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Protecting People and the Environment

Geosciences in a Regulatory Environment

April 25, 2022

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Office of Nuclear Reactor Regulation

Statutory Authority

- The Atomic Energy Act of 1954, as amended, created the NRC's predecessor organization the Atomic Energy Commission (AEC)
- The Energy Reorganization Act of 1974 split the promotion and regulatory functions of the AEC into two separate organizations, the Department of Energy and the Nuclear Regulatory Commission
- Nuclear Waste Policy Act of 1982, as amended, establishes the Federal responsibility to provide a place for permanent disposal of high-level radioactive waste and spent nuclear fuel.
- Title 10 of the Code of Federal Regulations (10 CFR) contains the requirements for any person or organization seeking a license from the NRC to use nuclear materials or operate a nuclear facility

- The NRC does not set nuclear law, or advocate for one position or another. Matters of national nuclear policy are set by Congress. e.g. the use of nuclear power/waste.

https://www.nrc.gov/about-nrc/governing-laws.html

What we regulate and what we don't

- **Civilian** use of nuclear materials.
- Nuclear reactors, including small modular and advanced reactor designs, research and test reactors, and demonstration reactors.
- Fuel cycle facilities, including uranium recovery, and nuclear waste sites, such as independent spent fuel storage installations (ISFSI), consolidated interim storage facilities (CISF) and long-term geologic repository for nuclear waste (Yucca Mountain).
- Medical isotopes and other civilian uses.

- We do not regulate military uses of nuclear materials.

Fuel Cycle Facilities in the US

Depleted Uranium Deconversion Facility		Uranium Enrichment – Gas Centrifuge Facility	
Fuel Fabrication Facility		Uranium Enrichment – Laser Separation Facility	
Uranium Conversion Facility			

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Operating Reactor Sites in the US

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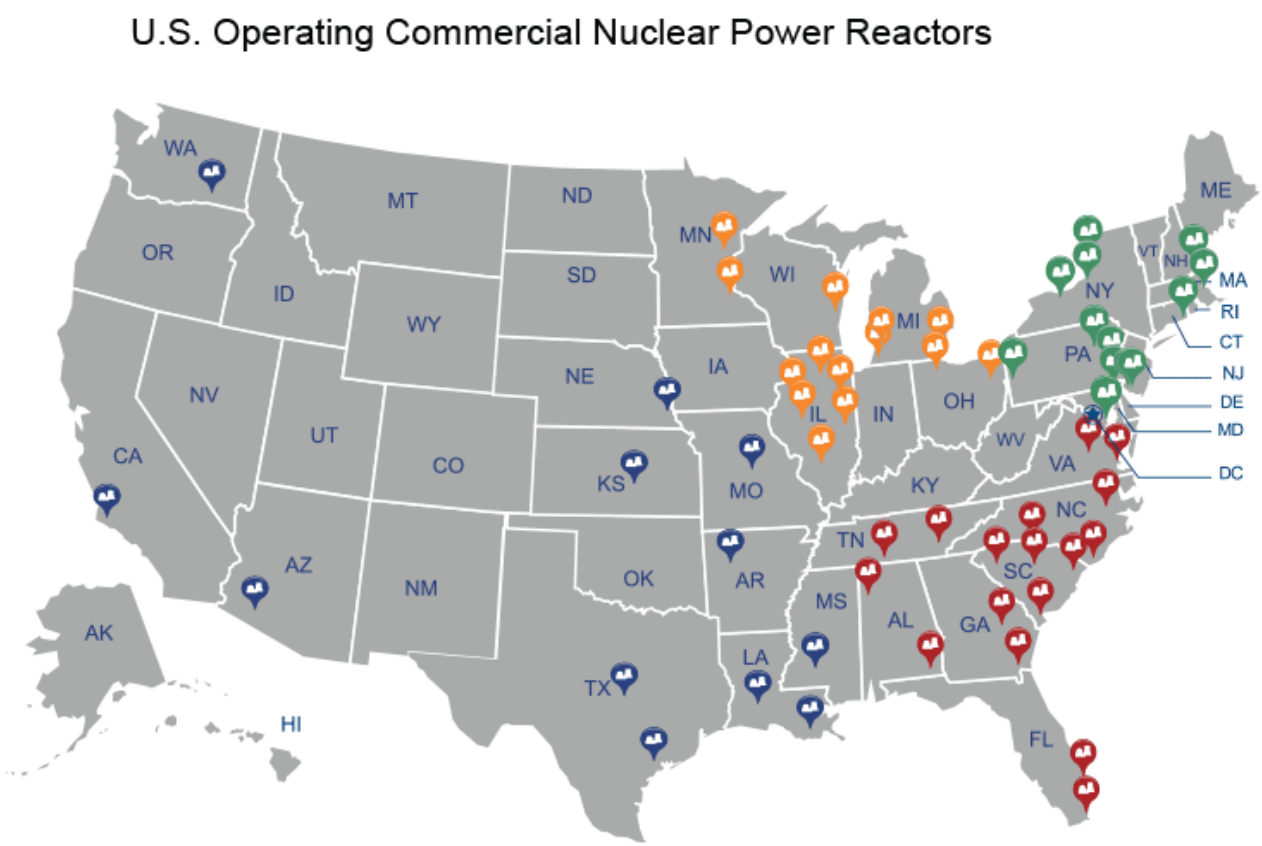
October 2021



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Proposed New Reactor Sites

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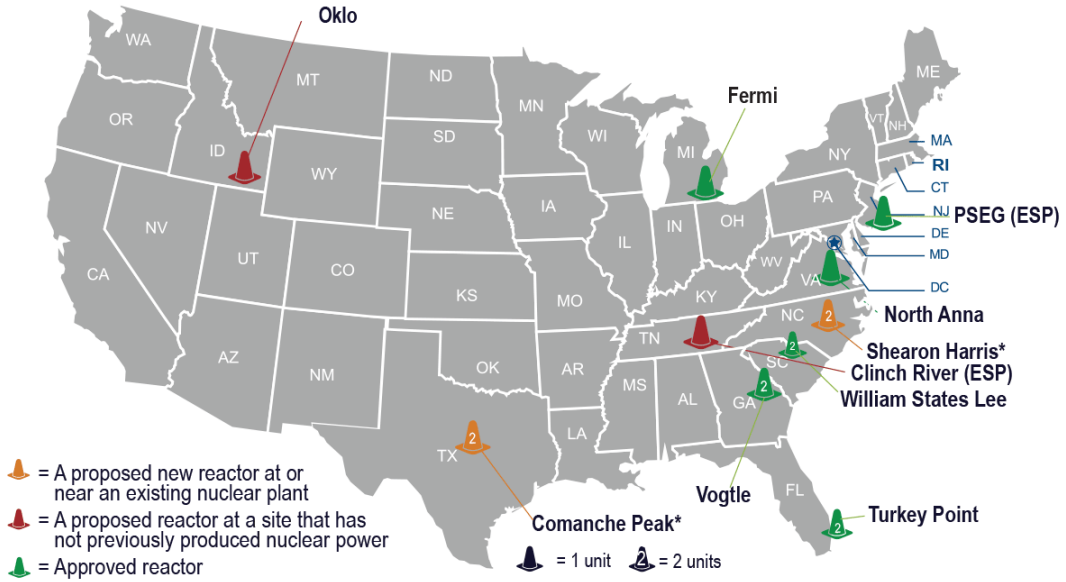
Locations of New Nuclear Power Reactor Active Applications and Approved Licenses



* Review suspended

Note: Alaska and Hawaii are not pictured, but have no sites. On July 31, 2017, South Carolina Electric and Gas announced its decision to cease construction on V.C. Summer Units 2 and 3, and the licensee has requested that the COLs be withdrawn. As of October 2017, Duke Energy has announced plans to cancel reactors at Levy County, FL, and William States Lee, SC. Applications were withdrawn for Calvert Cliffs, Grand Gulf, Nine Mile Point, Victoria County, and Callaway (COL and ESP). In June 2018, Nuclear Innovation North America submitted a letter requesting that the COLs for South Texas Project Units 3 and 4 be withdrawn. NRC-abbreviated reactor names are listed. Data are current as of August 2021. For the most recent information, go to the NRC Web site at https://www.nrc.gov.

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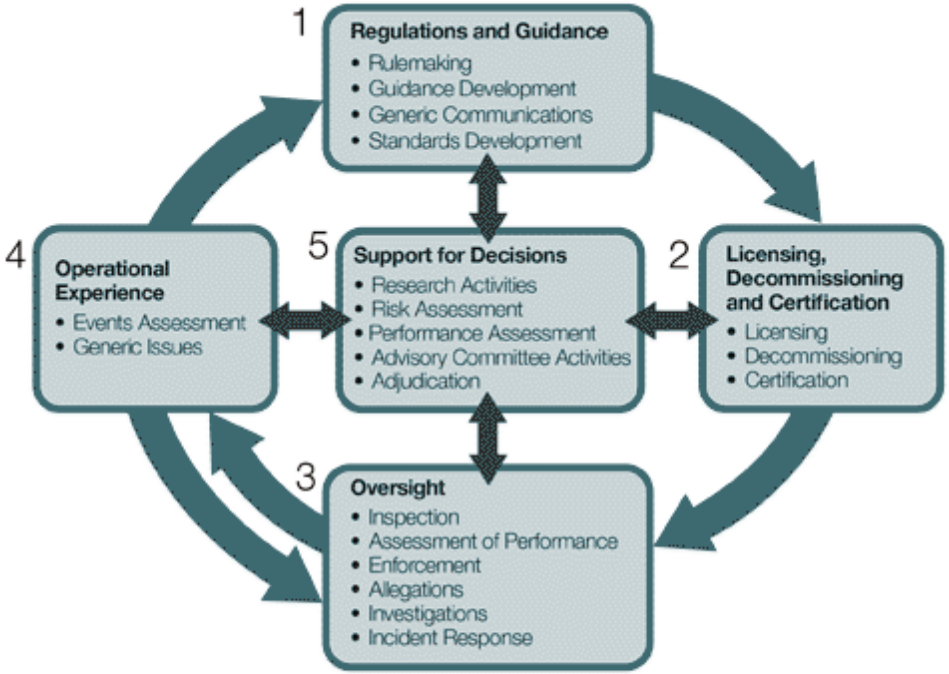
The Regulatory Process



1. *Developing regulations and guidance for applicants and licensees.*
2. *Licensing or certifying applicants to use nuclear materials, operate nuclear facilities, and decommission facilities.*
3. *Inspecting and assessing licensee operations and facilities to ensure licensees comply with NRC requirements, responding to incidents, investigating allegations of wrongdoing, and taking appropriate followup or enforcement actions when necessary.*
4. *Evaluating operational experience of licensed facilities and activities.*
5. *Conducting research, holding hearings, and obtaining independent reviews to support regulatory decisions.*

As of June 2017

Regulatory Requirements

Regulatory requirements are found in Title 10 of the Code of Federal Regulations (10 CFR).

- 10 CFR Part 52 – "Licenses, Certifications, and Approvals for Nuclear Power Plants"
  - Defines geologic and seismic characteristics of a proposed site that **must** be described by the applicant in a Safety Analysis Report (SAR) as part of the application process.
- 10 CFR Part 100.23 – "Geologic and Seismic Siting Criteria"
  - Further defines principle geologic and seismic factors that **must** be considered for evaluating site suitability and adequacy of design bases in light of geologic and seismic characteristics.

