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Vogtle ESP Mandatory Hearing

March 23-25, 2009

NRC Staff Presentation Topic #7

Seismic Evaluation:

Geology, Seismology and Geotechnical Engineering

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Section 2.5: Geology, Seismology and Geotechnical Engineering

- Section 2.5.1 Site and Regional Geology
- Section 2.5.2 Vibratory Ground Motion
- Section 2.5.3 Surface Faulting
- Section 2.5.4 Stability of Subsurface Materials
- Section 2.5.5 Slope Stability

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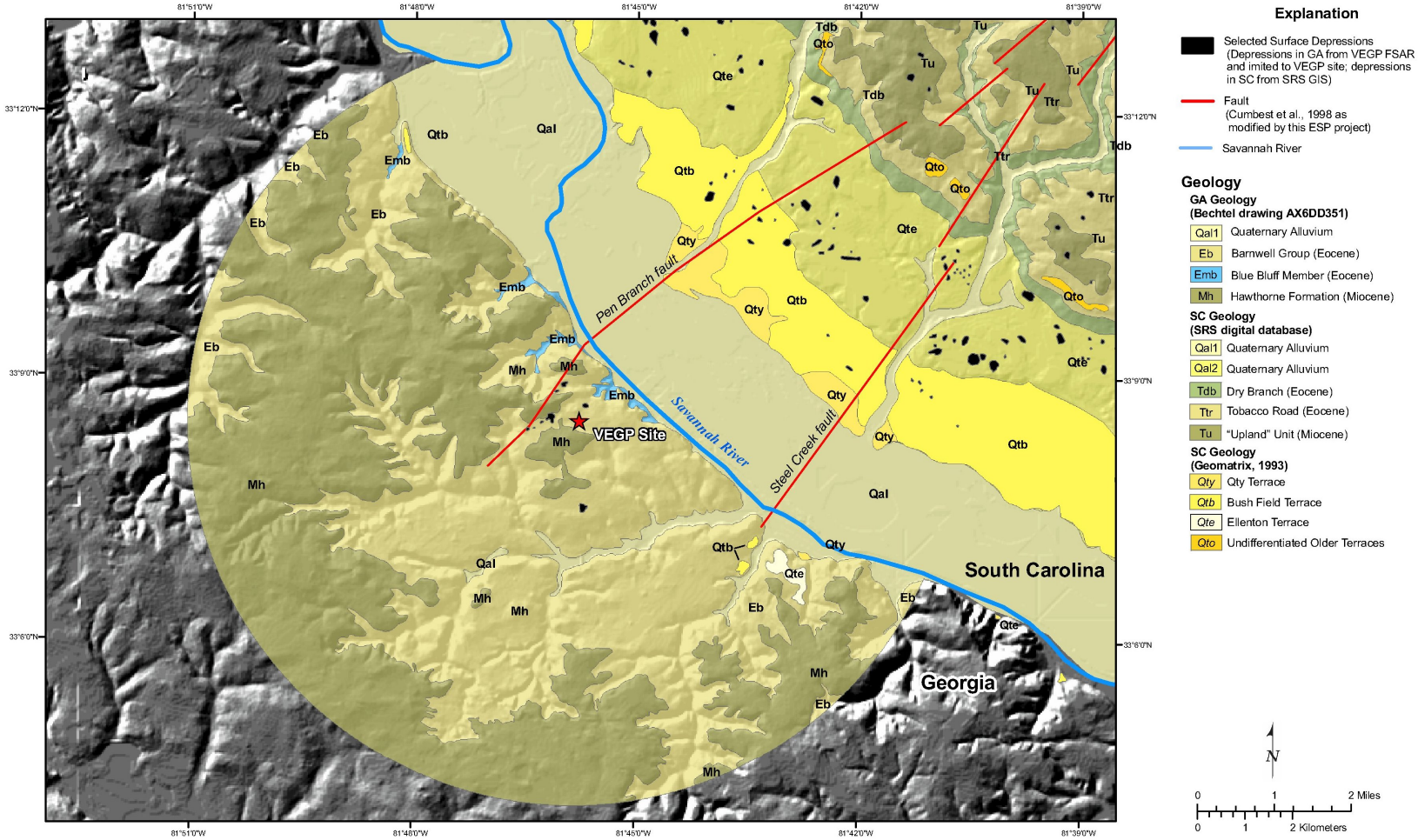
2.5.1 Basic Geologic & Seismic Information

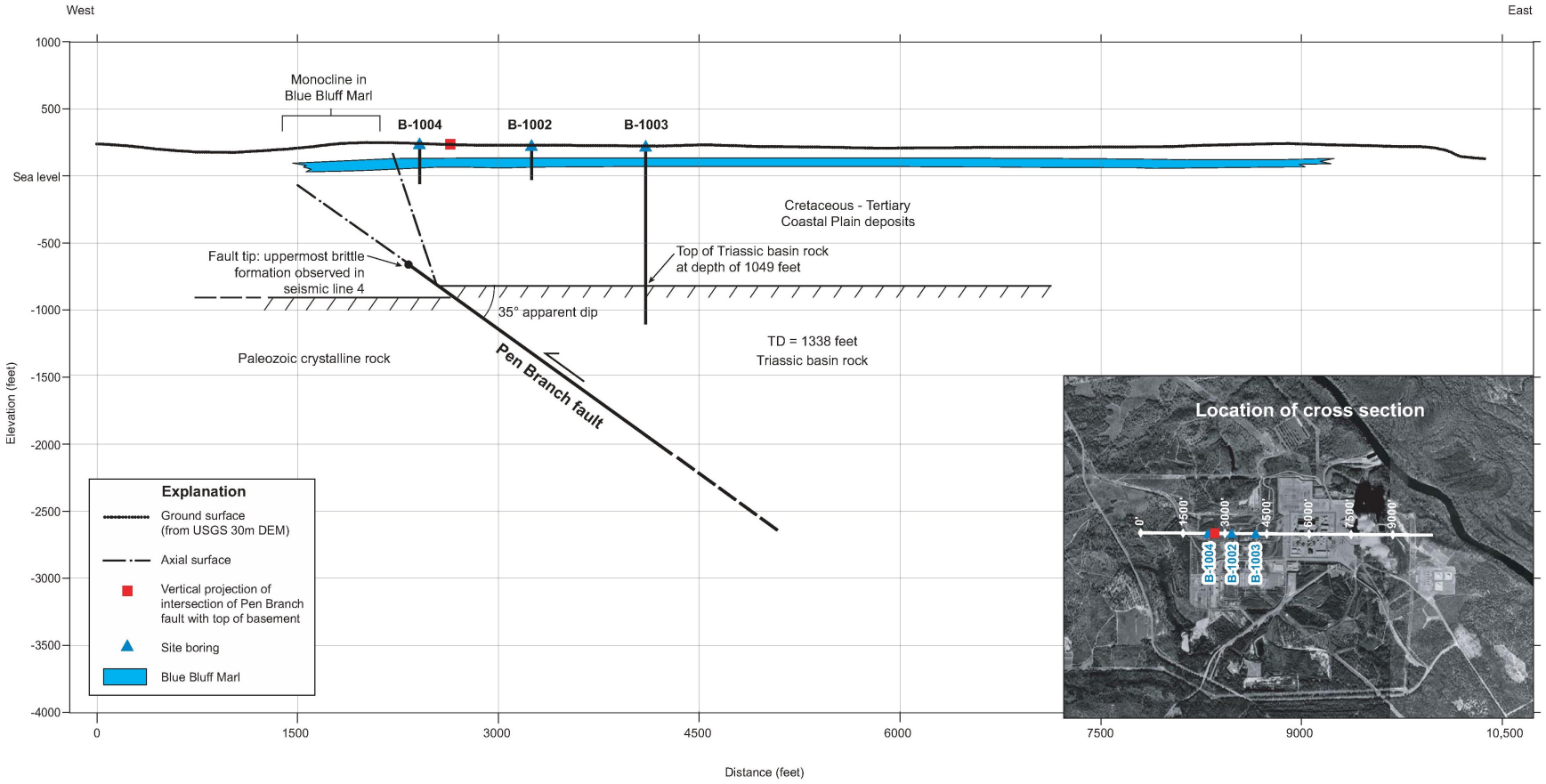
- **Pen Branch Fault**
  - 25 mi. total length, strikes NE, dips SE
  - Exhibits no expression of surface displacement
  - Exhibits no seismic activity
  - Extends beneath the ESP site based on subsurface geophysical data

