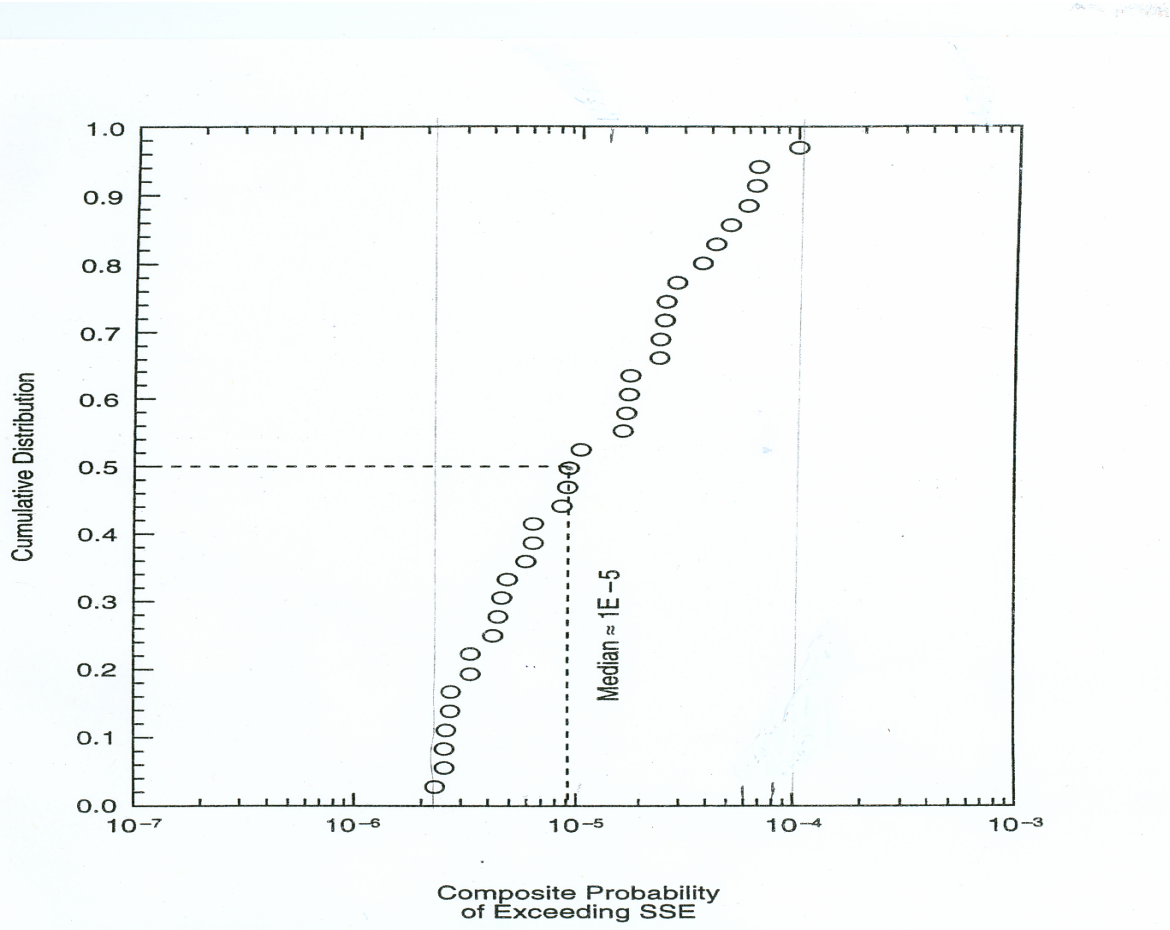
Regulatory Framework for PSHA

- Regulation – 10 CFR 100.23 (1996)
  - Required Uncertainty Analysis in Determining SSE
  - Allowed Use of PSHA
  - Allowed Use of "Suitable Sensitivity Analyses"
  - Supported by Regulatory Guidance and the Standard Review Plan (SRP)
- Regulatory Guide 1.165 (1997)
- Regulatory Guide 1.208 (2007)

Regulatory Framework for PSHA (cont'd)

- RG 1.165 – Identification and Characterization of Seismic Sources and Determination of Safe-Shutdown Earthquake Ground Motion
  - Endorsed the Use of PSHA in Determining the SSE Ground Motion (EPRI or LLNL Methodologies and Databases)
  - Defined the Reference Probability
  - Described the Content of the Geological and Seismological Site Investigations
  - Described the Process for Checking and Updating the PSHA for Site-Specific Use
  - Defined Controlling Earthquakes and Their Use
  - Provided Schematic for Determining SSE Ground Motion

Development of Reference Probability



Development of Reference Probability

Site Number	Controlling Earthquakes		Past Seismic Design	
	Magnitude	Distance (km)	Magnitude	Distance (km)
1	5.4	18	5.0	15
2	5.6 7.2	24 275	5.8 7	15 250
3	5.5	14	5.3	15
4	5.6	14	5.3	15
5	5.7	14	5.7	15
6	5.5	16	5.3	15
7	5.3 7.3	18 340	4.8 7.3	15 370
8	5.7	14	6	15
9	5.6	14	5.8	15