Regulatory Guides

Regulatory Guides (RGs) are prepared by NRC technical experts to provide **guidance** to applicants regarding appropriate technical content for an application.

- Reg Guides are intended to provide additional clarification on regulatory requirements.
- Use of a Reg Guide is not mandatory but can streamline reviews since they contain an NRC-approved way of meeting the applicable regulatory requirements

Example Regulatory Guides

- RG 1.132 – “Site Investigations for Foundations of Nuclear Power Plants” (October 2003).
- RG 1.208 – “A Performance-Based Approach to Define Site-Specific Earthquake Ground Motion” (March 2007).
  - Guidance for characterizing geology and seismicity of the site region (320-km [200-mi] radius), vicinity (40-km [25-mi]), area (8-km [5-mi]), and location (1-km [0.6-mi] radius).
  - Defines information needed on earthquake source zone parameters (e.g., recurrence rate and maximum magnitude) for Probabilistic Seismic Hazard Analysis (PSHA).
- RG 4.26 – “Volcanic Hazards Assessment for Proposed Nuclear Power Reactor Sites” (June 2021)

https://www.nrc.gov/reading-rm/doc-collections/reg-guides/index.html

NUREGs

NUREG-series publications are reports or brochures on regulatory decisions, results of research or incident investigations, and other technical or administrative information.

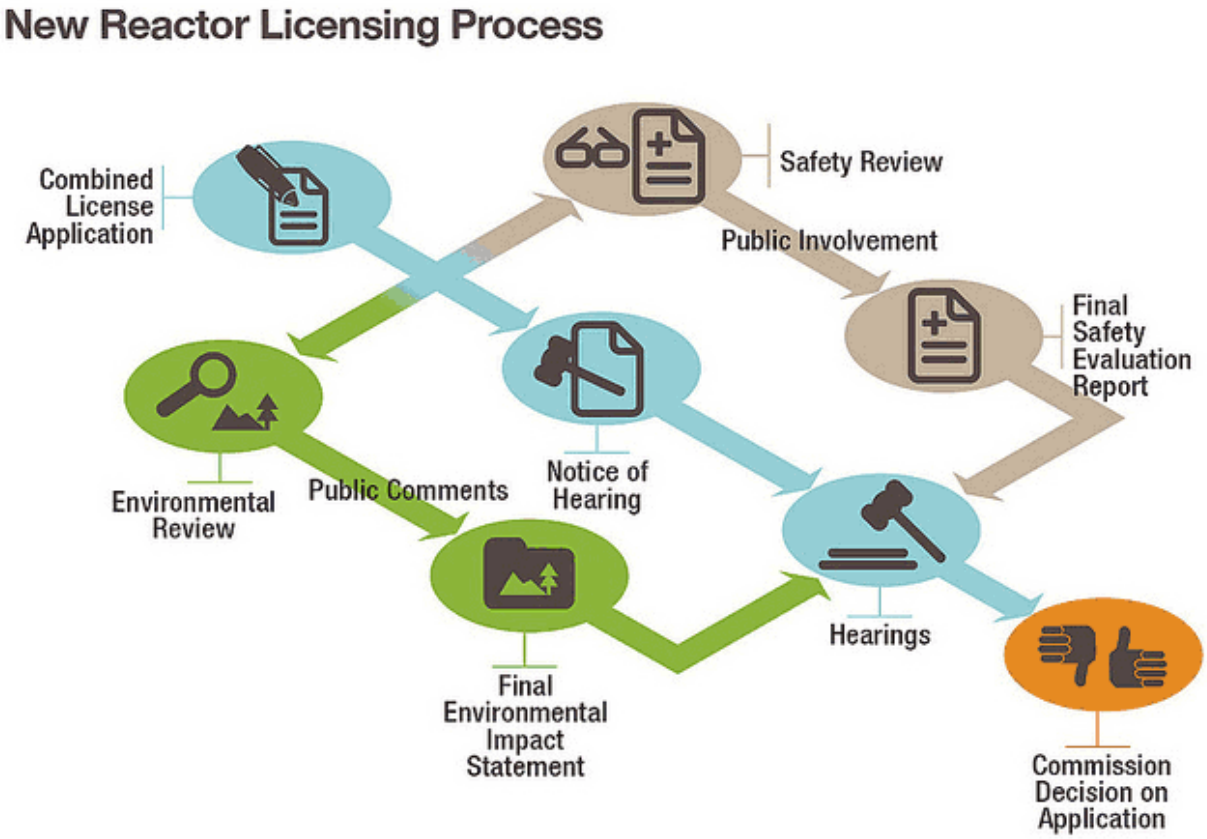
Different types of NUREGs can be generated by staff or contractors and may include informational brochures or knowledge management documents.

Link to NUREG-series publications.

Standard Review Plan

- NUREG-0800 outlines the overall content of applications and acceptance criteria.
- Section 2.5 concerns geologic, seismic and geotechnical engineering information
  - 2.5.1, Basic Geologic and Seismic Information
  - 2.5.2, Vibratory Ground Motion
  - 2.5.3, Surface Deformation
  - 2.5.4, Stability of Subsurface Materials and Foundations
  - 2.5.5, Stability of Slopes

The Licensing Process



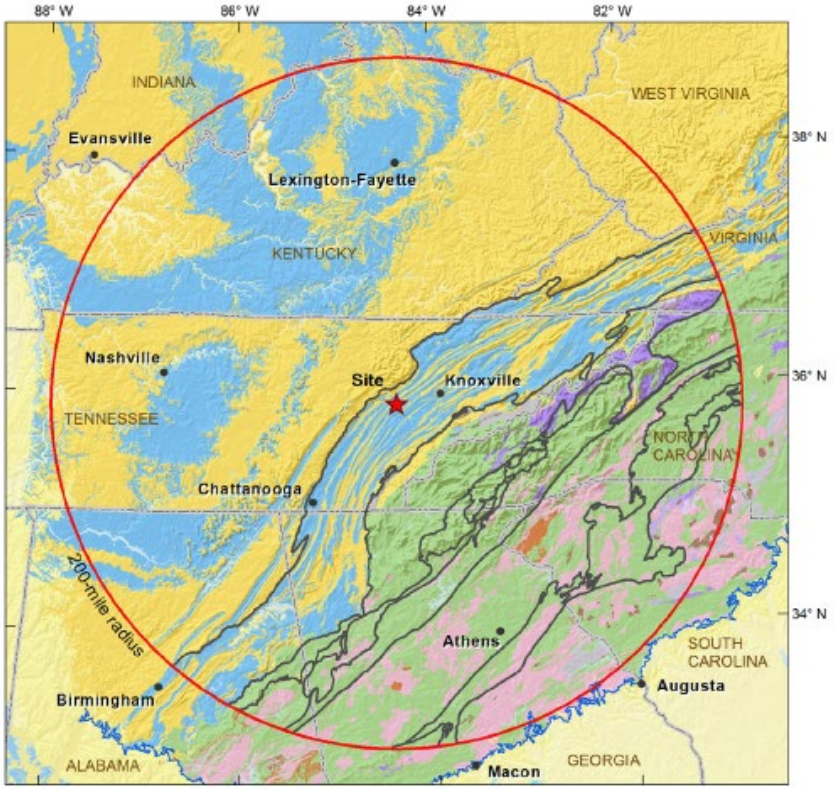
What do the geoscientists do?

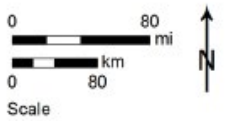
- Follow regulatory requirements and guidelines to ensure that any entity applying for a license or permit for a new facility has provided all the information required by statute or regulation sufficient to reach a regulatory finding of reasonable assurance of adequate protection
- Confirm applicants considered the potential geologic and seismic hazards for the proposed site to meet the regulatory requirements.
- Ask for clarification or additional information through the audit process or through a request for additional information (RAI)
- Document conclusions in a Safety Evaluation Report (SER).
- Ensure guidance documents are updated, as necessary

Types of Information

- Regions of interest with increasing detail
  - Region (320 km)
  - Vicinity (40 km)
  - Area (8 km)
  - Location (1 km)
- Period of interest - Quaternary
- Physical investigations vs. literature review

Site Region

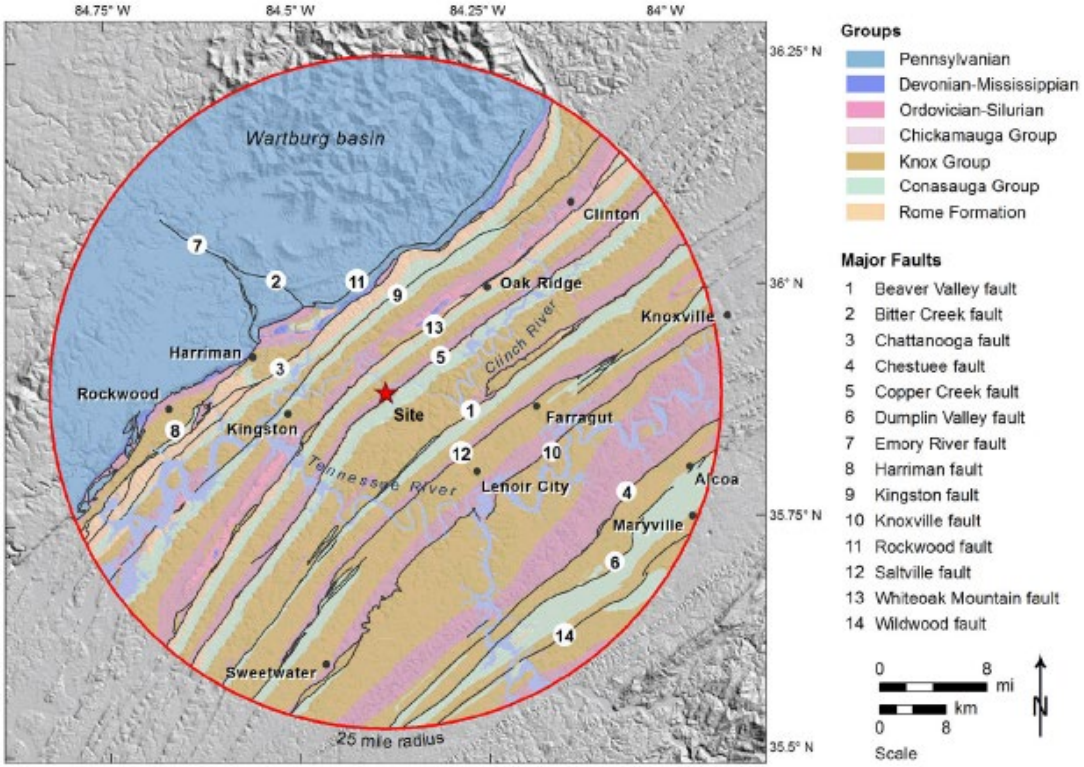




Note:
USGS sources for geologic map: A - OFR-04-1355, Reference 2.5.1-116; B - OFR-05-1325, Reference 2.5.1-115; C - OFR-05-1323, Reference 2.5.1-114; D - OFR-05-1324, Reference 2.5.1-117. Major faults from References 2.5.1-24 and 2.5.1-34. Fall Line from Reference 2.5.1-20.

