Approaches of the United States on Seismic Hazard Evaluation

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Outline

- US NRC Regulatory Positions
- Examples of US Regulatory Guides that are designed to satisfy the US requirements
  - Working Experience
- Deterministic/Probabilistic Seismic Hazard Assessment
- Site response
- Performance-based approach to determine the Design Ground Motion
- Summary

US Regulatory Position

To characterize earthquake hazard at a nuclear power plant site 10 CFR 100.23 requires:

1) The geological, seismological, and engineering characteristics of a site and its environs be investigated in sufficient scope to arrive at estimates of the Safe Shutdown Earthquake Ground Motion, and to permit adequate engineering solutions to actual or potential geologic and seismic effects at the proposed site

2) The size of the region to be investigated and the type of data pertinent to the investigations must be determined based on the nature of the region surrounding the proposed site.

US Regulatory Position

3) Data on the vibratory ground motion, tectonic surface deformation, nontectonic deformation, earthquake recurrence rates, fault geometry and slip rates, site foundation material, and seismically induced floods and water waves must be obtained by reviewing pertinent literature and carrying out field investigations. However, each applicant shall investigate all geologic and seismic factors (for example, volcanic activity) that may affect the design and operation of the proposed nuclear power plant irrespective of whether such factors are explicitly included in this section.

US Regulatory Position

4) Determination of the Safe Shutdown Earthquake Ground Motion.

Uncertainties are inherent in estimates. These uncertainties must be addressed through an appropriate analysis, such as a probabilistic seismic hazard analysis or suitable sensitivity analyses.

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US Regulatory Position

10 CFR Part 50 Appendix S defines SSE as "*Safe-Shutdown Earthquake ground motion* is the vibratory ground motion for which certain structures, systems, and components must be designed to remain functional"

10 CFR Part 50 also states that "*The nuclear power plant must be designed so that, if the SSE Ground Motion occurs, certain structures, systems, and components will remain functional and within applicable stress, strain, and deformation limits*."

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Satisfying the Regulations

Two Regulatory Guides (RG 1.165 and RG 1.208) provide general guidance on procedures acceptable to the NRC staff to satisfy the Geologic and Seismic Siting Criteria outlined in 10 CFR 100.23.

Steps:

- Conduct site and region specific geological, seismological, geophysical, and geotechnical investigations
- Perform a Probabilistic Seismic Hazard Analysis (PSHA)
- Conduct a Site Response Analysis to incorporate the effects of local structure
- Determine SSE using the reference probability method (RG 1.165) or preferably the performance-based approach (RG 1.208)

Estimating Seismic Hazard

Geological, seismological, geophysical and geotechnical investigations are conducted to identify seismic source regions and their impact on the hazard

- **Surface Investigation**

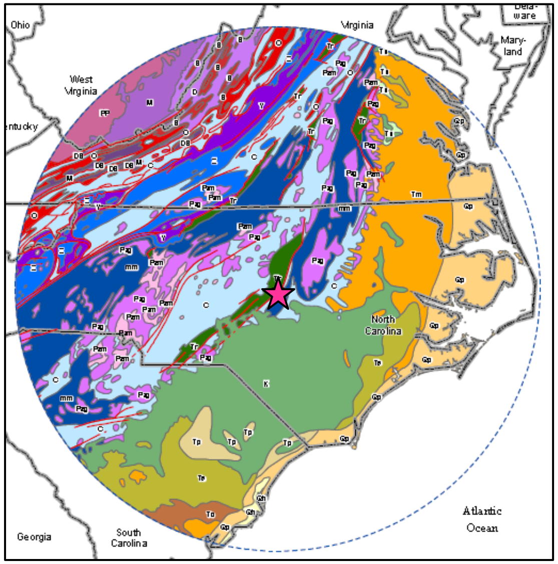
  Mapping topography/bathymetry, geomorphic and hydrologic features at sufficient scales, identifying rock outcrops, faults, tectonic features, geologic contacts, lineaments, evidence for land slides, soil liquefaction, etc.