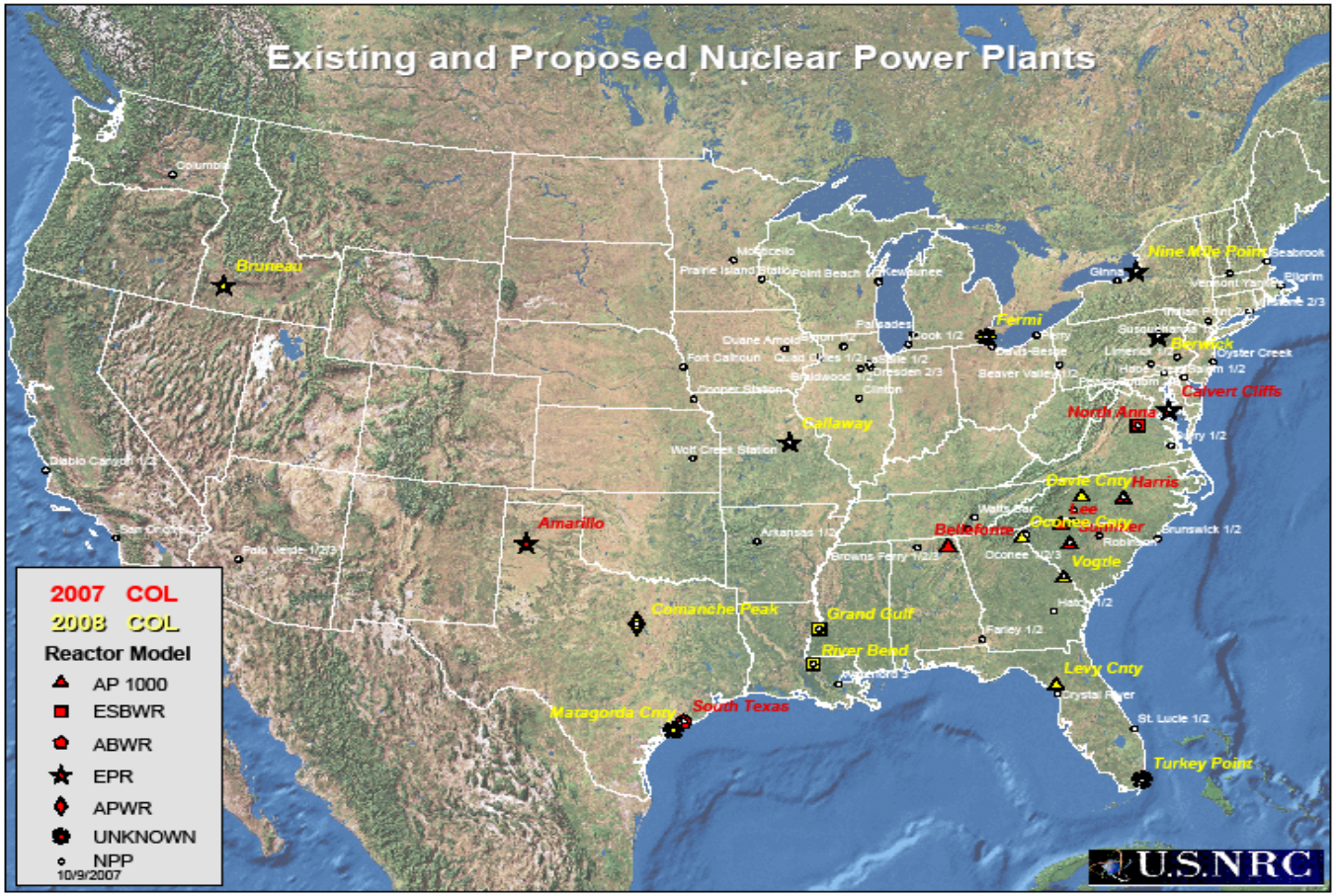
Regulatory Framework for PSHA (cont'd)

- RG 1.208 – A Performance-Based Approach to Define the Site-Specific Earthquake Ground Motion
  - Enhances the Role of PSHA in Defining Site-Specific Earhquake Ground Motion
  - Provides General Guidance for the following activities:
    - Conduct Geological, Geophysical, and Geotechnical Site Investigations
    - Identify and Characterize Seismic Sources
    - Conduct a Site-Specific PSHA
    - Determine Seismic Wave Transmission Characteristics
    - Determine the Site-Specific, Performance-Based Ground Motion Response Spectra (GMRS)
  - Supported by Complimentary Revisions to the SRP

PSHA for Early Site Permits and Combined Licenses

- Clinton Power Station ESP
- Grand Gulf Nuclear Power Station ESP
- North Anna Power Station ESP
- Vogtle Electric Generating Plant ESP
- South Texas Project COL

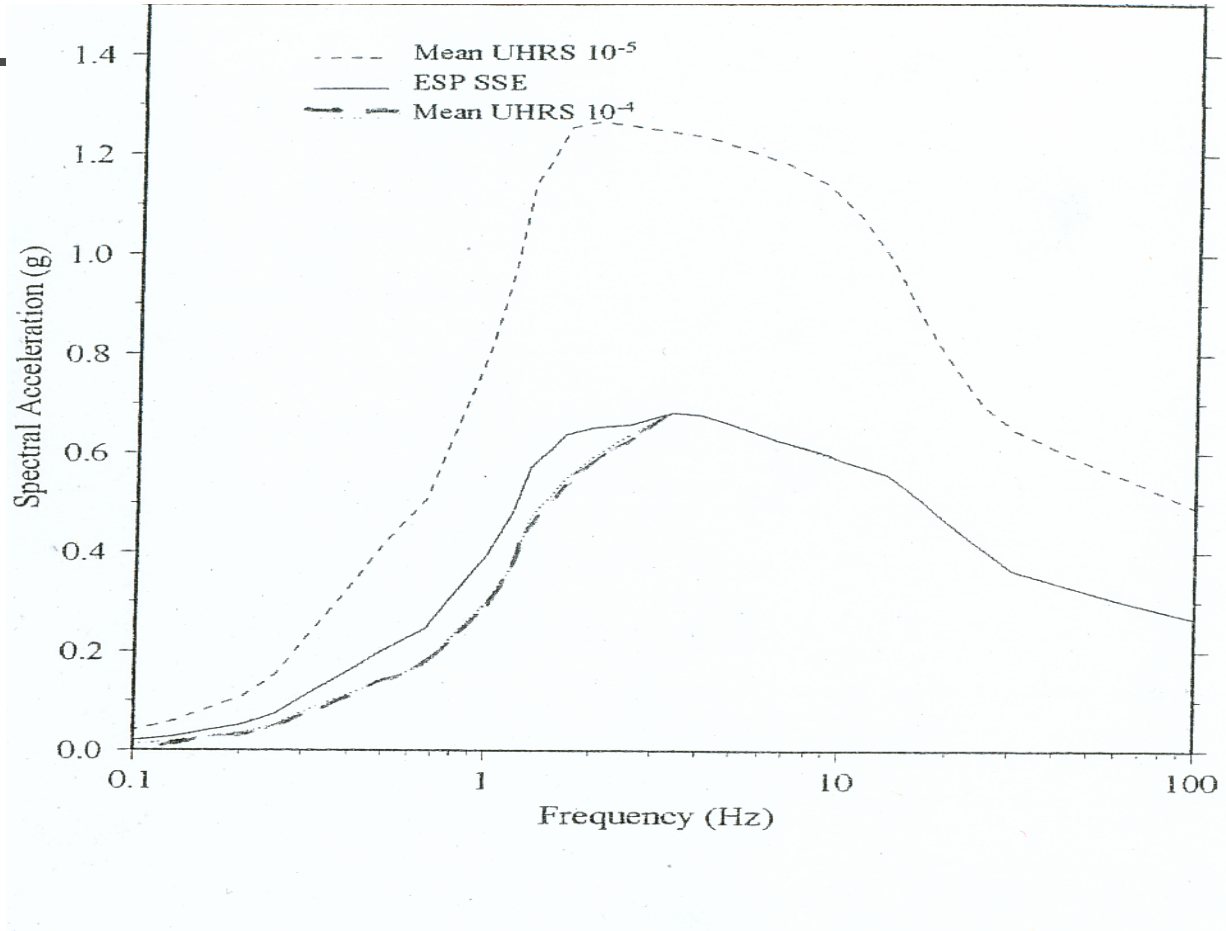
Existing and Proposed Nuclear Power Plants