2.5.1 Basic Geologic & Seismic Information



Reproduced from SSAR Figure 2.5.1-29

2.5.1 Basic Geologic & Seismic Information



Reproduced from SSAR Figure 2.5.1-40

E-W Cross Section: Pen Branch Fault beneath VEGP site

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2.5.1 Basic Geologic & Seismic Information

- **Pen Branch Fault (Cont'd)**
  - Field evidence indicates that the Pen Branch is not a capable fault
    - No stratigraphic evidence of fault displacement that is younger than 33.7 million years ago (mya)
    - Analysis of fluvial terraces along the Savannah River indicate no evidence of fault displacement during the Quaternary (i.e.,1.8 mya or less)

2.5.1 Basic Geologic & Seismic Information

Quaternary Terrace Surface Overlying the Pen Branch Fault at the SRS (Photo Source: USNRC)

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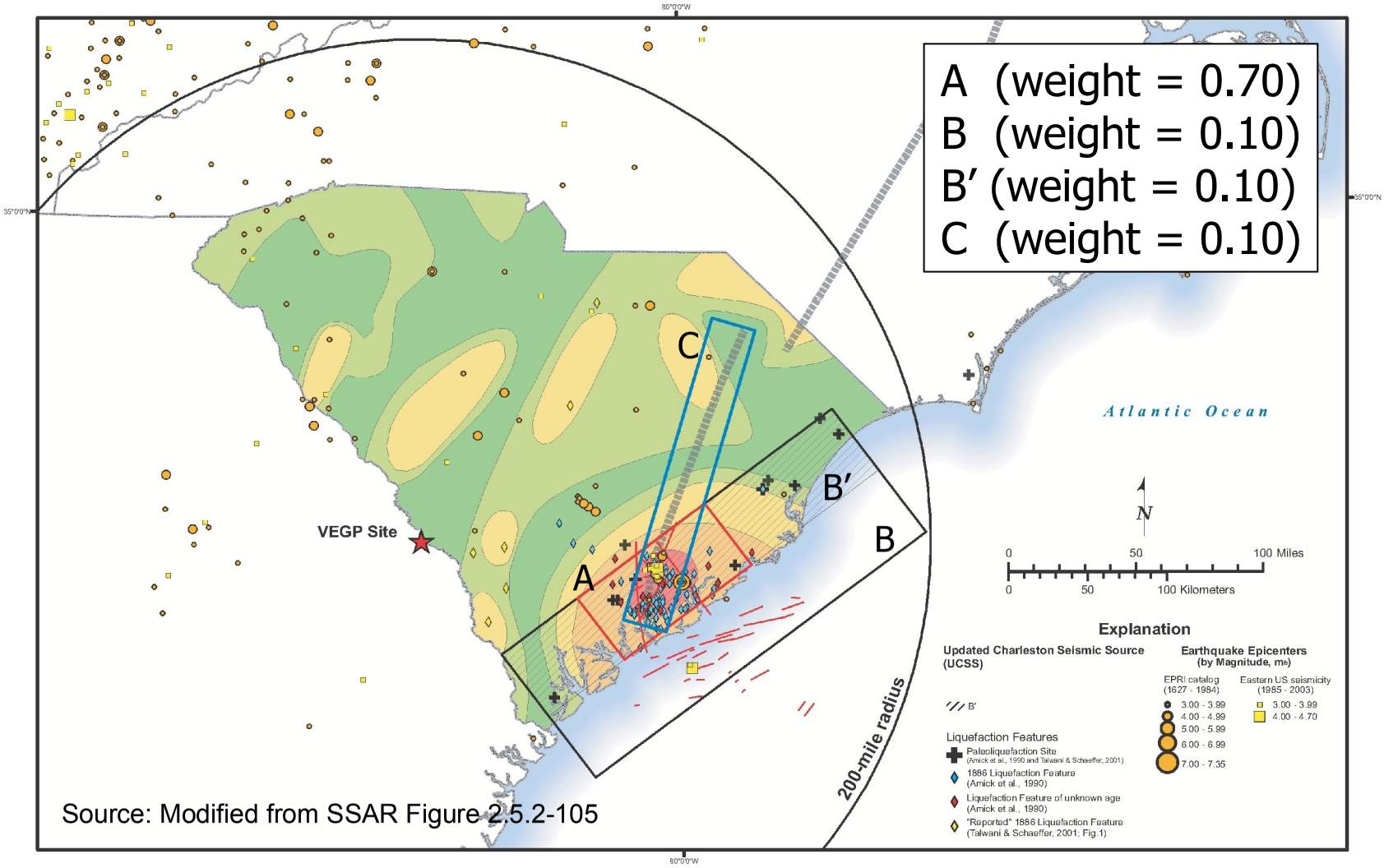
2.5.2 Vibratory Ground Motion

- **Updated Charleston Seismic Source Zone**
  - Applicant's update of the 1986 EPRI source model involved significant changes in geometry, and maximum magnitudes (M_{max}), and recurrence interval.
  - Update based on liquefaction features from historic and prehistoric earthquakes discovered since the EPRI study.
  - Average recurrence interval of M_{max} earthquakes decreased significantly, increasing the overall hazard.
    - Average recurrence decreased from several thousand years to less than a thousand years.