  Fault displacements (tectonic and non-tectonic deformation)

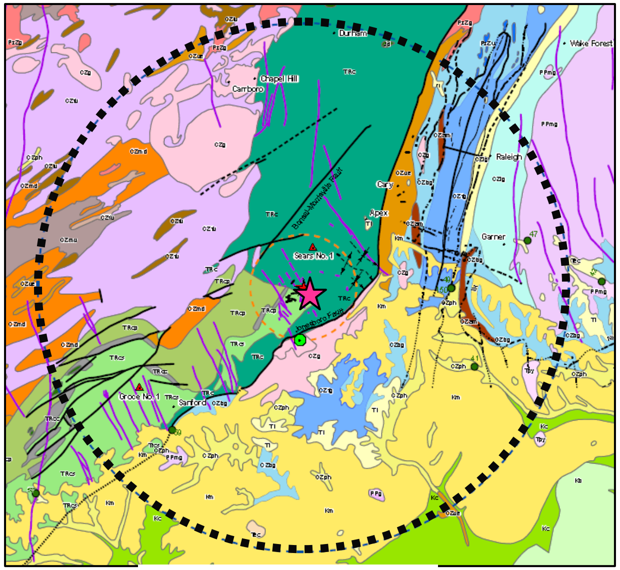
- **Subsurface Investigations**

  Seismic reflection, refraction surveys, gravity, magnetic, electrical surveys, ground penetrating radar, geophysical well-logging, core borings, exploratory trenches, etc.

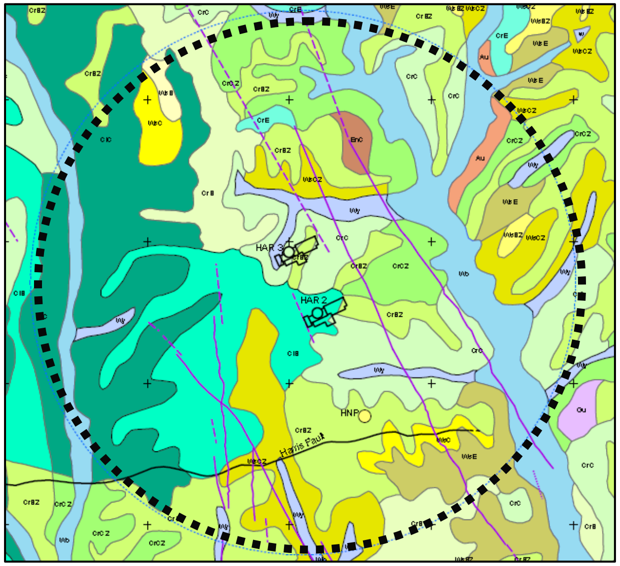
Regional to Local Scale Surface Investigations: Geologic Mapping