Figure 2.5.1-19. (Sheet 1 of 2) Site Region Geologic Map

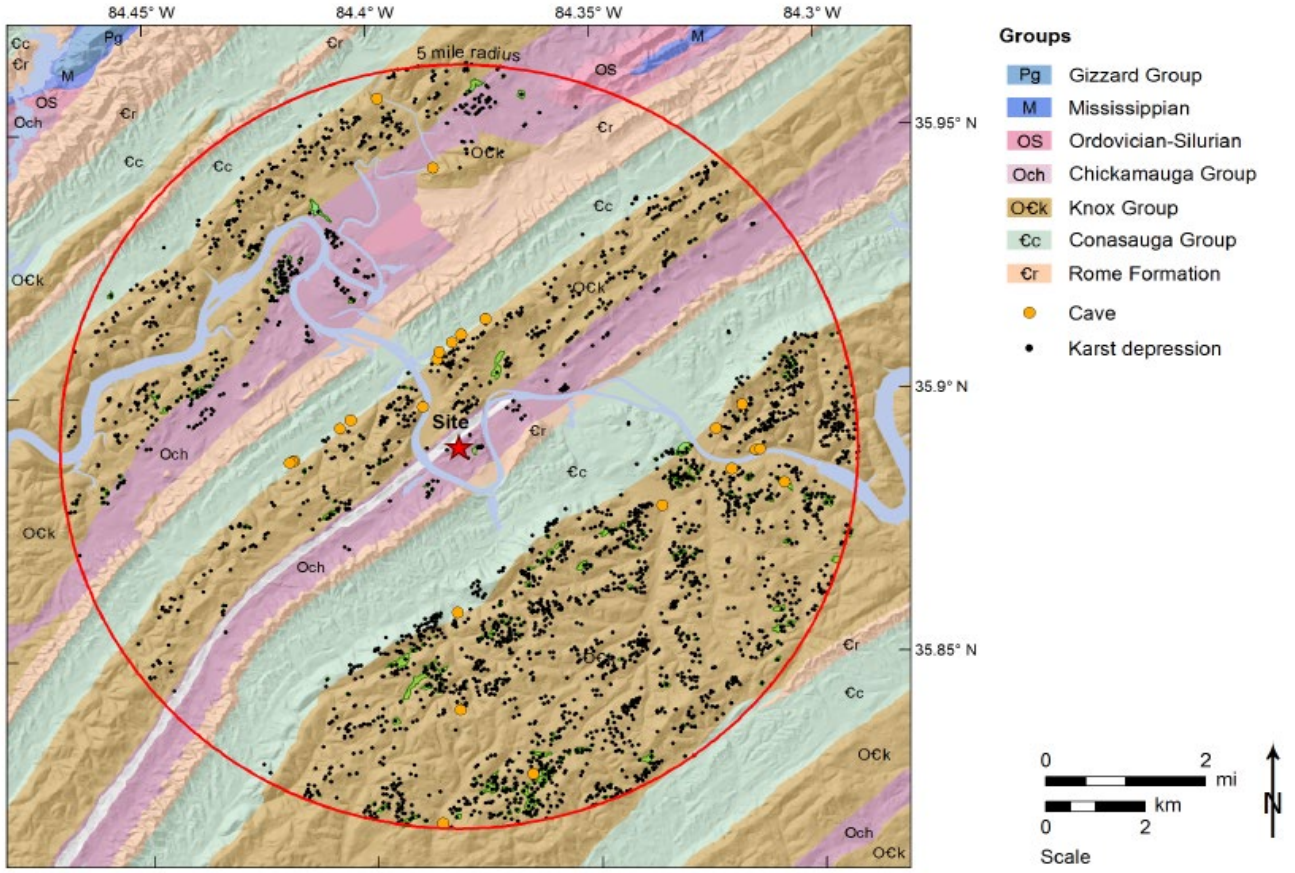
Site Vicinity



Note: Simplified geologic map of the Clinch River Nuclear site vicinity.

Figure 2.5.1-27. Simplified Site Vicinity Geologic Map

Site Area



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Site Location

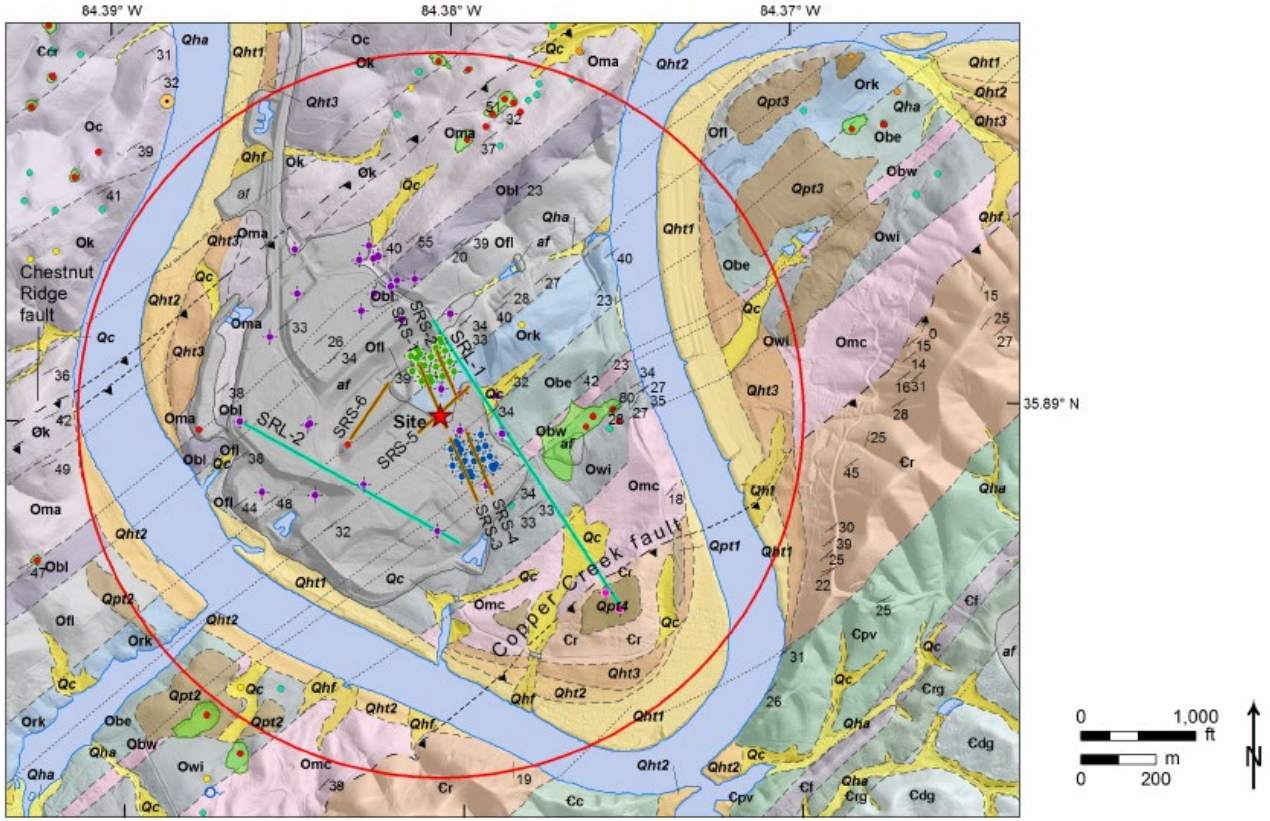
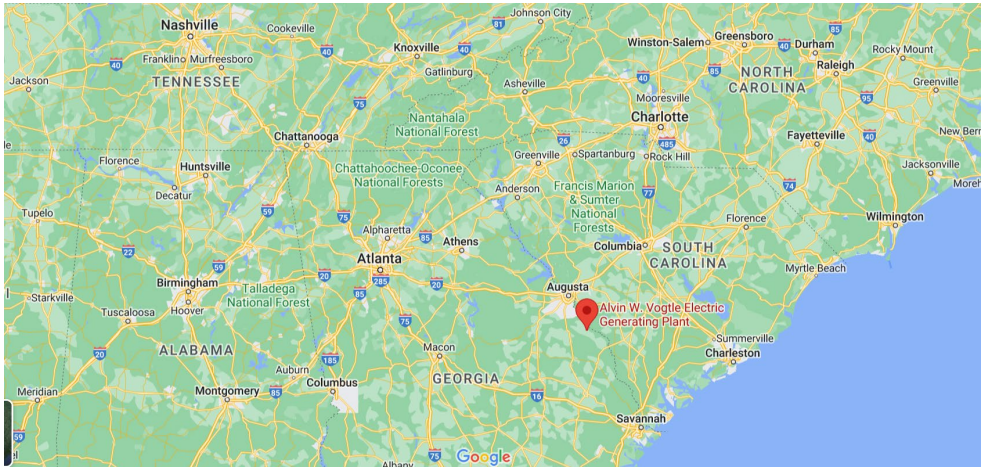


Figure 2.5.1-29. (Sheet 1 of 2) Site Location Geologic Map Showing Borings

Vogtle COL

- ESP application submitted 2006; issued 2009
- License application submitted to NRC in 2008
- License issued for two AP1000 units in 2012
- Both units are currently under construction



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Vogtle COL

- Site located along the Savannah River in the Coastal Plain physiographic province of eastern Georgia
- Pen Branch fault (PBF), dips beneath Units 2 and 3, based on seismic reflection data
- Meizoseismal area for the 1886 Charleston earthquakes is located approximately 150km (85 mi) southeast of the site in the Charleston seismic source