Clinton Power Station ESP

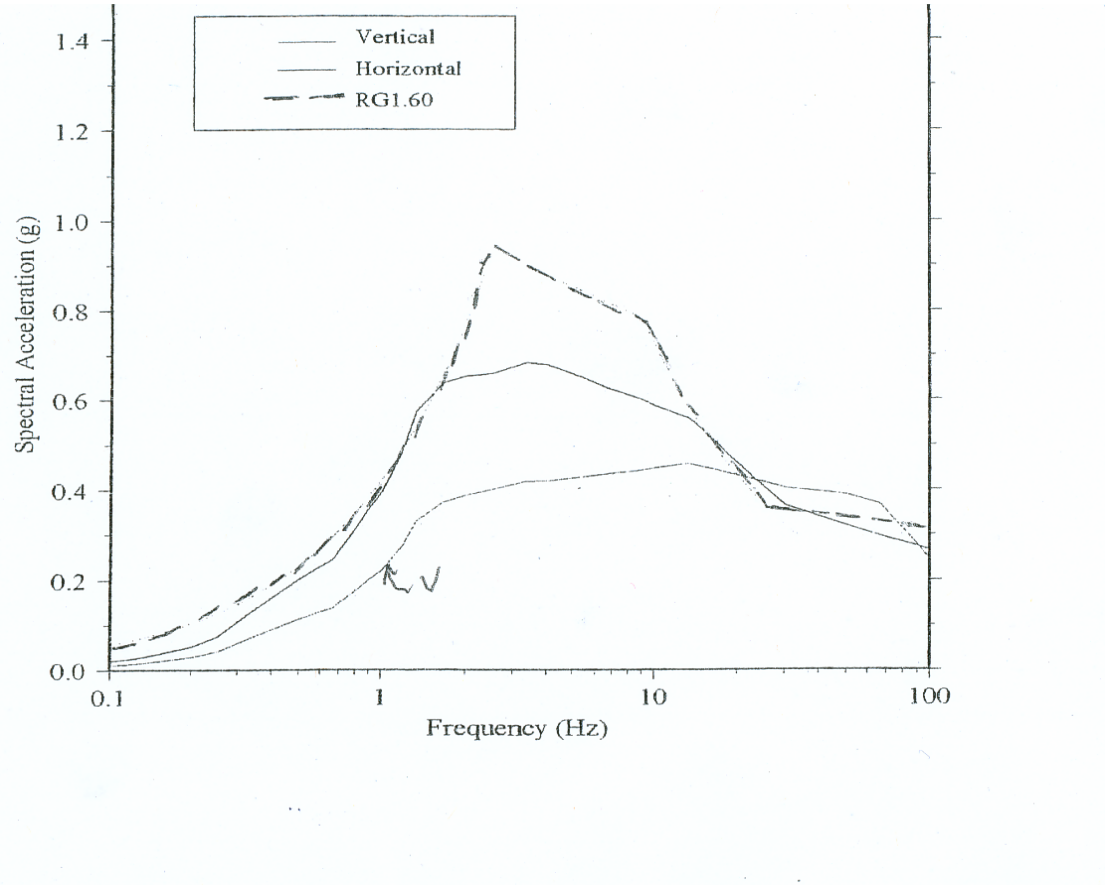
- PSHA following RG 1.165 + Performance–Based Procedure
- Controlling Earthquakes
  - High-Frequency 6.5 @ 83 km for 10^{-4}
    6.2 @ 24 km for 10^{-5}
  - Low-Frequency 7.2 @ 320 km for 10^{-4}
    7.2 @ 320 km for 10^{-5}

Clinton ESP
SSE Spectra



Comparison of performance-based SSE spectrum for the ESP site and the mean 10^{-4} and 10^{-5} UHRS

Clinton ESP
SSE Spectra



EGC ESP horizontal and vertical ESP SSE as well as the RG 1.60 DRS anchored at 0.3g

Grand Gulf Nuclear Power Station ESP

- PSHA following RG 1.165
- Controlling Earthquakes
  - High-Frequency 6.94 @ 175 km
  - Low-Frequency 7.55 @ 396 km
  - Controlling Earthquakes have similar values for 10^{-4}, 10^{-5}, & 10^{-6}