320 km radius



40 km radius



1 km radius

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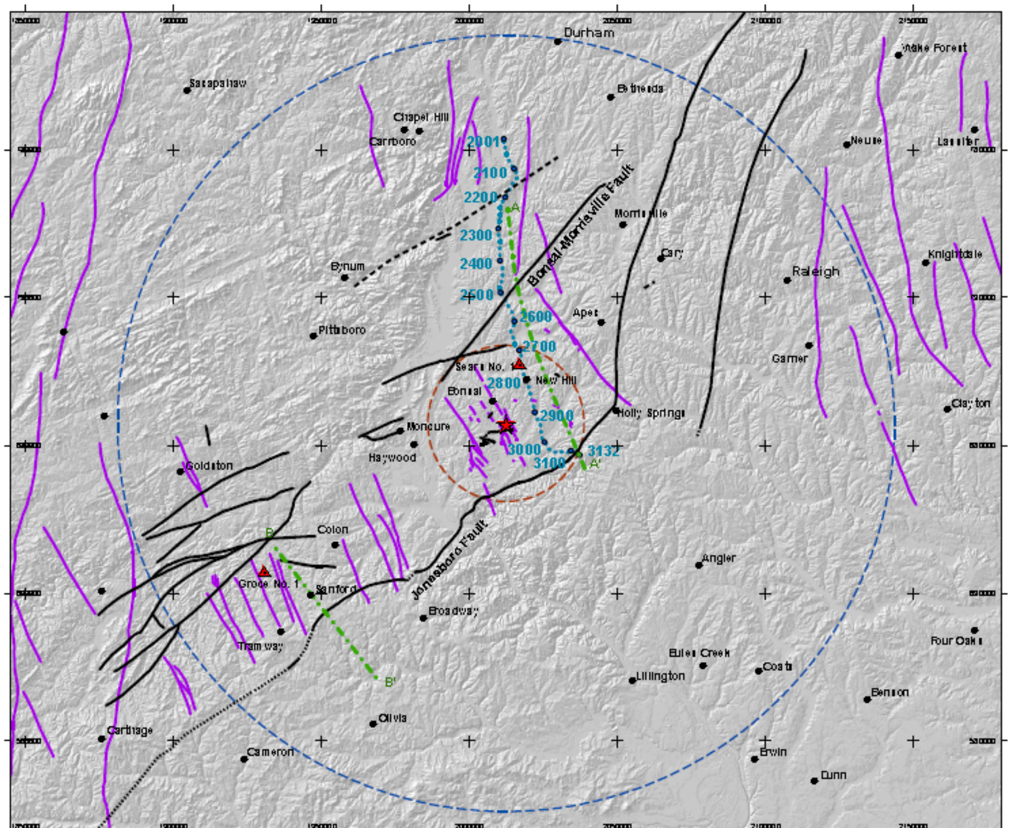
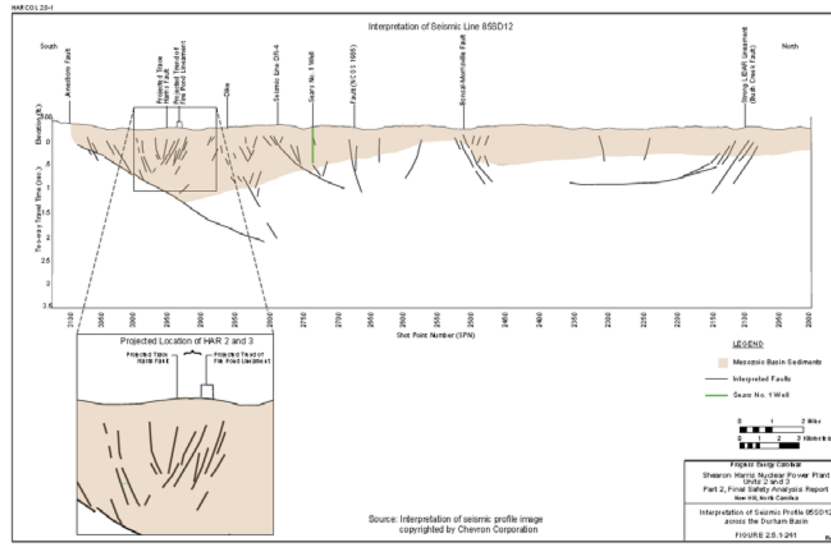
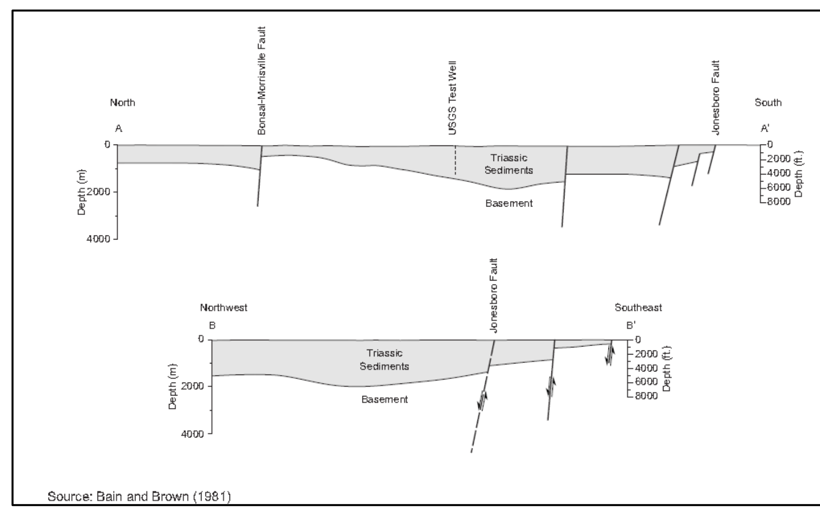
Subsurface Investigations -- Seismic, Electric, etc.