Vogtle COL

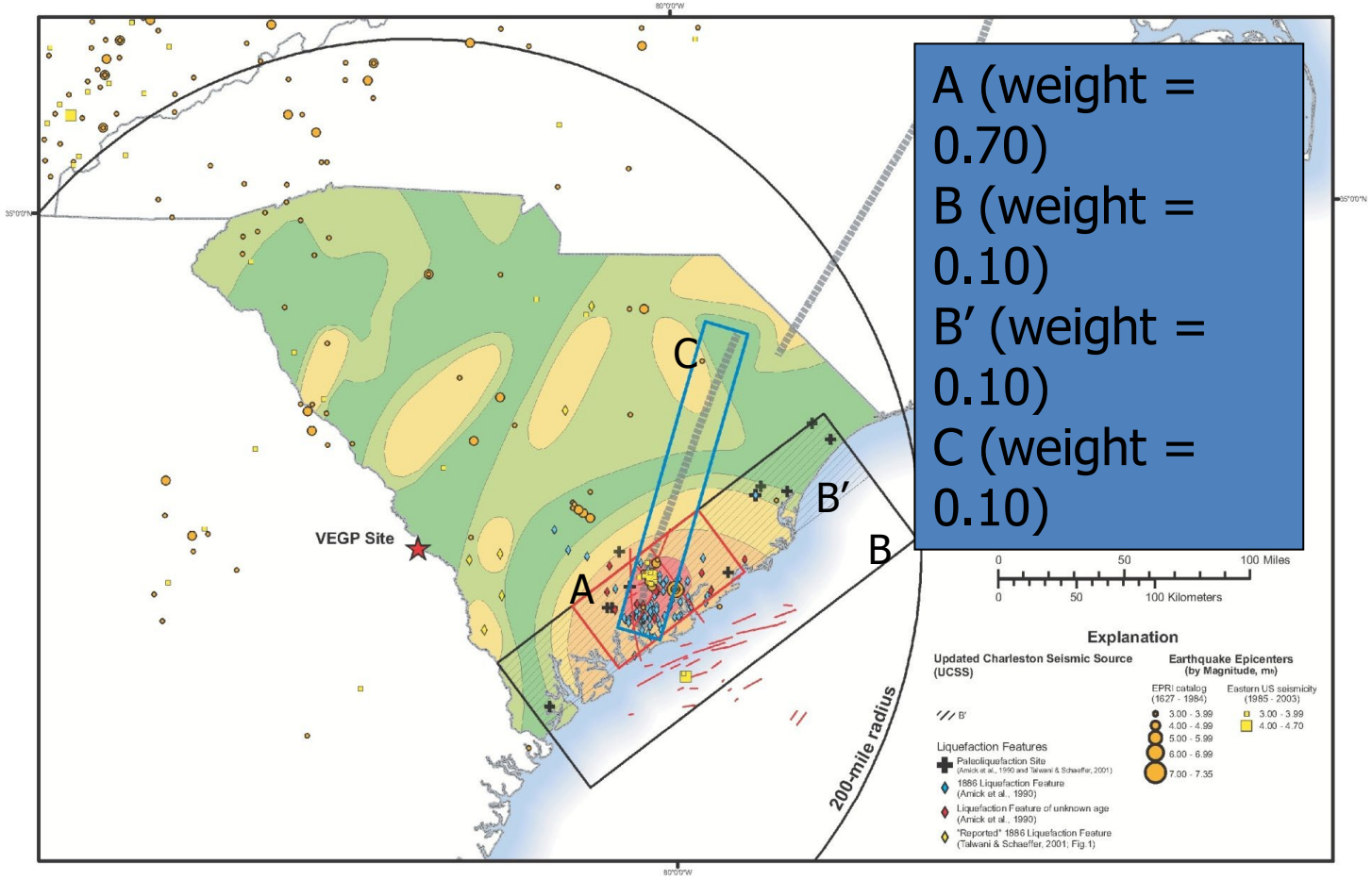
- Pen Branch Fault
- Charleston seismic source
- License issued for two AP1000 units in 2012

Pen Branch Fault

NRC geologists assessed information used by the applicant to characterize the PBF.

- Geologic characteristics of the PBF:
  - Northwestern border fault of the Dunbarton Triassic Basin.
  - Originally an extensional normal fault which was reactivated as a reverse fault during the Cenozoic.
  - About 40 km (25 mi) in length, strikes N46-66E, and dips 60-75SE beneath proposed Units 2 and 3 based on seismic reflection data.
  - Exhibits no surface expression or spatially-associated seismicity, so location was defined based on borehole and seismic reflection data.

UCSS Zone Geometries A, B, B’, C and Distribution of Liquefaction Features



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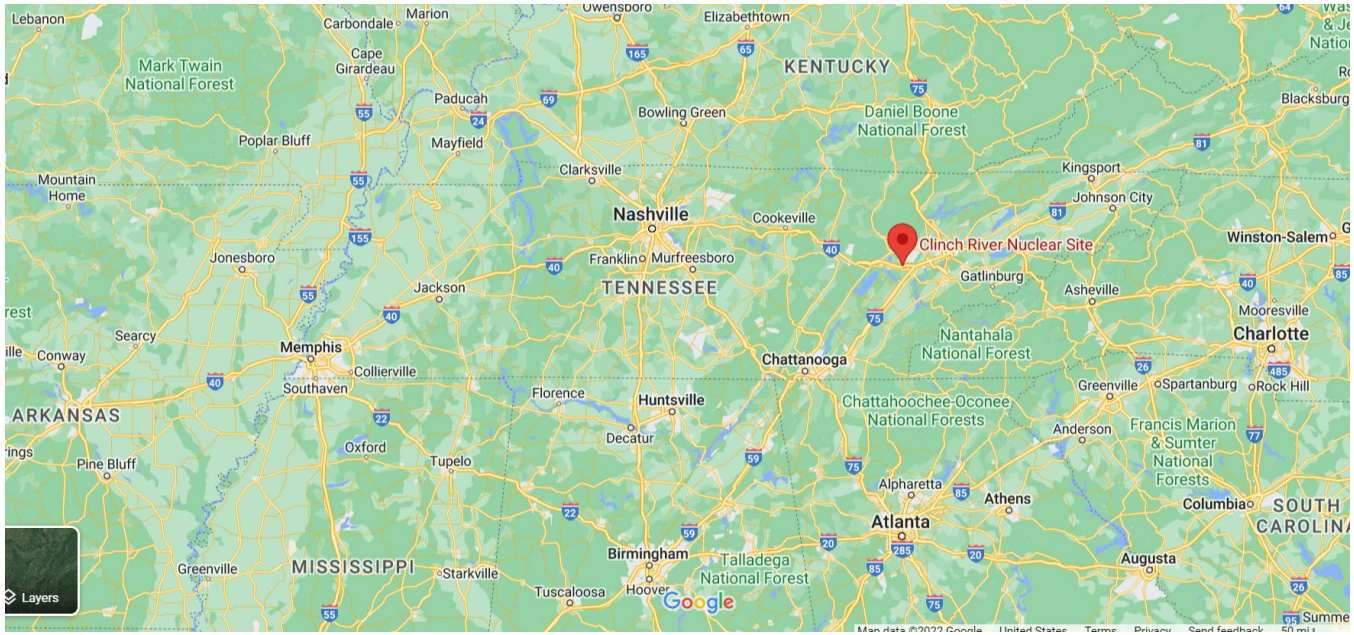
Vogtle Unit 3 Excavation - Geologists as Scale

Clinch River ESP

- Early Site Permit application received 2016
- ESP issued in December 2019



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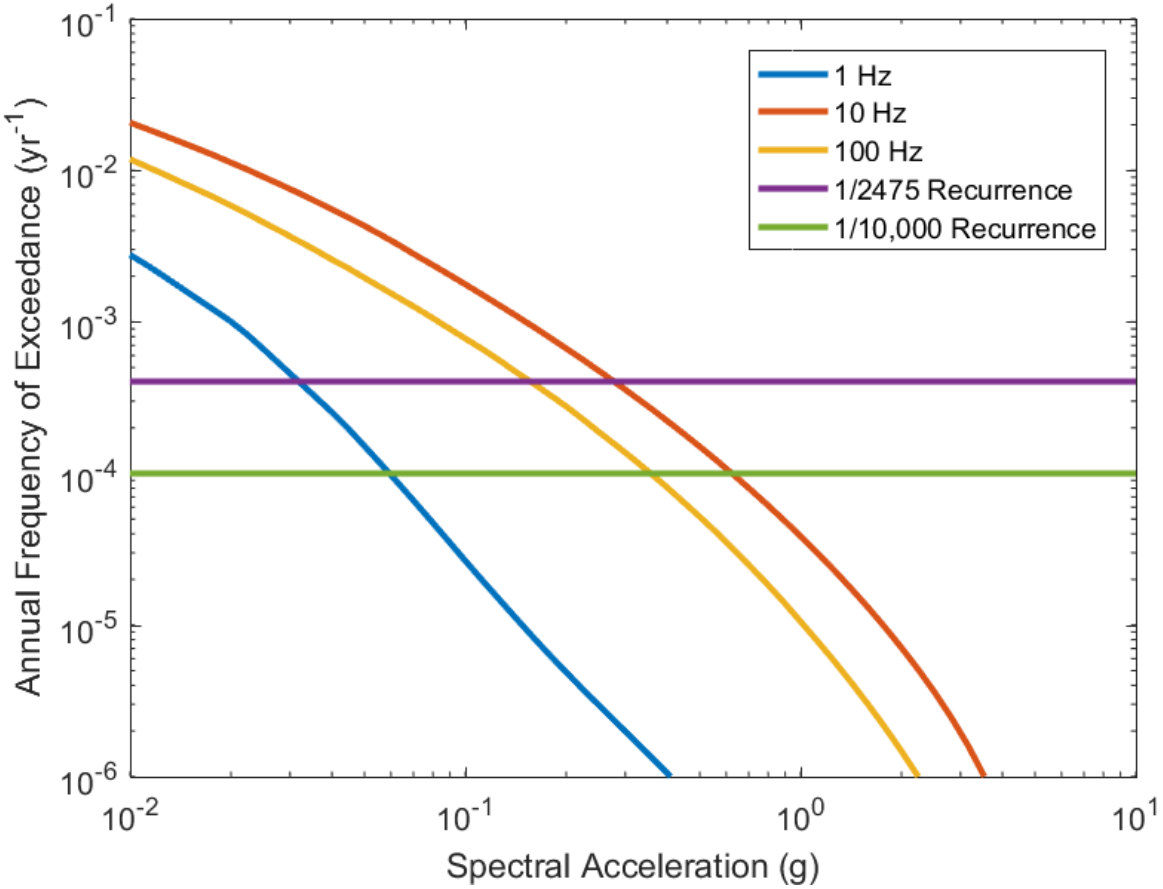
Seismic Hazards