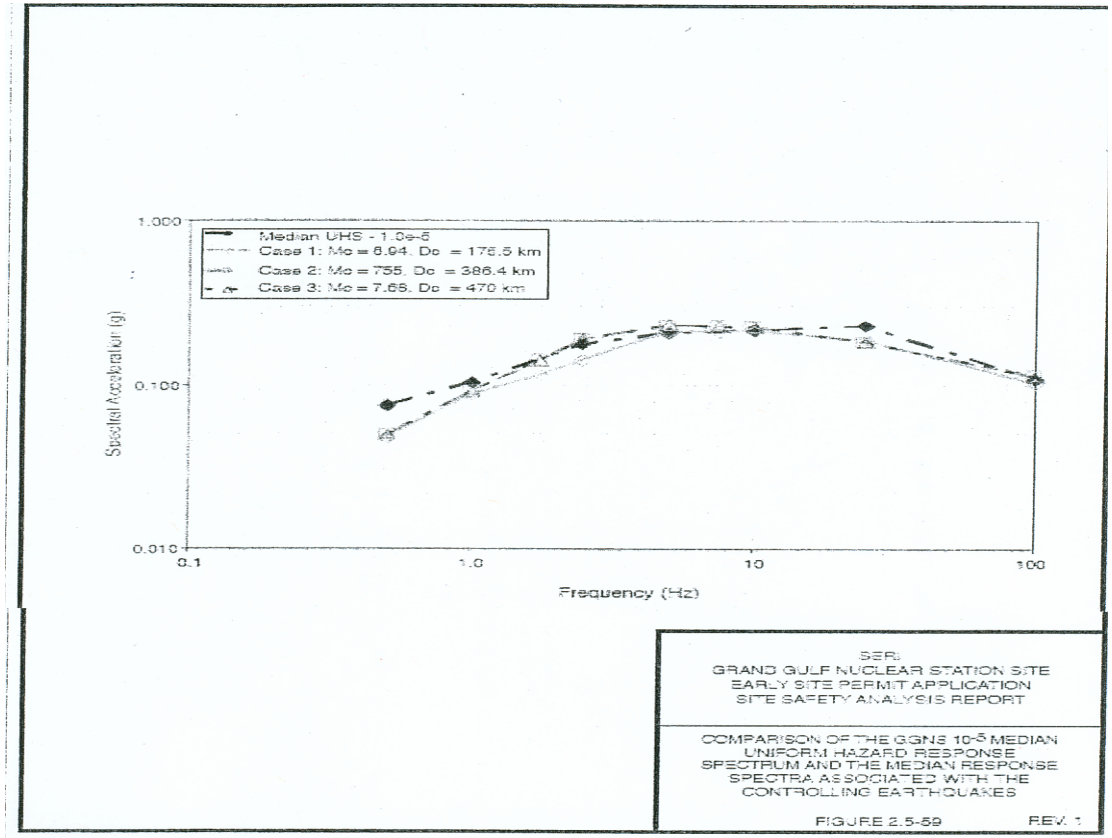
Grand Gulf ESP

- Influence of Saline River Seismic Source on High-Frequency Controlling Earthquake

Magnitude & Distance Assuming 5% Contribution	Magnitude & Distance Assuming 10% Contribution	Magnitude & Distance Original Controlling Earthquake
6.93 @ 174.46 km	6.92 @ 173.44 km	6.94 @ 175.5

Grand Gulf ESP

SSE Spectra



(SSAR Figure 2.5-59) Medium response spectra (10^{-5}) UHRS and controlling earthquakes

South Texas Project COL

- Application Delivered to the NRC in September 2007
- Currently under Acceptance Review
- Making Use of RG 1.208 Guidance

Summary and Concluding Remarks

- The NRC is committed to the use of PSHA for regulatory purposes
- The reference probability was initially set to the median annual probability of exceedance (APE) of the SSE for 29 operating NPPs (RG 1.165)
  - The value was 1×10^{-5}, which for the plants selected was approximately equal to 1×10^{-4}
  - Comparability shown between DSHA and PSHA for "controlling earthquakes" for operating NPPs
    - LLNL methodology
    - EPRI methodology
  - Comparability for controlling earthquakes between
    - Operating NPPs
    - ESP applications

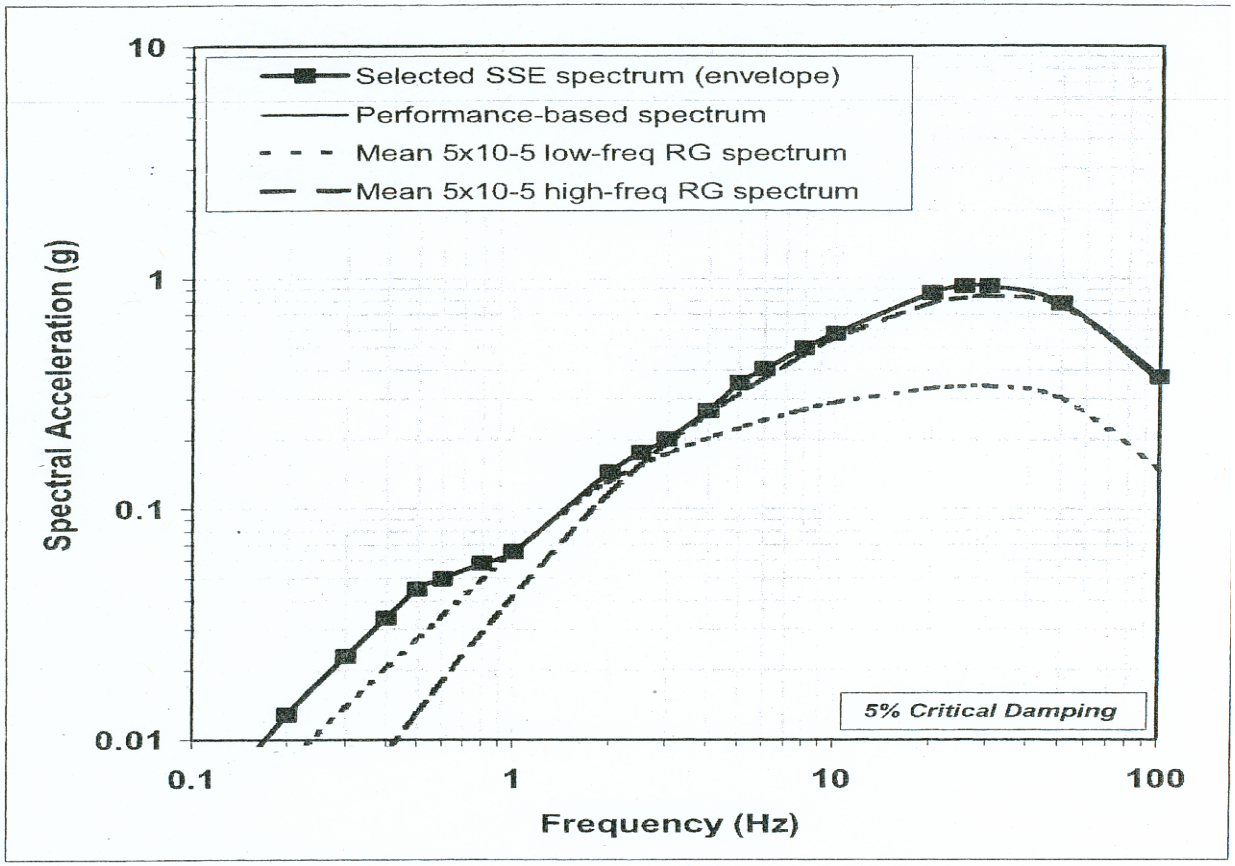
Backup Slides

- Additional Examples
  - North Anna Power Station ESP
  - Vogtle Electric Generating Plant ESP
- EPRI PSHA Comparisons