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Determining Earthquake Hazard at a NPP Site Given Geologic and Geophysical Information

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Safe Shutdown Earthquake Ground Motion Estimations

Approach A. Deterministic (10 CRF Part 100 Appendix A)

The earthquake which could cause the maximum vibratory ground motion at the site is designated as the Safe Shutdown Earthquake

-Identify earthquakes of greatest magnitudes or intensities and place them at the point closest to the site on the tectonic structures

-If earthquakes cannot be reasonably related to tectonic structures that encompass the site, assume these earthquakes occur at the site

-If earthquakes are in an adjacent tectonic structure, place them at the nearest point to the site.

-Characteristics of the Safe Shutdown Earthquake are derived from more than one earthquake to assure that the maximum vibratory acceleration at the site throughout the frequency range of interest is included.

- Design basis motion typically defined by a standard broad spectrum anchored to the maximum vibratory acceleration

Safe Shutdown Earthquake Ground Motion Estimations

Approach B. Probabilistic

(10 CRF Part 100.23 1997 – present)

PSHA incorporates the effects of all earthquakes capable of affecting the site including their uncertainty and their rate of recurrence

- Identify seismic source regions and their magnitude distribution

- Determine the rates at which earthquakes of various magnitudes occur

- Calculate predicted ground motion for each seismic source at COL or ESP site

-Obtain a combined probability of exceedance of a ground motion during a particular time period

Incorporating Site Effects into PSHA calculations

Local site characteristics are studied using geotechnical, geologic, and geophysical methods

Dynamic properties of subsurface material are obtained through in-situ and laboratory measurements as well as geophysical methods

Performance Target

- Performance Target (P_{FT}) is $1x10^{-5}$ per year
  - IPEEE Seismic PRAs conducted for 25 NPPs during mid/late 1990s determined annual seismic Core Damage Frequency values
  - Median SCDF is $1.2x10^{-5}$/yr
- Performance is measured in terms of Frequency of Onset of Significant Inelastic Deformation (FOSID), essentially elastic behavior

Performance-Based Approach to Determine SSE (GRMS)