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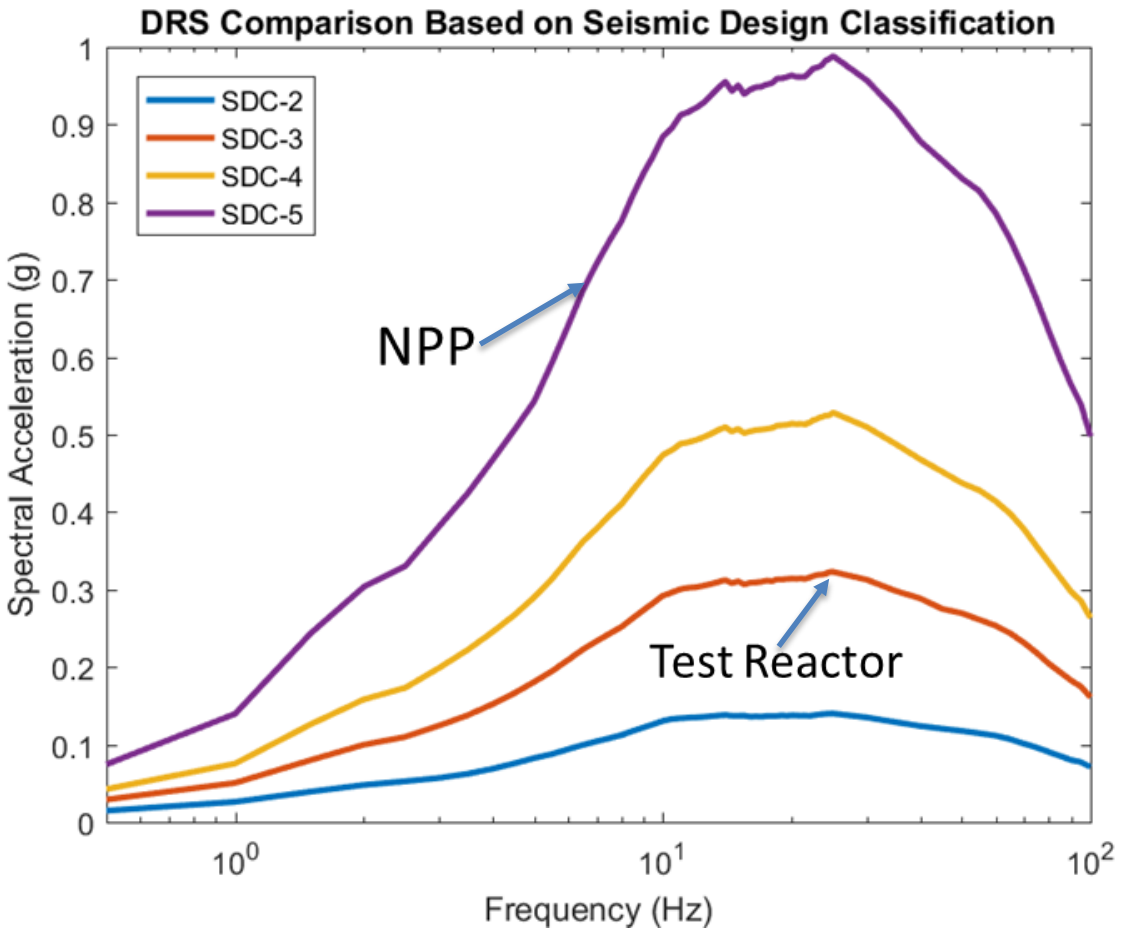
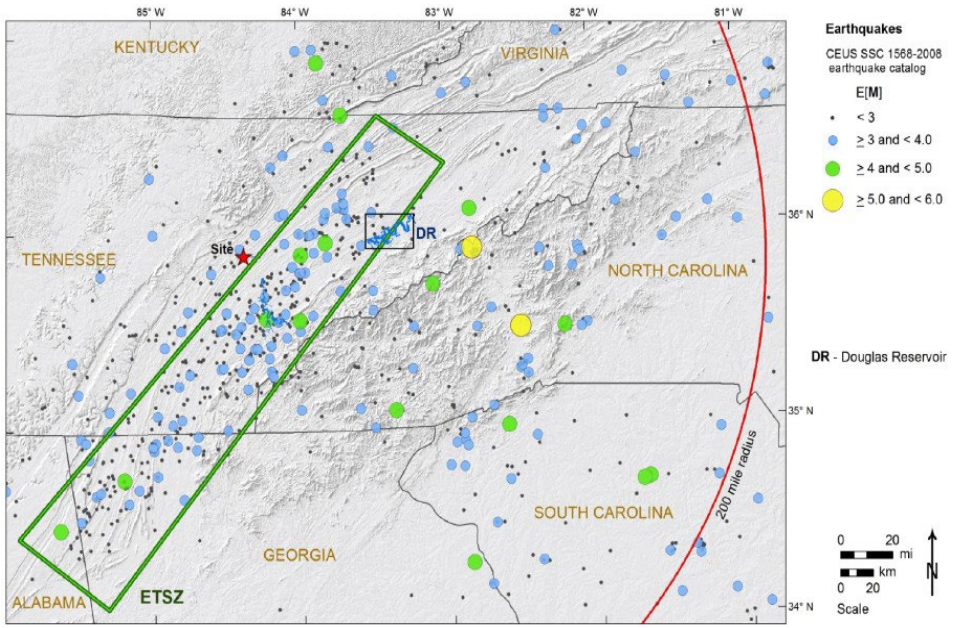
Seismic Hazards



Treatment of Eastern Tennessee Seismic Zone (ETSZ)

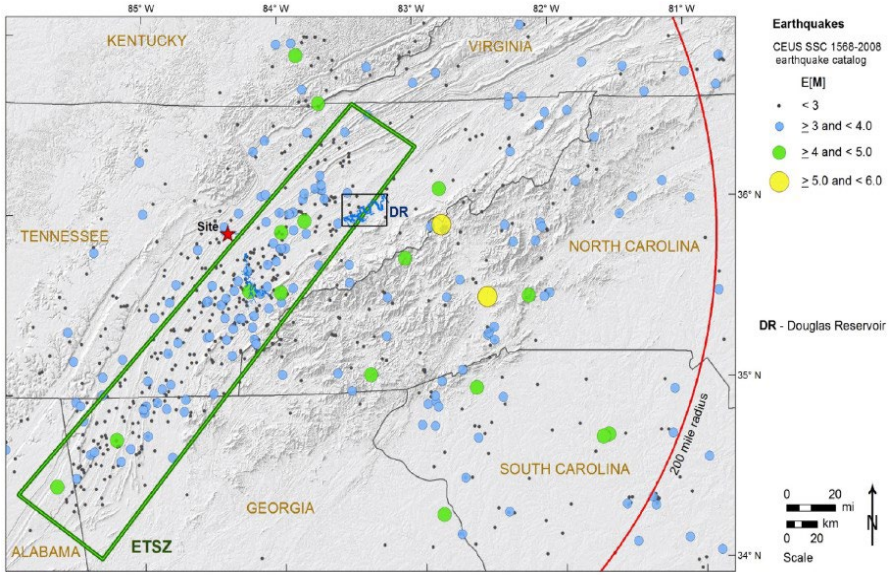
- ETSZ is region of elevated seismicity rates.
  - Small magnitude earthquakes
  - Occur within basement rocks below sedimentary section
- Included in NUREG-2115 within seismotectonic and M_{max} source zones
  - Sensitivity studies done during study to ensure that source zones adequately capture seismicity in ETSZ
- Recent geologic studies interpret potential for larger (**M**≥6.5) earthquakes



SSAR Figure 2.5.2-26

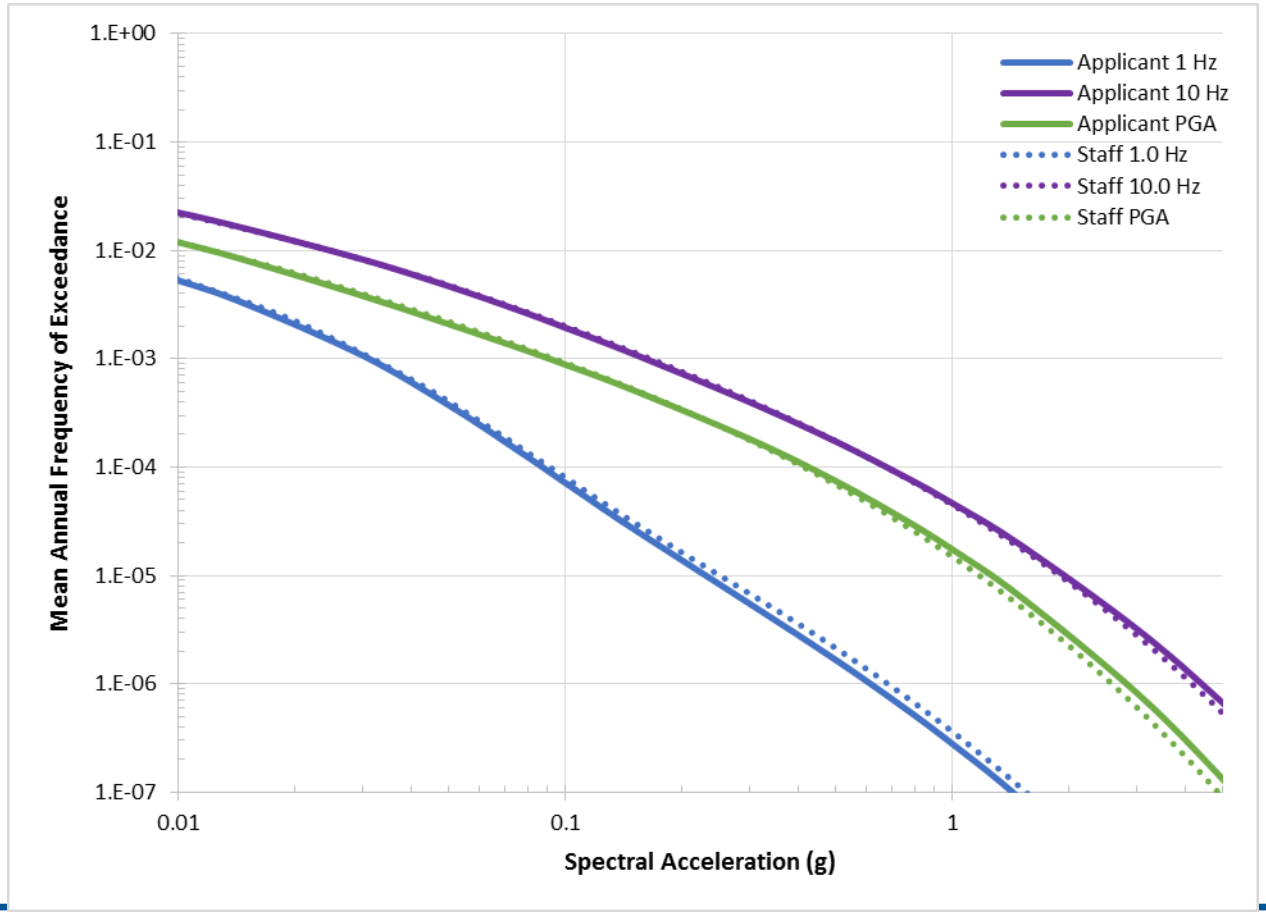
Treatment of Eastern Tennessee Seismic Zone

- Applicant performed two sensitivity studies following SSHAC guidance for Level II study
  - Evaluate M_{max}
  - Evaluate Magnitude-Frequency relations
- M_{max} values in NUREG-2115 encompass proposed M_{max} developed using new data
- Recurrence of large magnitude events in NUREG-2115 consistent with proposed values in new geologic studies
- Staff concludes that NUREG-2115 adequately captures current understanding of seismic hazard in the Eastern Tennessee Seismic Zone



SSAR Figure 2.5.2-26

Probabilistic Seismic Hazard Analysis (PSHA) Confirmatory Calculations



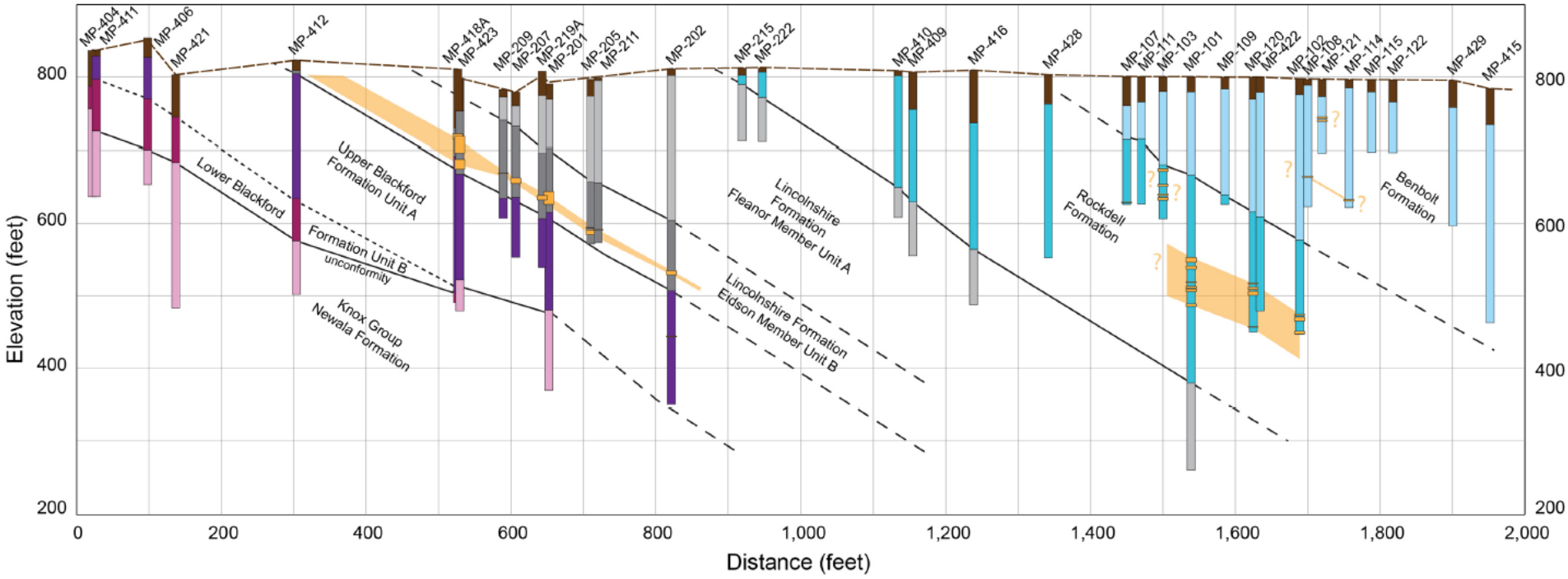
Staff independently calculated seismic hazard curves at the Clinch River site. Comparisons show that the seismic hazard curves are in good agreement at the annual frequency of exceedances of interest: 10^{-4}, 10^{-5}, and 10^{-6}