2.5.2 Vibratory Ground Motion



Source: Modified from SSAR Figure 2.5.2-105

Updated Charleston Seismic Source

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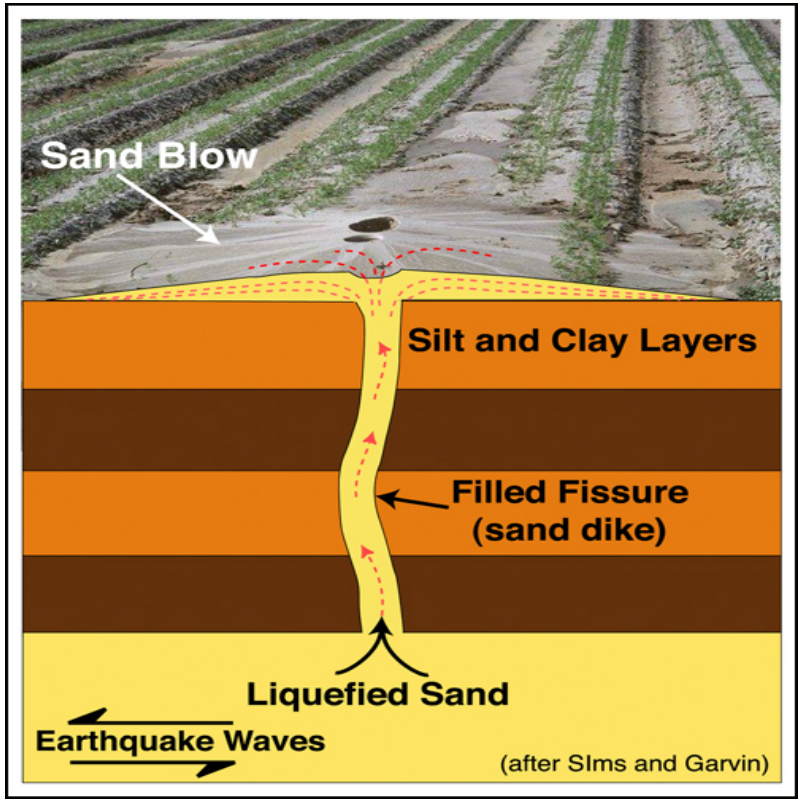
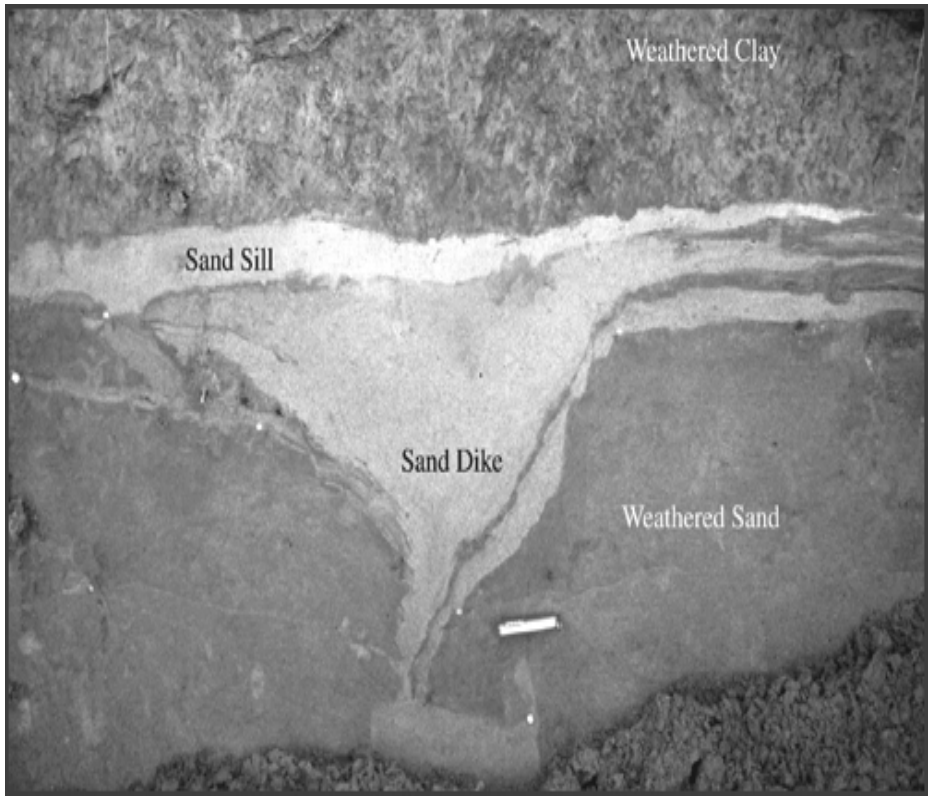
2.5.2 Vibratory Ground Motion

- Charleston update based on liquefaction features from historic and prehistoric earthquakes
- Liquefaction features occur in response to strong ground shaking





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2.5.2 Updated Charleston Seismic Source Zone

- **Charleston Liquefaction Features**
  - Abundant liquefaction features from historic and prehistoric earthquakes were mapped for ~130 mi. NE-SW along the South Carolina coast and >65 mi. inland from coast.
  - Liquefaction features represent 5 similar magnitude earthquakes (in addition to 1886) during the past ~5000 years.

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2.5.2 Updated Charleston Seismic Source Zone

- **Charleston Liquefaction Features (Cont'd)**
  - Staff was concerned that the applicant did not provide sufficient paleoliquefaction evidence to rule out the occurrence of large inland earthquakes. (Open Item 2.5-5)
  - In response to open item, the applicant provided documented expert opinion regarding actual observed inland liquefaction features characteristic of a localized Charleston earthquake source, rather than an inland earthquake source.
  - Staff determined this information was sufficient to close out Open Item 2.5-5.