North Anna Power Station ESP

- PSHA following RG 1.165 and Performance-Based
- Controlling Earthquakes
  - High-Frequency 5.4 @ 20 km for 10^{-5}
  - Low-Frequency 7.2 @ 308 km for 10^{-5}
- Initial Application Proposed 5×10^{-5}; Revised to 1×10^{-5}

North Anna ESP
SSE Spectra

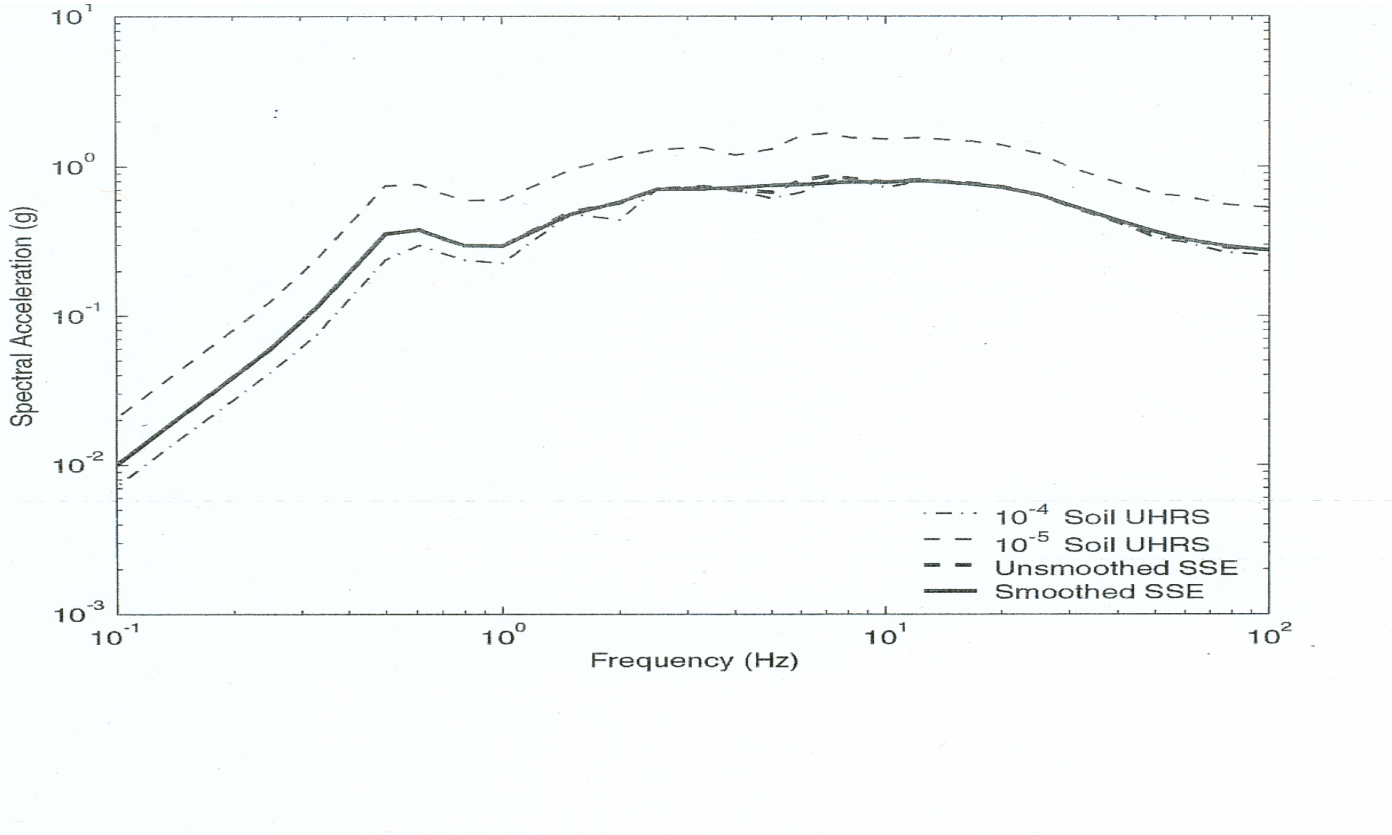


Comparison of performance-based spectrum, mean $5x10^{-5}$ scaled spectra and selected SSE spectrum (which overlaps the performance-based spectrum and envelops the other two)