Approach to Site Response Inputs

- Clinch River site has significantly dipping rock layers
  - Approximately 30 degrees
- High seismic velocities
  - 5,000 to >10,000 fps
- Applicant developed site response inputs using
  - 3 profiles for each location
  - Log mean seismic velocity as function of depth as base case
  - Upper and lower case using log standard deviation
  - Effect of smearing geologic units together

- Staff requested that applicant explain how the use of multiple base cases accurately accounts for dip across site
- Applicant responded the smearing of units is appropriate because mean and range of values at a specific depth is maintained, implicitly accounting for stratigraphic variations.
- Staff performed confirmatory site response considering dip explicitly (i.e. upsection; middle; and downsection profiles)
- Staff truncated profiles at the top of the Knox Group due to thickness and velocity of layer
- Staff's results are consistent with applicant's

Approach to Site Response Inputs



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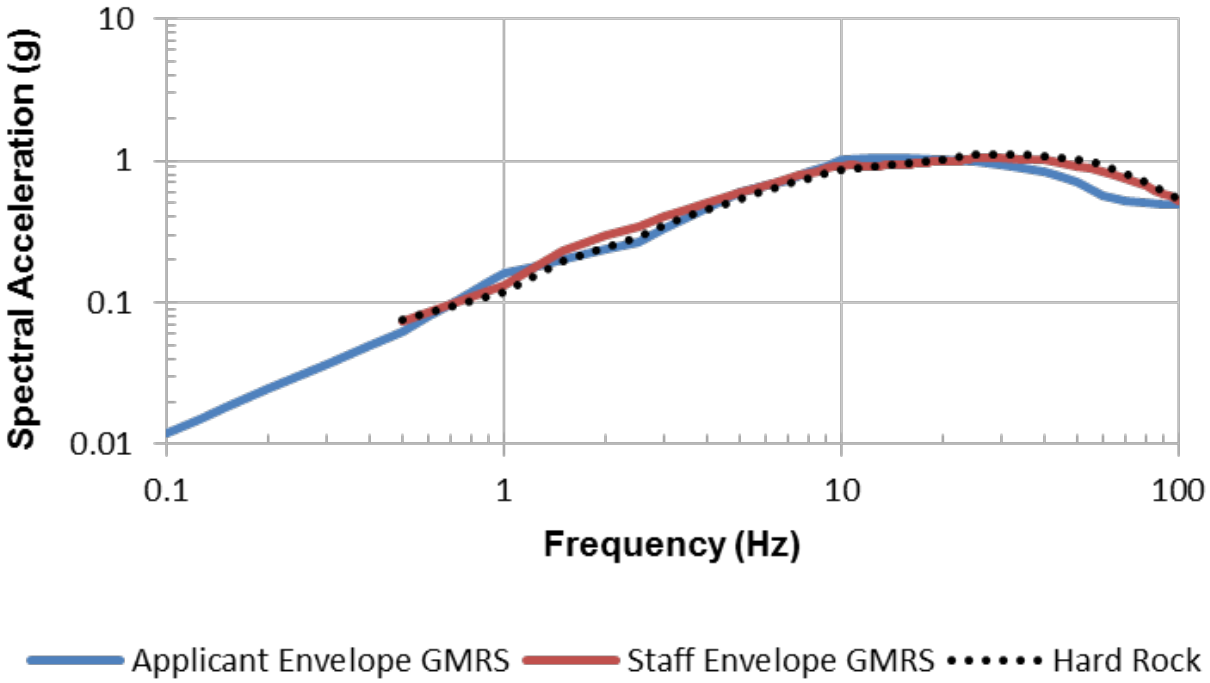
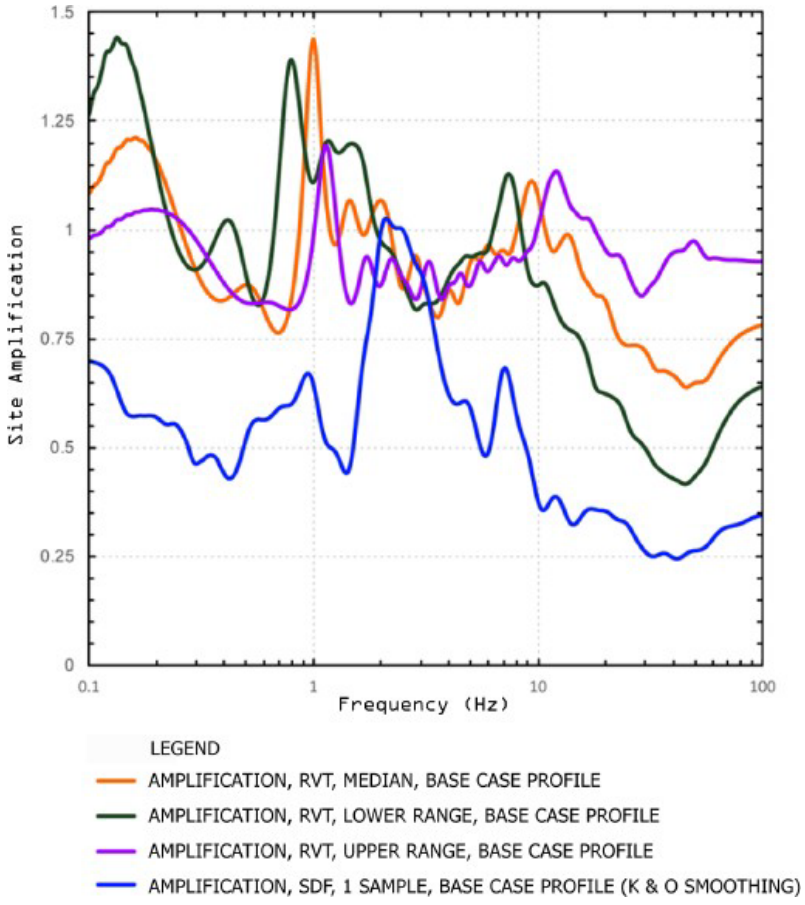
Ground Motion Response Spectrum (GMRS) Confirmatory Analysis



Staff developed alternative input parameters for site response analysis. Staff independently calculated site response and developed a site ground motion response spectrum (GMRS) based on its preferred inputs. Site GMRS developed by staff is consistent with that developed by the applicant.

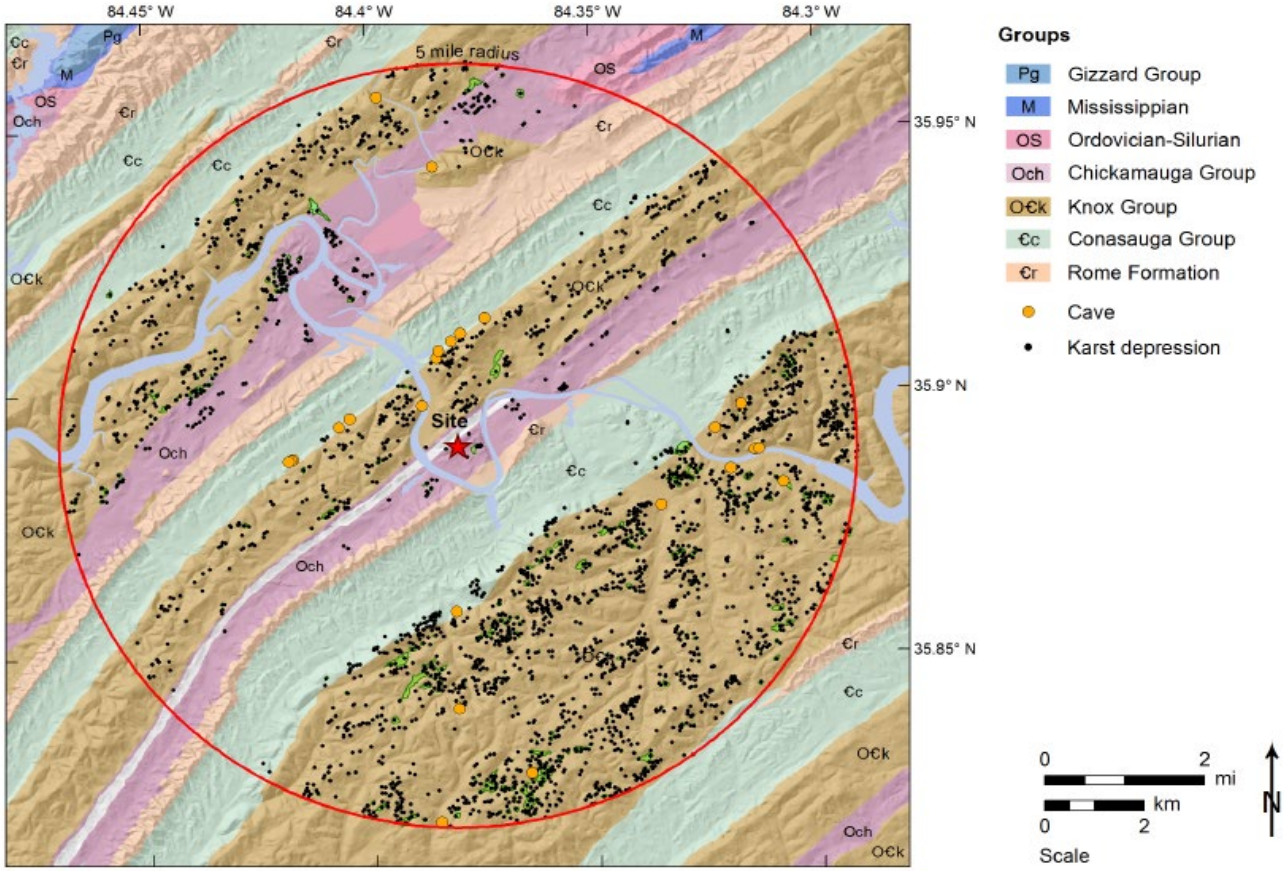
2-D Site Response

- Clinch River site has significantly dipping (>30 degrees) rock layers in subsurface
- RG 1.208 states that for sites with complicated subsurface structure, a multi-dimensional approach to site response may be necessary
- Applicant developed a 2-D site response analysis and compared amplification functions to 1-D results developed using 2-D inputs
- Staff requested that applicant compare 2-D results to 1-D results used in developing GMRS
- Applicant's 2-D results compare favorably with 1-D results, satisfying staff's concern