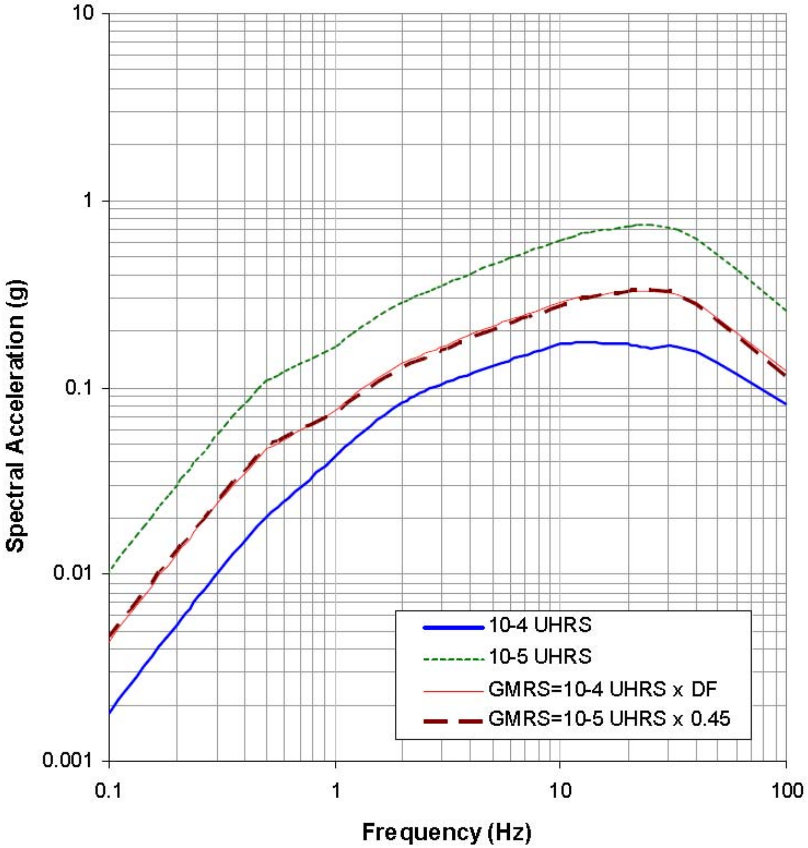
Described in RG 1.208

$$PB\ SSE = DF \times UHRS_{10^{-4}}$$

$$DF = \mathrm{Max}\,(0.6 A_R{}^{0.8}, 1.0)$$

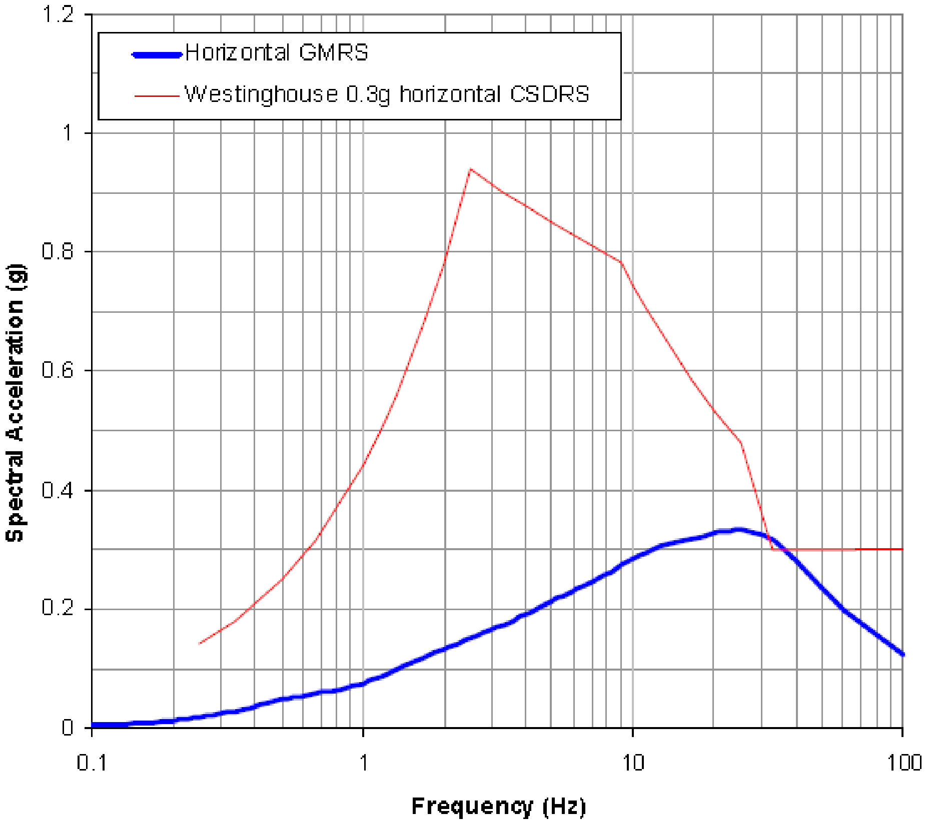
$$A_R = \frac{UHRS_{10^{-5}}}{UHRS_{10^{-4}}}$$

DF: Design Factor
AR: Hazard curve slope
$UHRS_{10\text{-}5}$ and $UHRS_{10\text{-}4:}$ mean Uniform hazard response spectra with annual probability of exceedance of 10^{-5} and 10^{-4}



Performance-based GRMS

Comparison with AP1000 CSDRS



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Summary

- Geological structures surrounding a site are studied in detail. Any structure that might cause hazard at the site is identified
- Earthquake history of the area surrounding a site is documented using instrumental, historic and geologic records
- Region specific ground motion prediction models are used
- PSHA calculations are conducted
- Performance-based, site-specific GRMS is calculated
- GRMS is then used as input to engineering design