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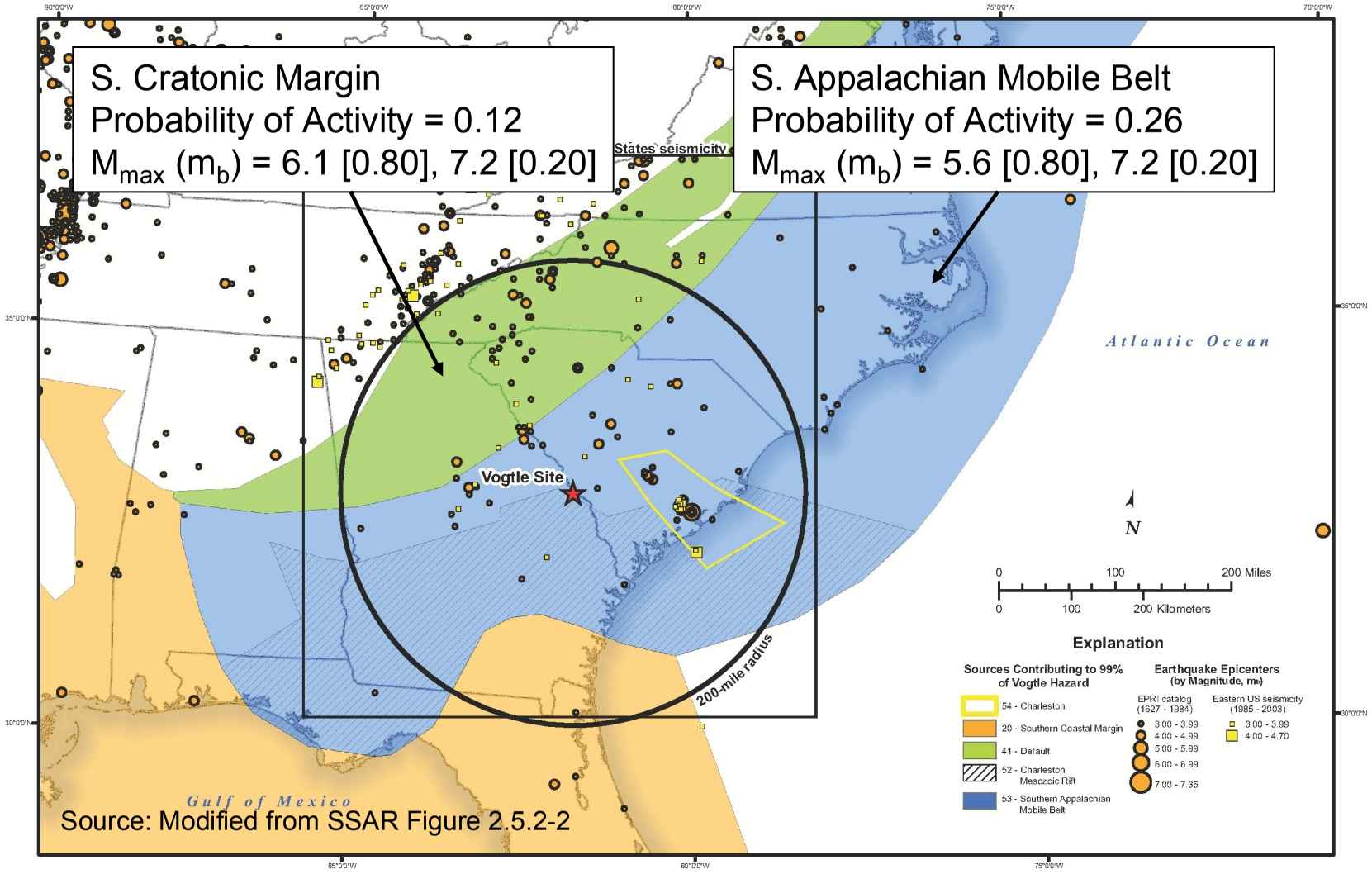
2.5.2 Vibratory Ground Motion

- **Regional Seismic Source Zone M_{max} and Probability of Activity**
  - EPRI seismic source zones were determined by six Earth Science Teams during the 1980s.
    - Dames and Moore team assigned low weights for larger M_{max} values (and low probabilities of activity) to two of their regional source zones.
  - The staff was concerned that the Dames and Moore hazard curves for the ESP site may not adequately characterize the regional hazard. (Open Item 2.5-1)

2.5.2 Vibratory Ground Motion



Source: Modified from SSAR Figure 2.5.2-2

Dames and Moore EPRI Zones

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2.5.2 Vibratory Ground Motion

- **Regional Seismic Source Zone M_{max} and Probability of Activity (Cont'd)**
  - Applicant demonstrated that the contribution to the total seismic hazard from the Dames and Moore team is insignificant at the Vogtle site.
    - The increase in seismic hazard is less than ~5 percent if the Dames and Moore results are excluded.

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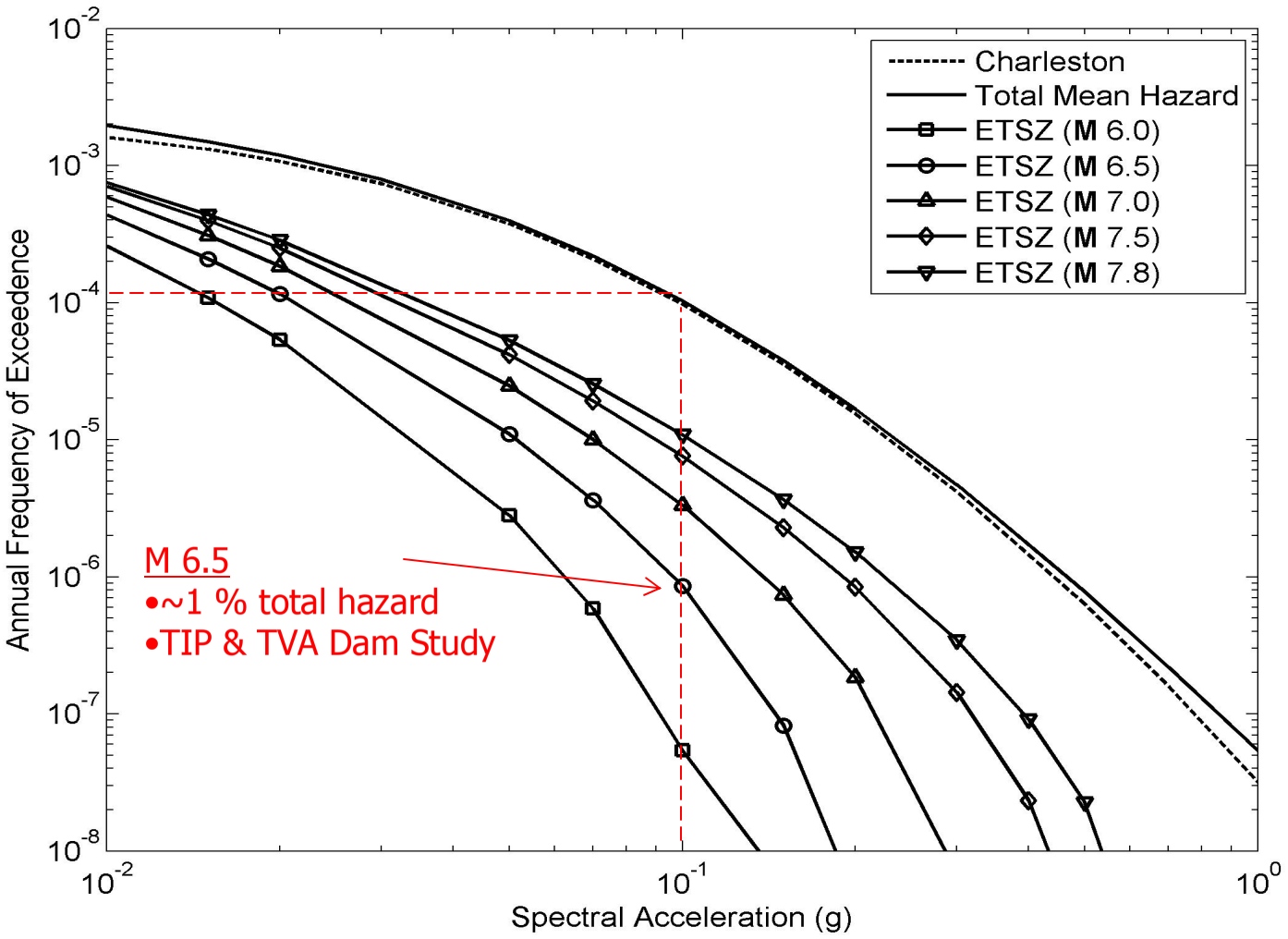
2.5.2 Vibratory Ground Motion