Vogtle Electric Generating Plant ESP

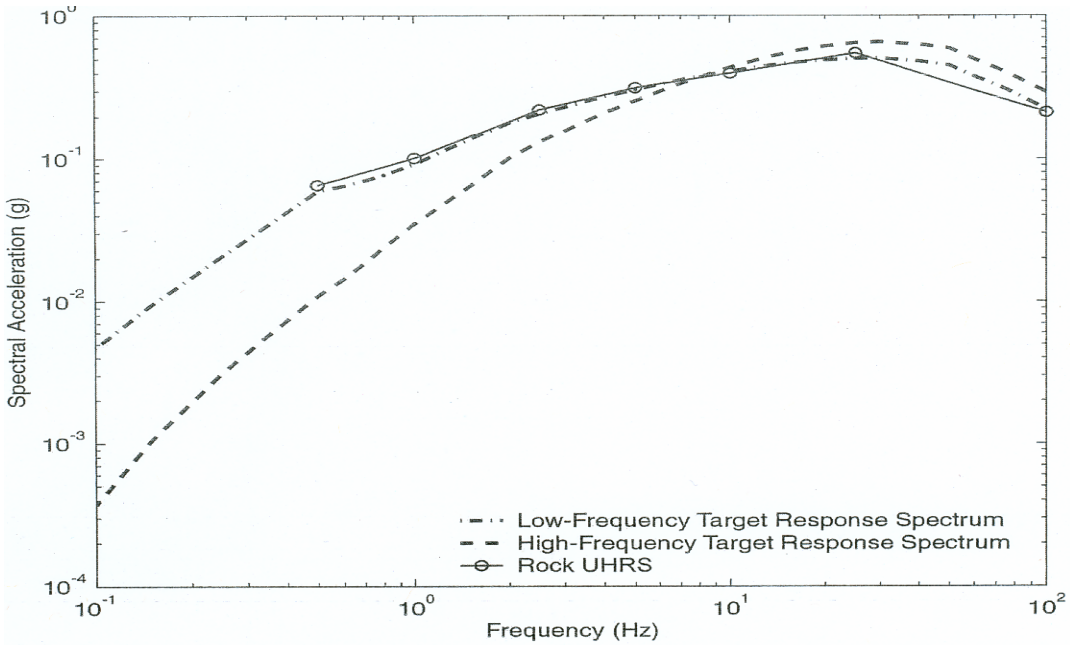
- PSHA Performed Following RG 1.165
- Controlling Earthquakes
  - High-Frequency 5.6 @ 9.0 km
  - Low-Frequency 7.2 @ 130 km
  - Controlling Earthquakes for 10^{-4}, ~ 10^{-5}, and ~ 10^{-6}

Vogtle ESP
SSE Spectra



Horizontal raw and smoothed SSE (based on the information provided in SSAR Table 2.5.2-22)

Vogtle ESP
Development of SSE Spectra



Low- and high frequency target response spectra representing the 10^{-4} hazard level. The 10^{-4} rock uniform hazard response spectrum is also shown for comparison (based on the information provided in SSAR Tables 2.5.2-16, 2.5.2-20a. And 2.5.2-20b).

Vogtle ESP
Development of SSE Spectra

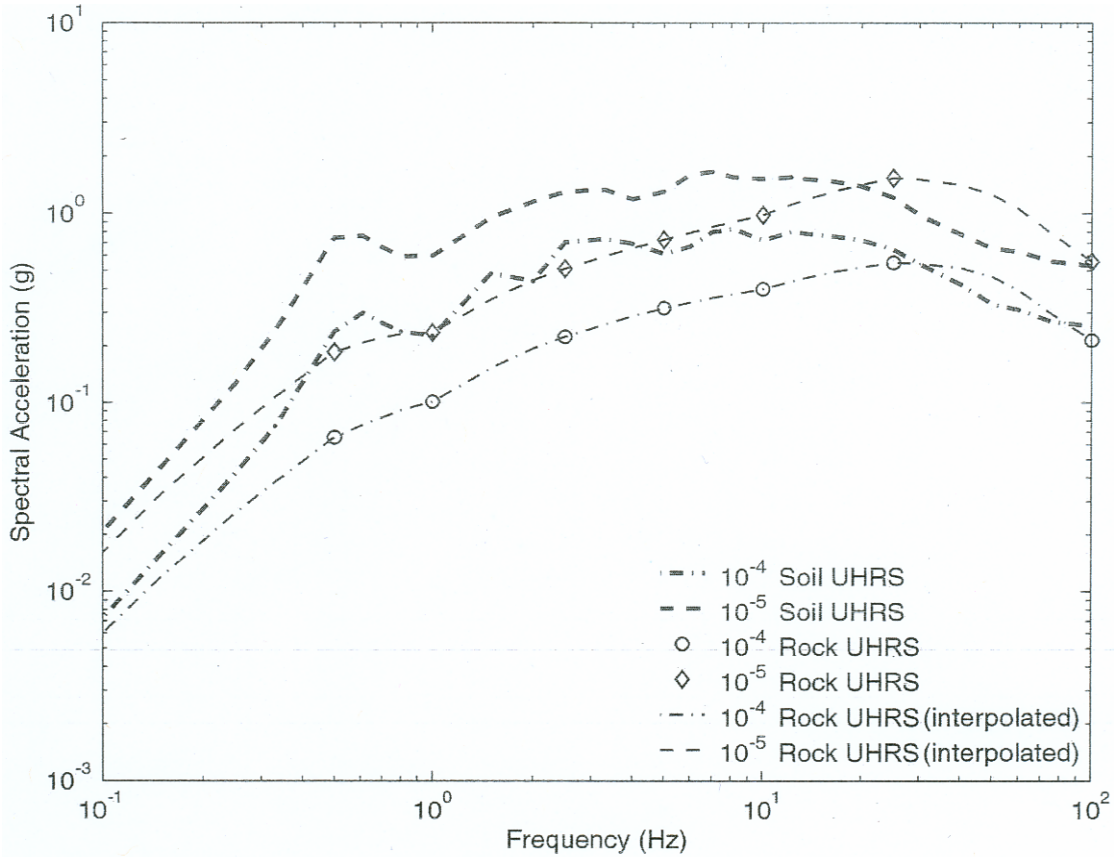


Figure 2.5.2-7 Horizontal soil-based UHRS for the 10^{-4} and 10^{-5} hazard levels (based on the information provided in SSAR Figures 2.5.2-16 and 2.5.2-21)