SSAR Figure 2.5.2-108

Karst in Site Area



Swale: small wet depression
Swallet: slightly larger depression through which water drains
Sinkhole: surface depression as a result of subsurface collapse due to dissolution

Distribution of Mapped Karst Features in the CRN Site Area (Reproduced from SSAR Figure 2.5.1-47)

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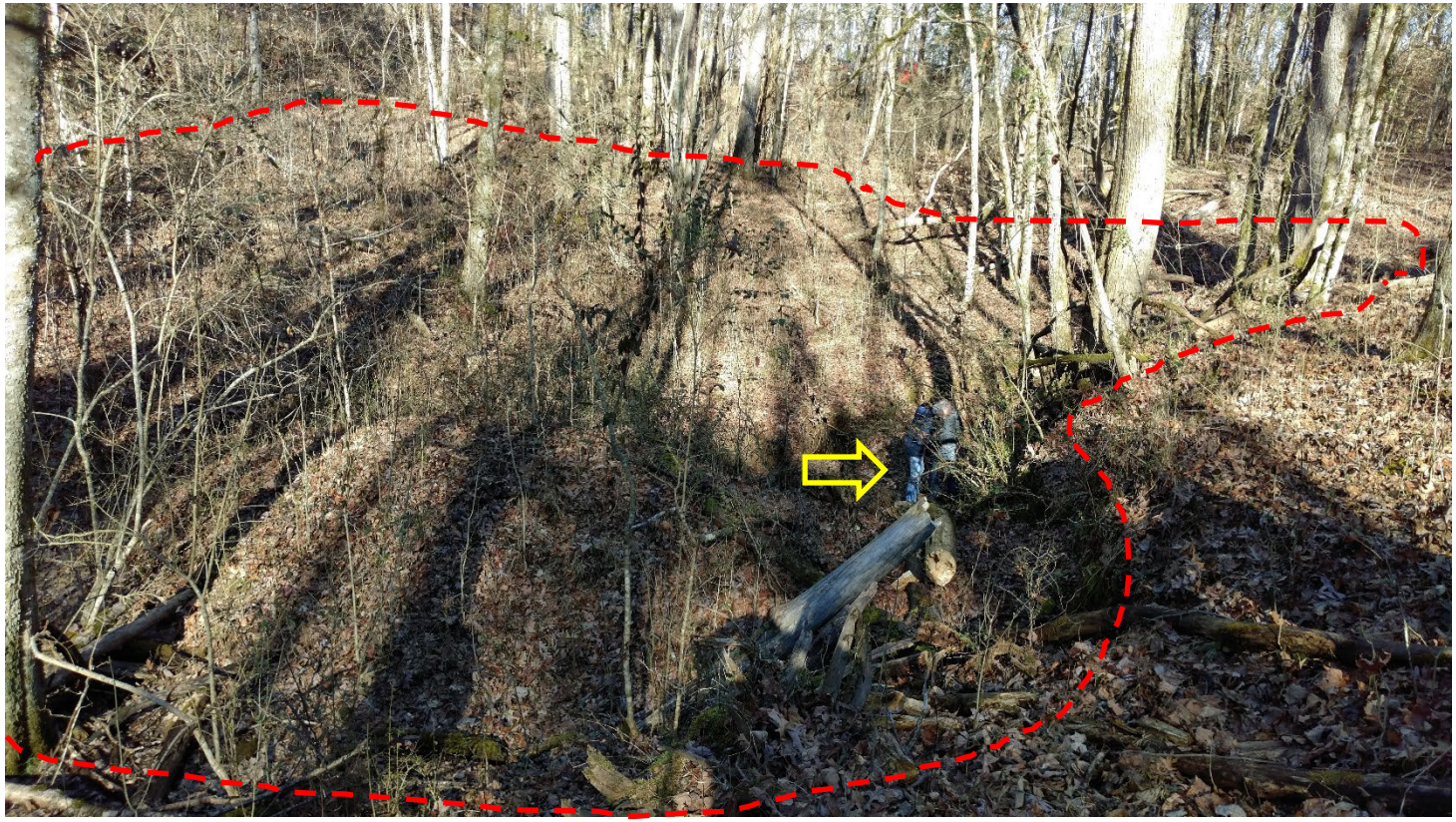
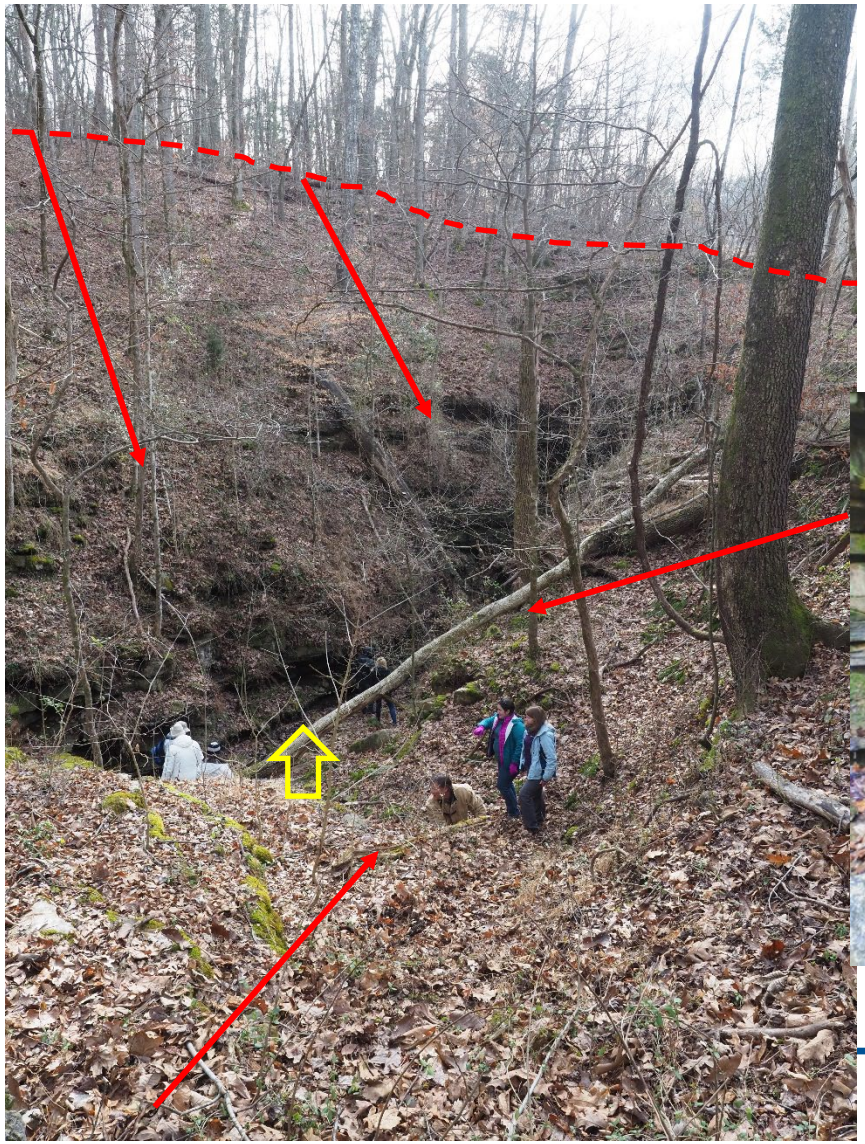
Karst Features – Swales, Swallets and Sinkholes



Pinnacle and cutter surficial karst features

Dissolution features along joints and bedding planes resulting in cavities in the exposed rock

Karst Features – Copper Ridge Cave



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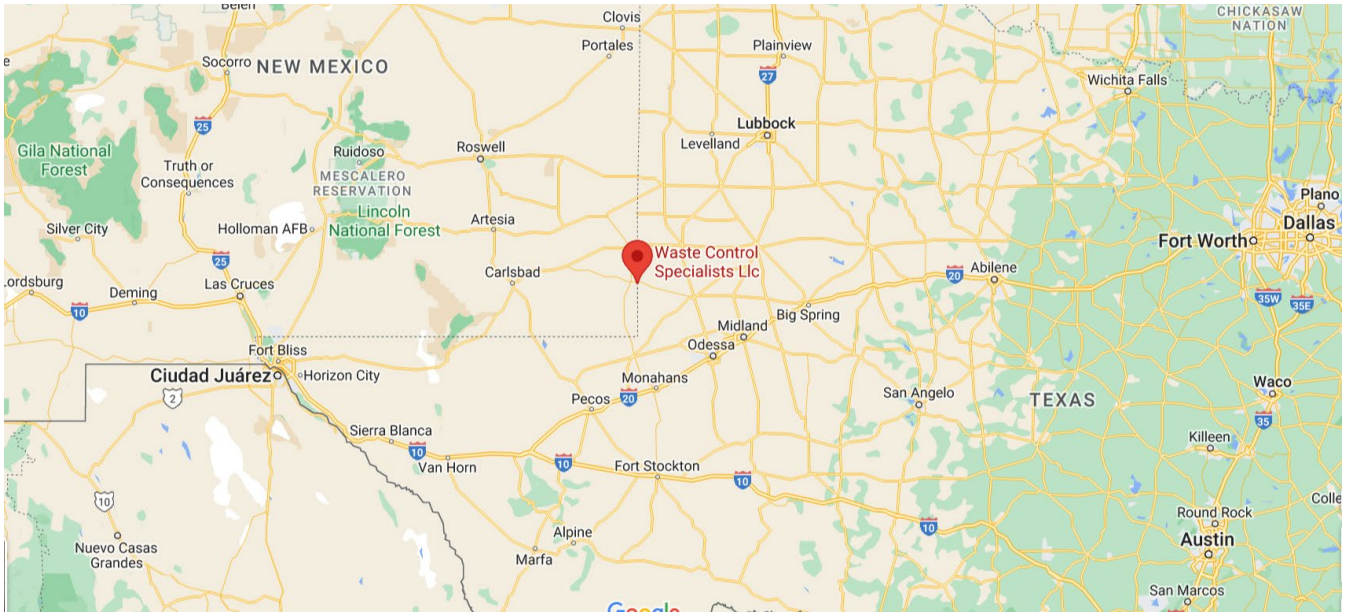
Geologic Mapping License (Permit) Condition

- NRC's Geologic Mapping License (Permit) Condition requires a licensee to perform detailed geologic mapping of excavations for safety-related structures at a new plant site; evaluate geologic features discovered; and notify the NRC once the excavations are open for examination by NRC staff.