- **Eastern Tennessee Seismic Zone**
  - Applicant concluded no new information has been developed since 1986 that would require significant revision to the EPRI seismic source model.
    - More recent studies suggest revisions to the EPRI seismic source model may be warranted. (Open Item 2.5-3)
  - Staff's sensitivity study showed that the increasing ETSZ M_{max} did not result in a significant increase in the Vogtle total site hazard.
  - Staff determined that the results of the sensitivity study were sufficient to close out Open Item 2.5-3.

2.5.2 Vibratory Ground Motion

Source: Modified from FSER Figure 2.5.2-12



Results of Staff's ETSZ Sensitivity Study

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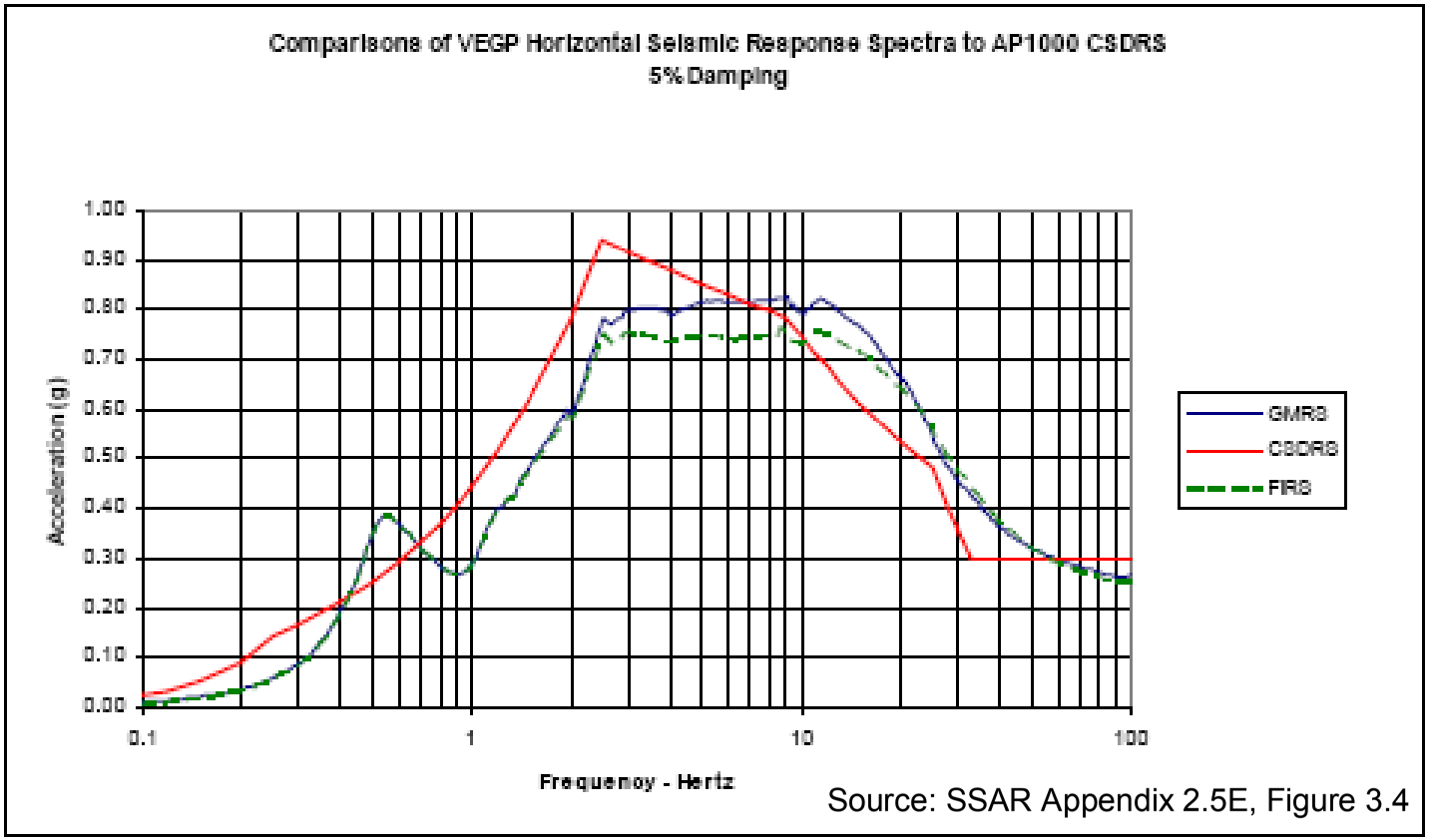
2.5.2 Vibratory Ground Motion



Source: SSAR Appendix 2.5E, Figure 3.4

Applicant identified the GMRS as a site characteristic

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2.5.2 Vibratory Ground Motion

- **The site-specific GMRS is not bounded by the AP1000 CSDRS.**
  - Staff concludes Vogtle GMRS is an adequate representation of regional and local seismic hazard and meets the applicable requirements of 10 CFR Part 52 and Part 100.
  - Staff considers the Vogtle GMRS values to be within the range of values that new reactor designs generally are engineered to withstand.
  - Appropriateness of the reactor design chosen for the site will be determined at the COL stage.

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2.5.3 Surface Faulting

- **Injected sand dikes at the Vogtle ESP site**
  - Stratigraphic relationships suggested dikes possibly as young as 1.8 mya to 10,000 yrs.
  - Applicant did not initially demonstrate that dikes were not associated with seismically-induced liquefaction. (Open Item 2.5-10)
  - In response to open item, the applicant provided field evidence to demonstrate that dikes most likely formed due to collapse of saturated sediments overlying minor dissolution features.
  - Staff determined the information provided was sufficient to close Open Item 2.5-10.