Comparison of DSHA and PSHA for EPRI Methodology

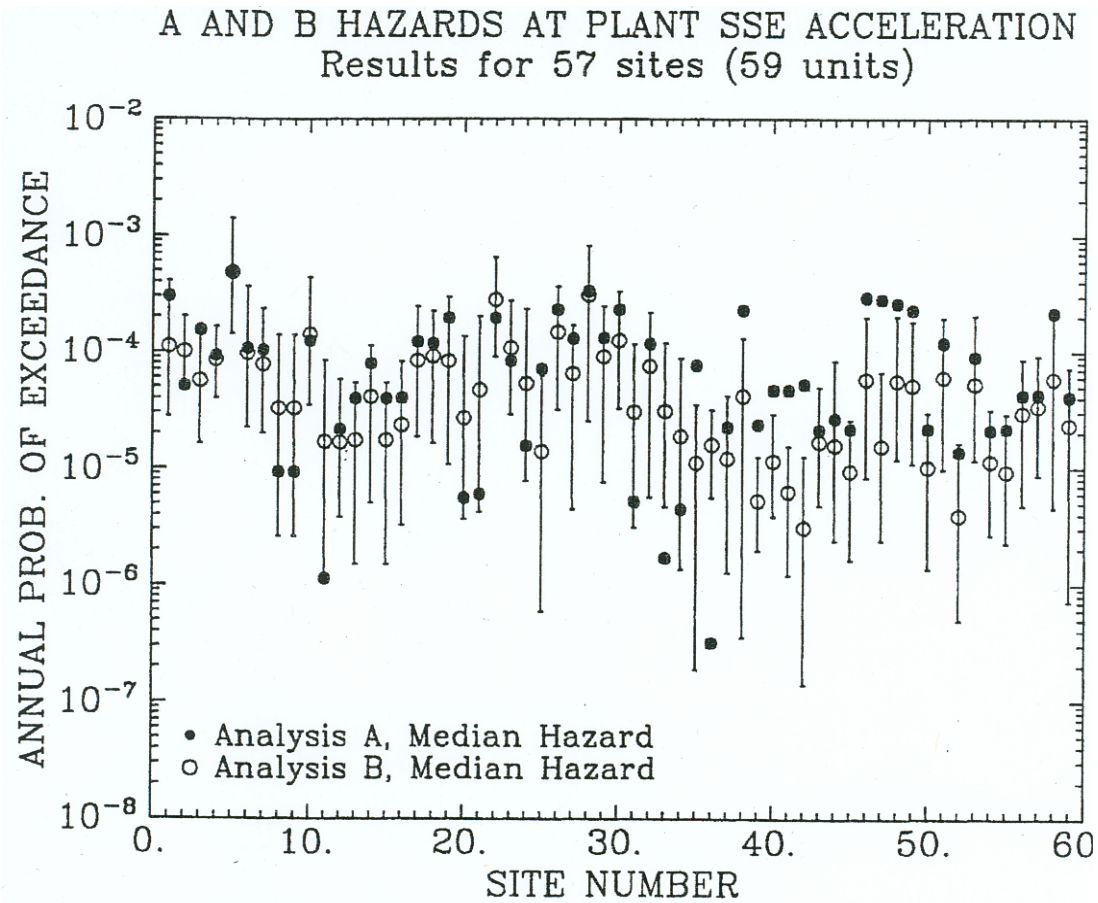


Figure 6-2. Seismic hazard results at plant SSE acceleration, for Analysis A and B. (Error bars denote the range of 15th and 85th percentile hazards for Analysis B).

Comparison of DSHA and PSHA for EPRI Methodology (cont'd)

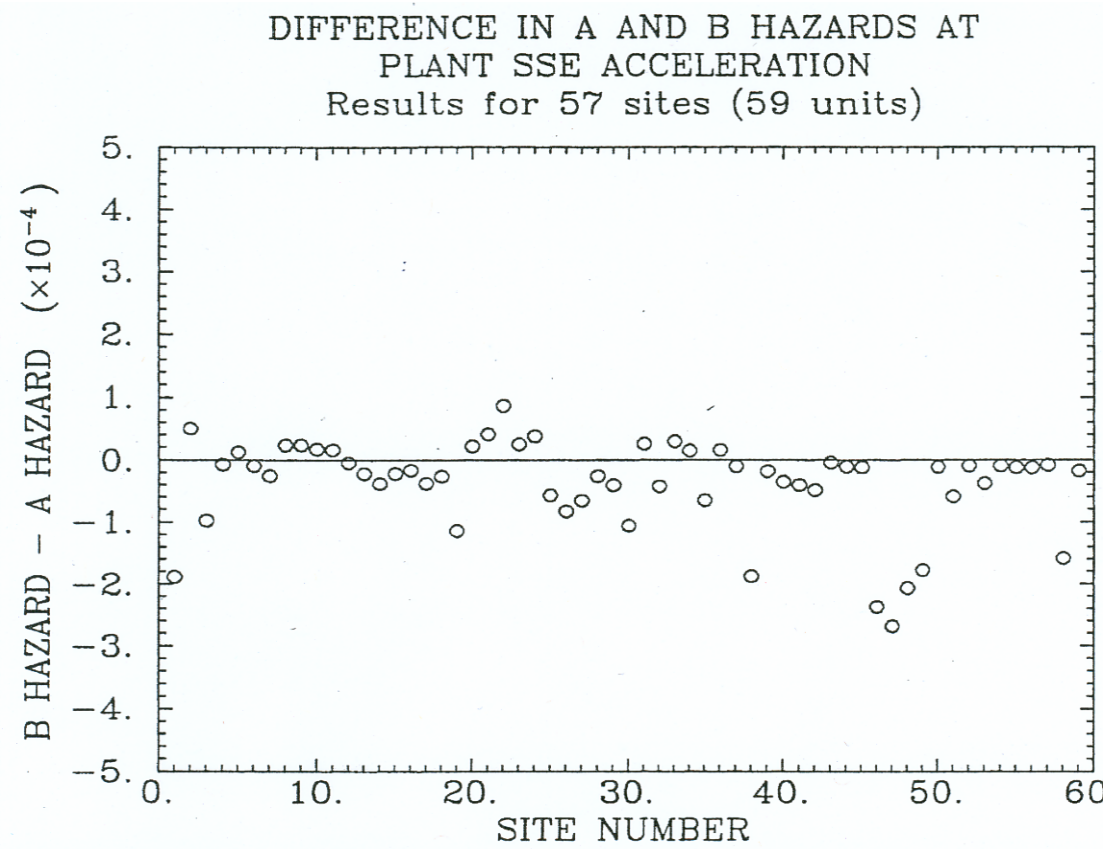


Figure 6-3. Arithmetic difference in median hazards at plant SSE acceleration, for Analyses A and B.