WCS/ISP CISF

- Application received April 2016
- License issued September 2021



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Site Geology

- Uncertain Stratigraphy and Unit Thickness
  - Clarified the composition and physical properties of the subsurface layers at the site
- Red Bed Ridge
  - Structurally stable drainage divide with a low gradient and is not associated with the regional escarpment and does not pose a structural hazard to the site
- Features of Unknown Origin

Geologic Features of Interest

Figure 2-1. Proposed CISF 1-mile Radius (Modified SAR Revision 2, Figure 2-3)

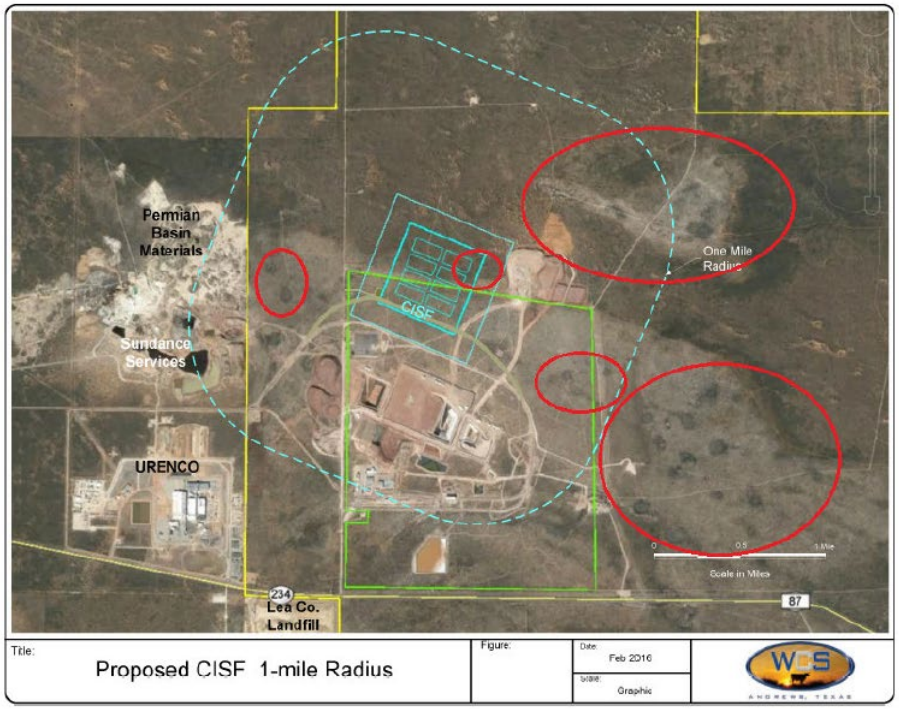
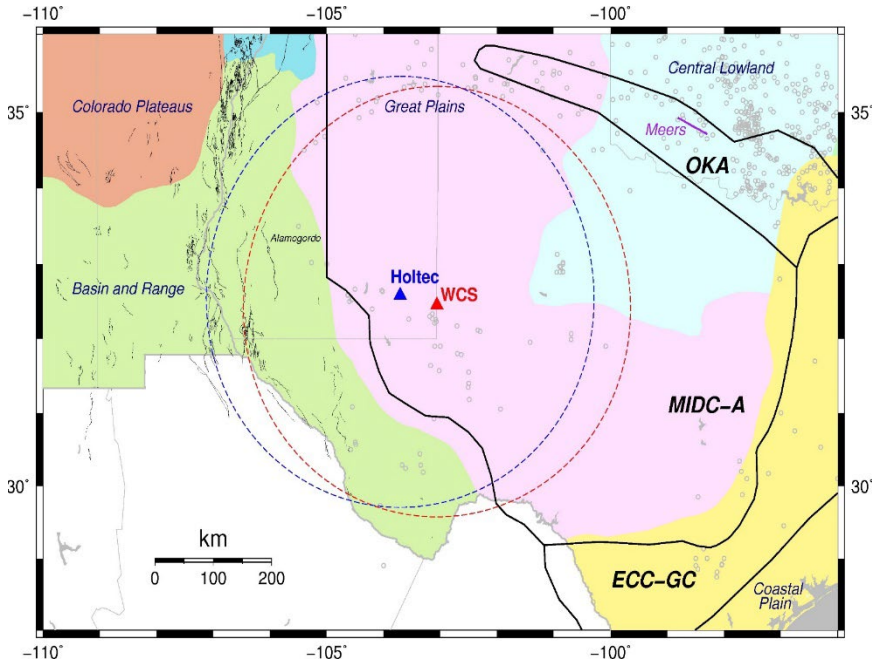


Figure 2-3
Proposed WCS CISF 1-mile Radius

Site Geology

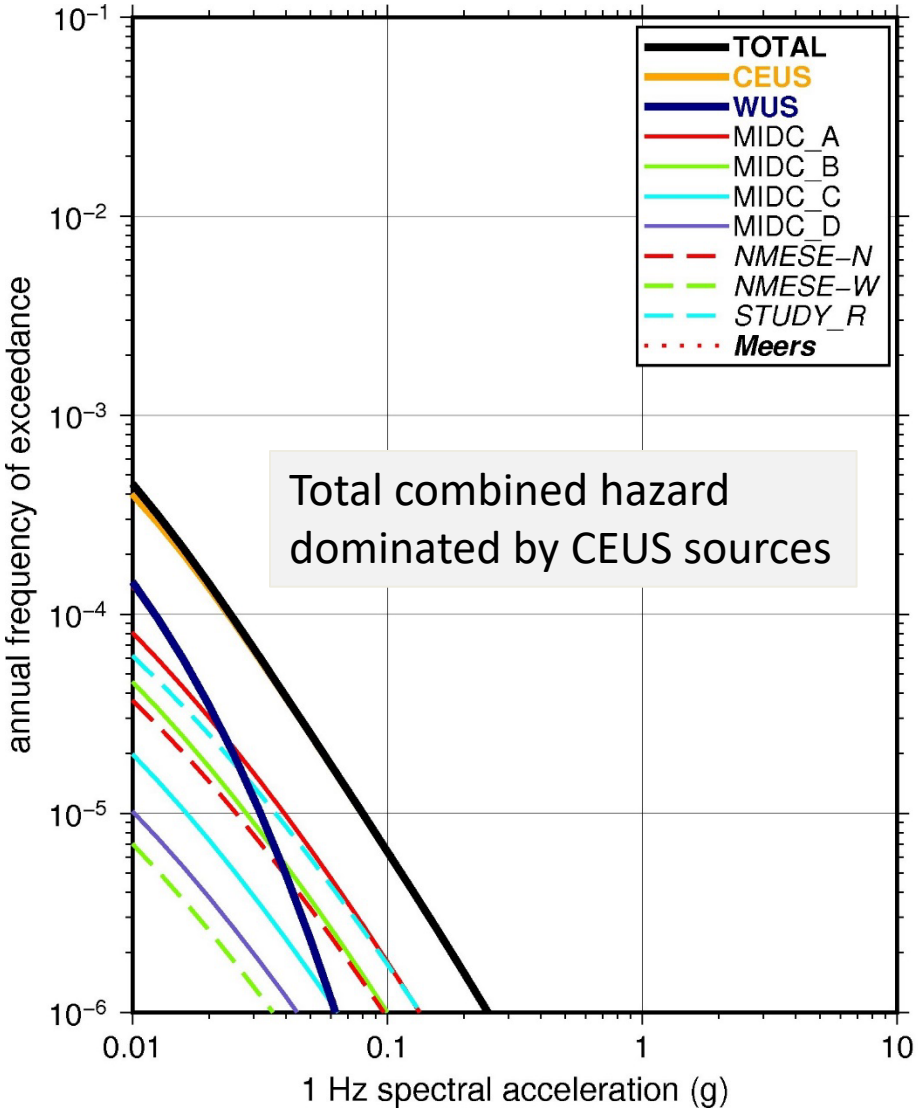
- Uncertain Stratigraphy and Unit Thickness
  - Clarified the composition and physical properties of the subsurface layers at the site
- Red Bed Ridge
  - Structurally stable drainage divide with a low gradient and is not associated with the regional escarpment and does not pose a structural hazard to the site
- Features of Unknown Origin
  - Erosional depressions that take tens of thousands of years to form

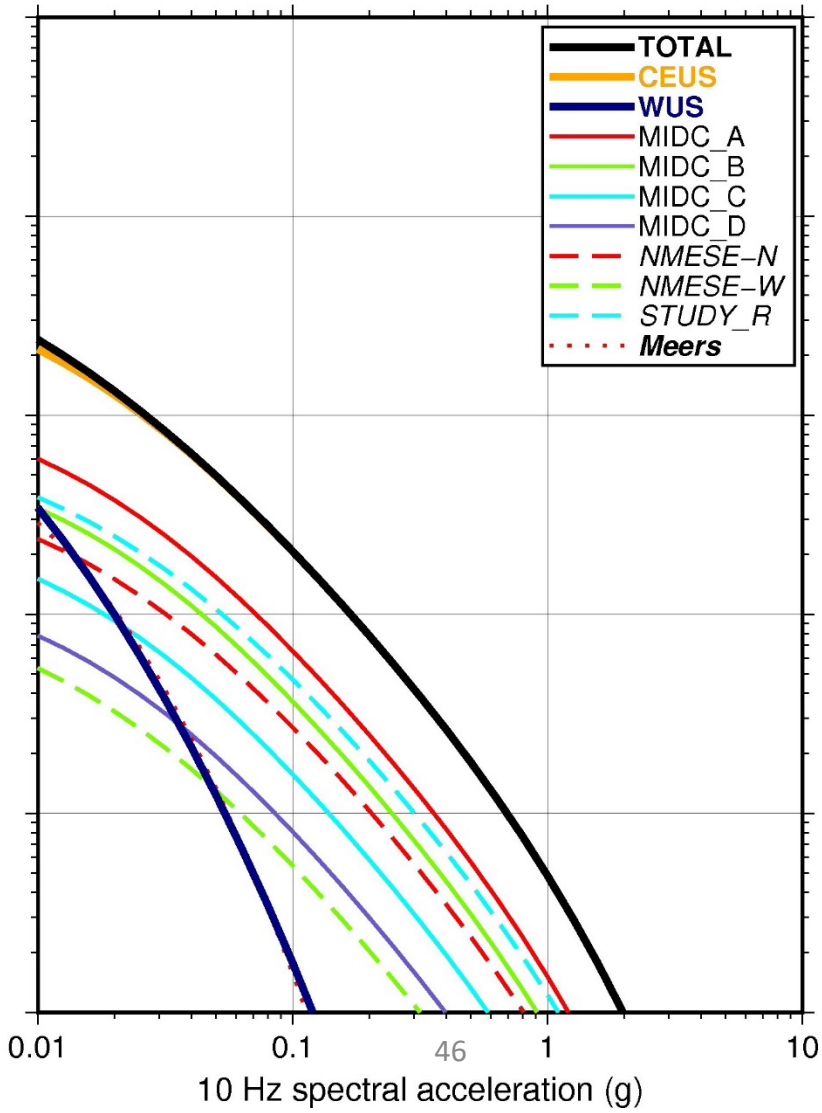
Seismic Hazard



- Sites located within CEUS boundary for seismic source and ground motion models
- Significant portion of regional hazard may also come from WUS sources

Combined CEUS & WUS Baserock Hazard Curves: ISP(WCS)





Process for the Ongoing Assessment of Natural Hazard Information (POANHI)

- Post-Fukushima Near-Term Task Force recommendations included the periodic re-evaluation of natural hazard information at reactor sites
- Assessment of new data should consider potential effect on operating fleet
  - Example, staff are currently looking at a new ground motion model and potential effects on operating fleet
- Report of activities is issued annually (link)

Additional Topics of Interest

- Yucca Mountain
- Fukushima Response