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2.5.4 Stability of Subsurface Material and Foundations

- **12 Open Items addressing the adequacy of:**
  - Field and Laboratory Testing of Subsurface Materials
  - Measurements of Shear Wave Velocity
  - Development of Soil Degradation and Damping Ratio Curves
- **Open Items resolved**
- **Permit Condition to require removal of Upper Sand Layer**
- **12 COL Action Items**
  - Resolved through the inclusion of additional information as part of the LWA request or SSAR revision in response to Requests for Additional Information

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2.5.4 Stability of Subsurface Material and Foundations

- **Field and Laboratory Testing of Subsurface Materials (Open Items 2.5-11 to 17, 20 and 21)**
  - Applicant did not initially conduct sufficient field and laboratory tests to reliably determine subsurface soil index properties.
  - Additional field and laboratory investigations were performed at the site, which closed the Open Items.

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2.5.4 Stability of Subsurface Material and Foundations

Site Investigations	ESP	LWA
Borings	14	174
CPTs	10	21
Test Pits	0	8
Observation Wells	15	0
P-S Velocity Logs	5	6

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2.5.4 Stability of Subsurface Material and Foundations

- **Shear-Wave Velocity**
  - Applicant provided insufficient shear-wave velocity measurements to define site characteristic values. (Open Item 2.5-18)
  - The applicant used additional data to re-evaluate the ESP profile following more detailed site investigations sufficient to close the Open Item.

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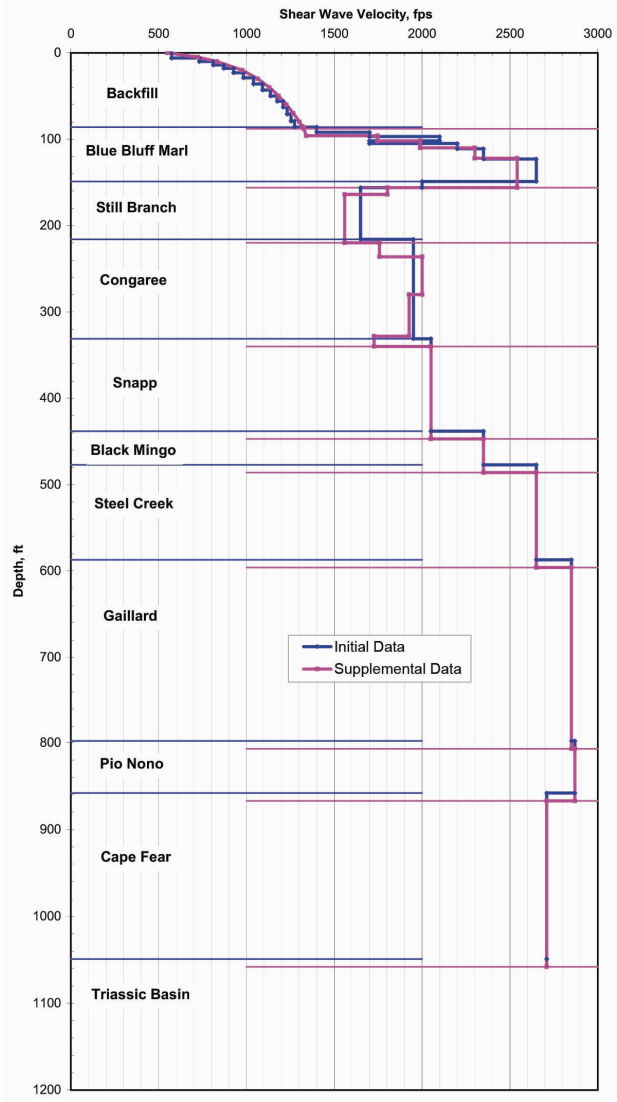
2.5.4 Stability of Subsurface Material and Foundations

Shear-Wave Velocity Profile



Source: Modified from SSAR Figure 2.5.4-7a

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2.5.4 Stability of Subsurface Material and Foundations

- **Soil Degradation and Damping Ratio Curves**
  - The applicant did not perform dynamic testing to verify dynamic material property curves used in site response analysis. (Open Item 2.5-19)
  - Applicant performed additional soil dynamic testing in support of the LWA request.

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2.5.4 Stability of Subsurface Materials and Foundations

- **Liquefaction**
  - Permit Condition 1
    - Required that the applicant shall either remove and replace, or shall improve, the soils directly above the Blue Bluff Marl for soil under or adjacent to Seismic Category 1 structures, to eliminate any liquefaction potential.
  - Site characteristic specifies that there is no liquefaction below approximately 26.8 m (88 ft) below the ground surface.

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2.5.4 Stability of Subsurface Materials and Foundations

- **Bearing Capacity (Static and Dynamic)**
  - Site characteristic value
    - Applicant specified a minimum bearing capacity of 1628 kPa (34 ksf) under static loading conditions and 2011 kPa (42 ksf) under dynamic loading conditions.
    - The staff concluded that the applicant provided sufficient information through field investigations, laboratory testing, and analyses with respect to the static and dynamic stability of the site to satisfy the applicable criteria of 10 CFR Parts 52 and 100.

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2.5.4 Stability of Subsurface Materials and Foundations

- **COL Action Items**
  - 12 COL Action Items:
    - Static Properties
    - Dynamic Properties
    - Backfill Criteria
    - Groundwater
    - Static Stability
    - Design Criteria
  - All COL Action Items resolved though inclusion of additional information as part of the LWA request or SSAR revision.

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2.5.5 Stability of Slopes

- **No safety-related permanent slopes near the proposed location of VEGP Units 3 and 4; therefore, a slope stability analysis was not necessary.**

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Section 2.5: Summary

- **2.5.1 Basic Geologic and Seismic Information**
  - Applicant provided a thorough and accurate characterization of the geologic and seismic characteristics of the site as required by 10 CFR 100.17(a)(1)(vi), 10 CFR 100.23(c), and 10 CFR 100.23(d).
  - Applicant provided an adequate basis to conclude that no capable tectonic faults exist in the plant site area that have the potential to generate surface or near-surface fault displacement.

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Section 2.5: Summary

- **2.5.2 Vibratory Ground Motion**
  - Applicant provided thorough characterization of seismic sources surrounding the site.
  - Applicant's GMRS adequately represents the regional and local seismic hazard.
  - The proposed Vogtle ESP site is suitable with respect to the vibratory ground motion criteria for new nuclear power plants and meets the applicable requirements of 10 CFR 100.23.

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Section 2.5: Summary

- **2.5.3 Surface Faulting**
  - Applicant presented adequate basis to conclude that there is no evidence to indicate that surface or near-surface faulting or nontectonic deformation presents a hazard for the site area.