Comparison of DSHA and PSHA for EPRI Methodology (cont'd)

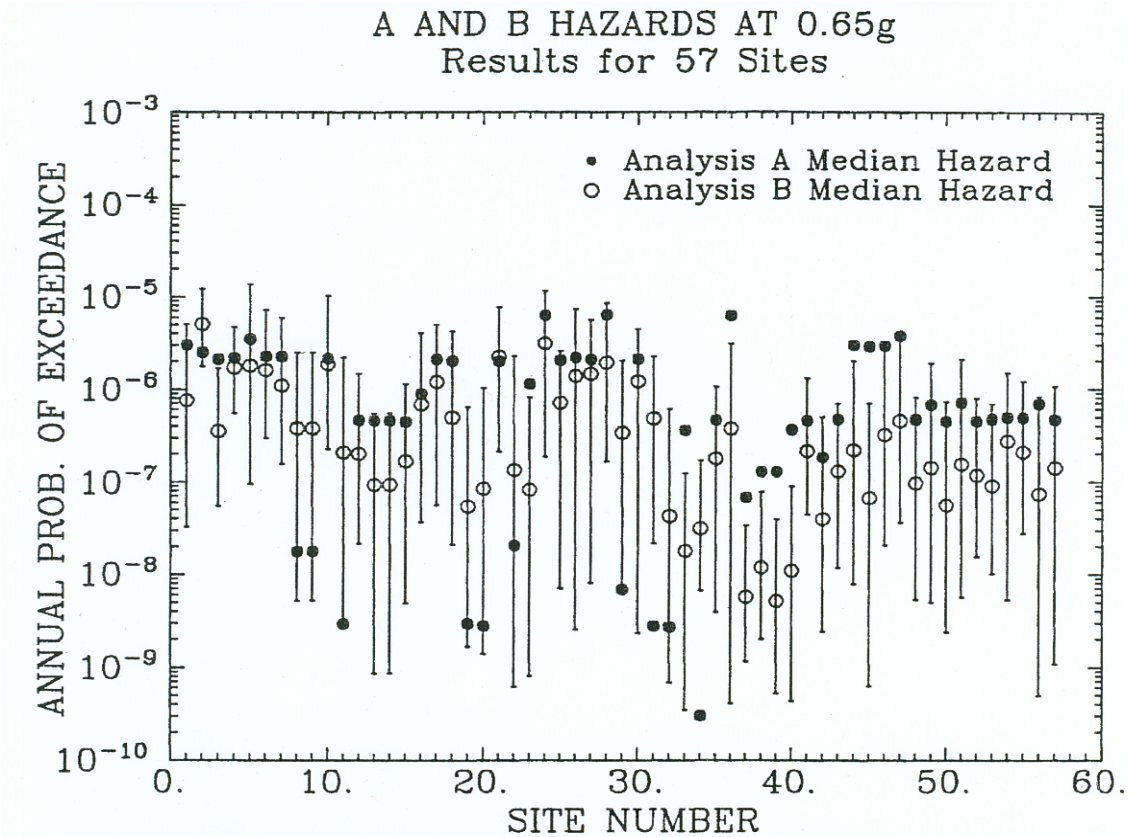


Figure 6-4. Seismic hazard results at an acceleration level (0.65g) representatives of a typical plant median acceleration-resistance against core damage, for Analyses A and B. (Error bars denote the range of 15th and 85th percentile hazards for Analysis B.

Comparison of DSHA and PSHA for EPRI Methodology (cont'd)

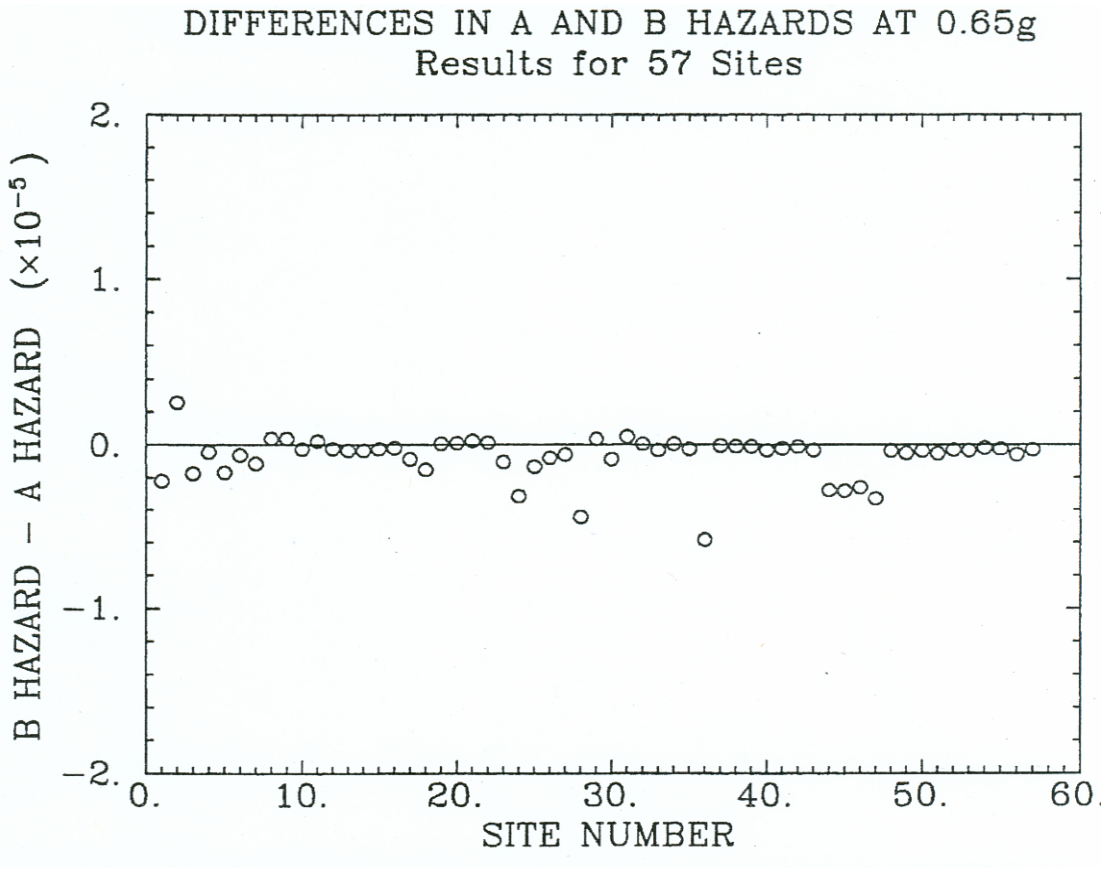


Figure 6-5. Arithmetic difference in median hazards at an acceleration level (0.65g) representative of a typical plant median acceleration-resistance against core damage, for Analyses A and B.