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Section 2.5: Summary

- **2.5.4 Stability of Subsurface Materials and Foundations**
  - Applicant conducted sufficient subsurface investigations and field and laboratory testing and associated analyses to characterize the site
    - Adequately determined the engineering properties of subsurface soils
    - Provided sufficient information to characterize the shear-wave velocity profiles
    - Demonstrated static and dynamic stability of the site and structural backfill materials
    - Determined that subsurface soils and backfill materials are not subject to liquefaction

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Vogtle ESP Mandatory Hearing

March 23-25, 2009

NRC Staff Presentation Topic #7

Seismic Evaluation:

Geotechnical and Structural Engineering Review of Vogtle Limited Work Authorization

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Presenters:

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Geoscience and Geotechnical Engineering Branch 1 (RGS1)

Bret Tegeler

John Ma

Structural Engineering Branch 1 (SEB1)

Carl Costantino (BNL)

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Purpose

- Present the structural engineering review of the Vogtle Limited Work Authorization (LWA) application
- Scope of LWA
- Geotechnical Review
- Structural Review

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Scope of LWA

- Scope of LWA involves soil foundation work, placement of a concrete mudmat, a waterproofing membrane, a mechanically stabilized earth (MSE) retaining wall, and temporary drains.

- Supporting Media
  - Nuclear Island will be founded on approximately 50 ft of engineered fill.
  - 70-80 ft layer of hard, slightly sandy clay (Blue Bluff Marl, BBM).
  - Approximately 900 ft of dense sands beneath BBM.
  - Rock with Vs> 9,200 fps at approximately 1049 ft depth.
  - Water table at least 15-ft below bottom of basemat.

- Referenced AP1000 DCD, Revision 15.

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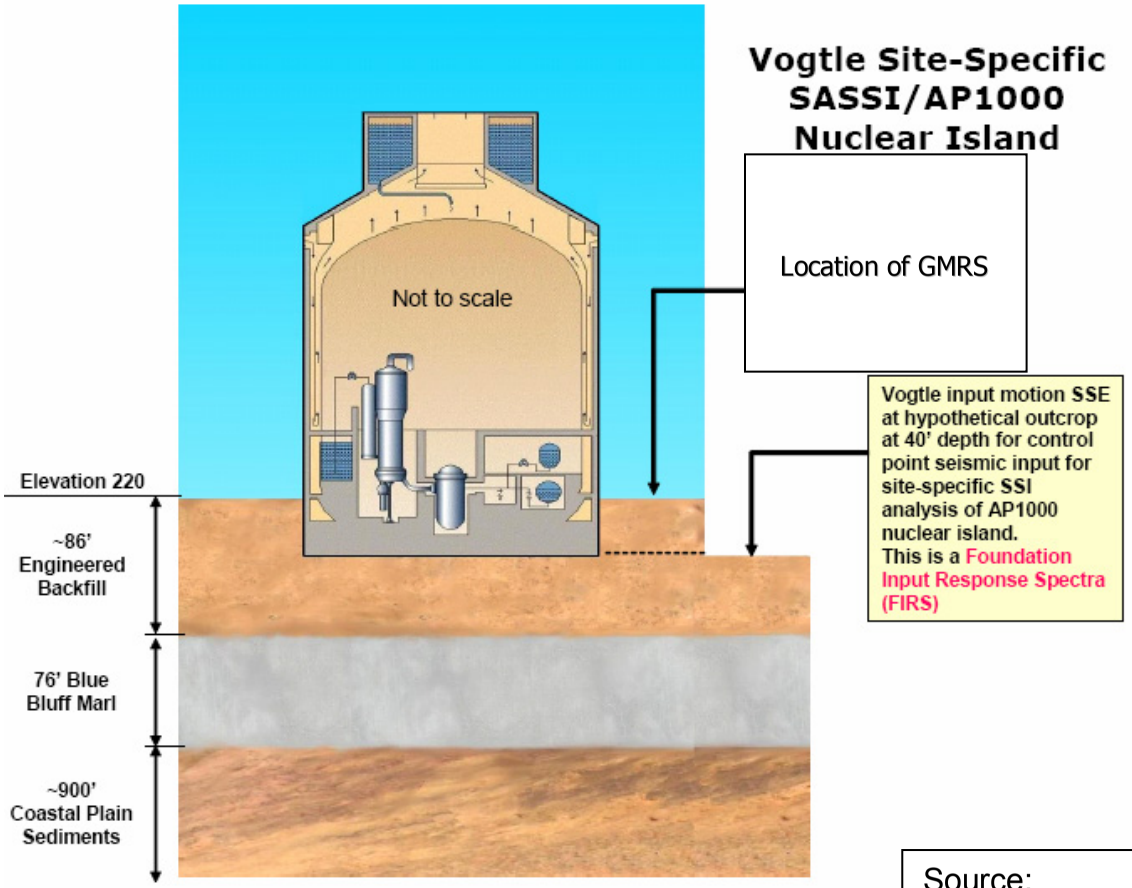
Nuclear Island Supporting Media



Source:
SSAR Appendix 2.5E, Figure 5.0-2

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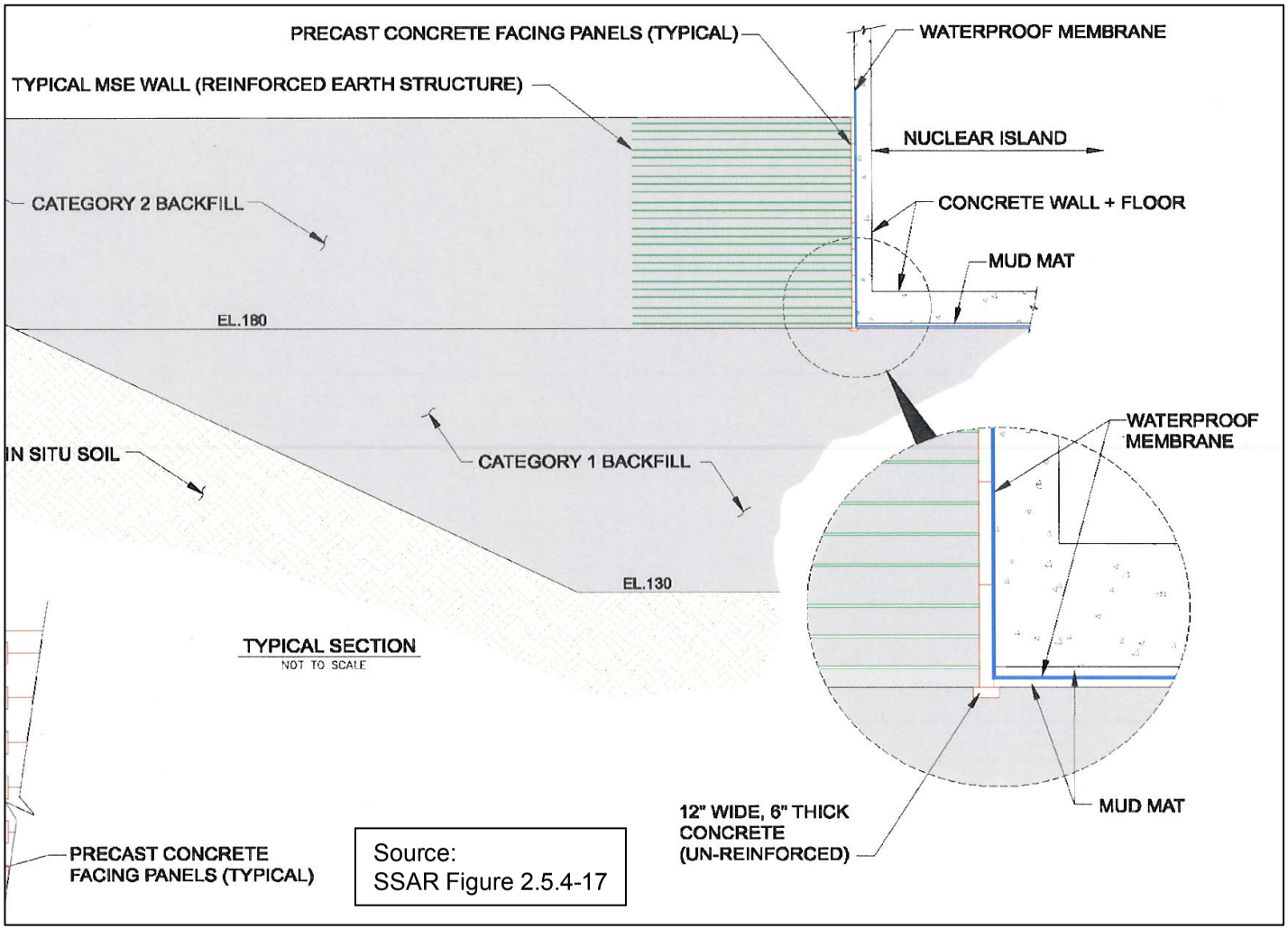
Scope of LWA (Cont'd)



Source:
SSAR Figure 2.5.4-17

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Geotechnical Review

- The applicant conducted more explorations and testing on the subsurface materials, in support of the LWA request.

- Additional geotechnical data was submitted by the applicant as part of the LWA request.
  - Additional data submitted in response to Requests for Additional Information (RAIs).
  - Resolved Open Items and removed need for COL Action Items for the ESP.

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Geotechnical Review (Cont'd)

- Additional laboratory tests on soil samples to determine soil dynamic properties
  - Determine the site-specific soil columns used in the soil structure interaction (SSI) analyses
  - These dynamic properties are needed to determine the site-specific Ground Motion Response Spectra (GMRS)
    - GMRS is equivalent to Safe Shutdown Earthquake (SSE)
    - GMRS is compared to DCD design spectrum at COL stage

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LWA Key Issues

- Adequacy of site investigations
  - Additional subsurface exploration and testing to adequately characterize subsurface conditions and material properties
- Backfill requirements and engineering criteria
  - Additional laboratory and field testing to demonstrate that backfill materials will perform as required to meet DCD requirements for uniformity, shear wave velocity, and static and dynamic bearing capacity

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LWA Key Issues – Adequacy of Site Investigations

- 174 borings at the site
  - 42 penetrating the Blue Bluff Marl
- Adequate to characterize site and relationship between ESP and Units 1 and 2 borings
- Transportation procedures for boring core samples transported long distances for dynamic testing

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LWA Key Issues - Backfill Requirements and Engineering Criteria

- Seismic Category 1 and 2 Backfill
  - Seismic Category 1 – beneath all Category 1 structures
  - Seismic Category 2 – beneath all Category 2 structures
  - All backfill will be compacted to 95% maximum dry density
  - Flowable backfill used in a limited extent away from the safety-related structures

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LWA Key Issues - Backfill Requirements and Engineering Criteria (continued)

- Physical Characteristics
  - Percent Fines – no more than 25%
  - Compaction Criteria – design requirement to be confirmed through ITAAC

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LWA Key Issues – Backfill Requirements and Engineering Criteria (Backfill ITAAC)

Design Requirement	Inspections and Tests	Acceptance Criteria
Backfill material under Seismic Category 1 structures is installed to meet a minimum of 95 percent modified Proctor compaction.	Required testing will be performed during placement of the backfill materials.	A report exists that documents that the backfill material under Seismic Category 1 structures meets the minimum 95 percent modified Proctor compaction.
Backfill shear wave velocity is greater than or equal to 1,000 fps at the depth of the nuclear island foundation and below.	Field shear wave velocity measurements will be performed when backfill placement is at the elevation of the bottom of the Nuclear Island foundation and at finish grade.	A report exists and documents that the as-built backfill shear wave velocity at the nuclear island foundation depth and below is greater than or equal to 1,000 fps.

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LWA Key Issues - Backfill Requirements and Engineering Criteria (continued)

- Shear Wave Velocity
  - Determined as part of Test Pad Program
- Test Pad Program
  - Phase 1
    - Establish site-specific design properties
    - Establish that backfill will satisfy AP1000 DCD
  - Phase 2
    - Develop construction specifications and finalize placement procedures & equipment

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LWA Geotechnical Conclusions

- Applicant adequately characterized the engineering properties and conditions of subsurface materials.
- Applicant developed adequate backfill specifications.
  - ITAAC will confirm adequate placement and compaction of backfill materials.

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Structural Engineering Review

- LWA involves placement of a concrete mudmat with an embedded waterproofing membrane.
  - MSE constructed with pre-cast concrete panels with tie-backs.
    - Approximately 40 ft in height.
  - Mudmat footprint is approximately 160ft x 260ft.
  - Mudmat is 12-inches thick (two 6-inch layers) and has a compressive strength of approximately 2,500 psi.
  - Elastomeric spray-on waterproofing membrane (approximately 0.080 to 0.120 inches thick) placed between two mudmat layers.
  - Membrane also applied to the MSE wall.
- Waterproofing membrane ITAAC
  - Testing to confirm that membrane/mudmat interface has a coefficient of friction of 0.7.
- Referenced AP1000 DCD, Revision 15.

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Scope of Review

- LWA involves foundation construction.
  - Staff review limited to three SRP sections (3.7.1, 3.7.2, 3.8.5).
- Basis for approval of LWA will not be impacted unless there is a major change in the footprint of the NI basemat.
- Moderate changes in structural design will not invalidate basis for LWA approval.

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Scope of Review (Cont'd)

SRP 3.7.1-Seismic Design Parameters

- Vibratory Ground Motion
- Critical Damping
- Supporting Media (pertaining to SSI modeling)

SRP 3.7.2- Seismic Systems Analysis

- Seismic Model Description
- Soil-Structure-Interaction Analysis

SRP 3.8.5-Foundations

- Foundation Stability
  - Sliding
  - Overturning

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SER Section 3.7.1 Seismic Design Parameters

Summary of Application

- Vogtle site GMRS exceed AP1000 Certified Seismic Design Response Spectra (CSDRS) in high and low frequency ranges (site-specific soil-structure-interaction analysis is required).
  - Required more in-depth staff review.
- Foundation Input Response Spectra (FIRS) defined at foundation elevation.

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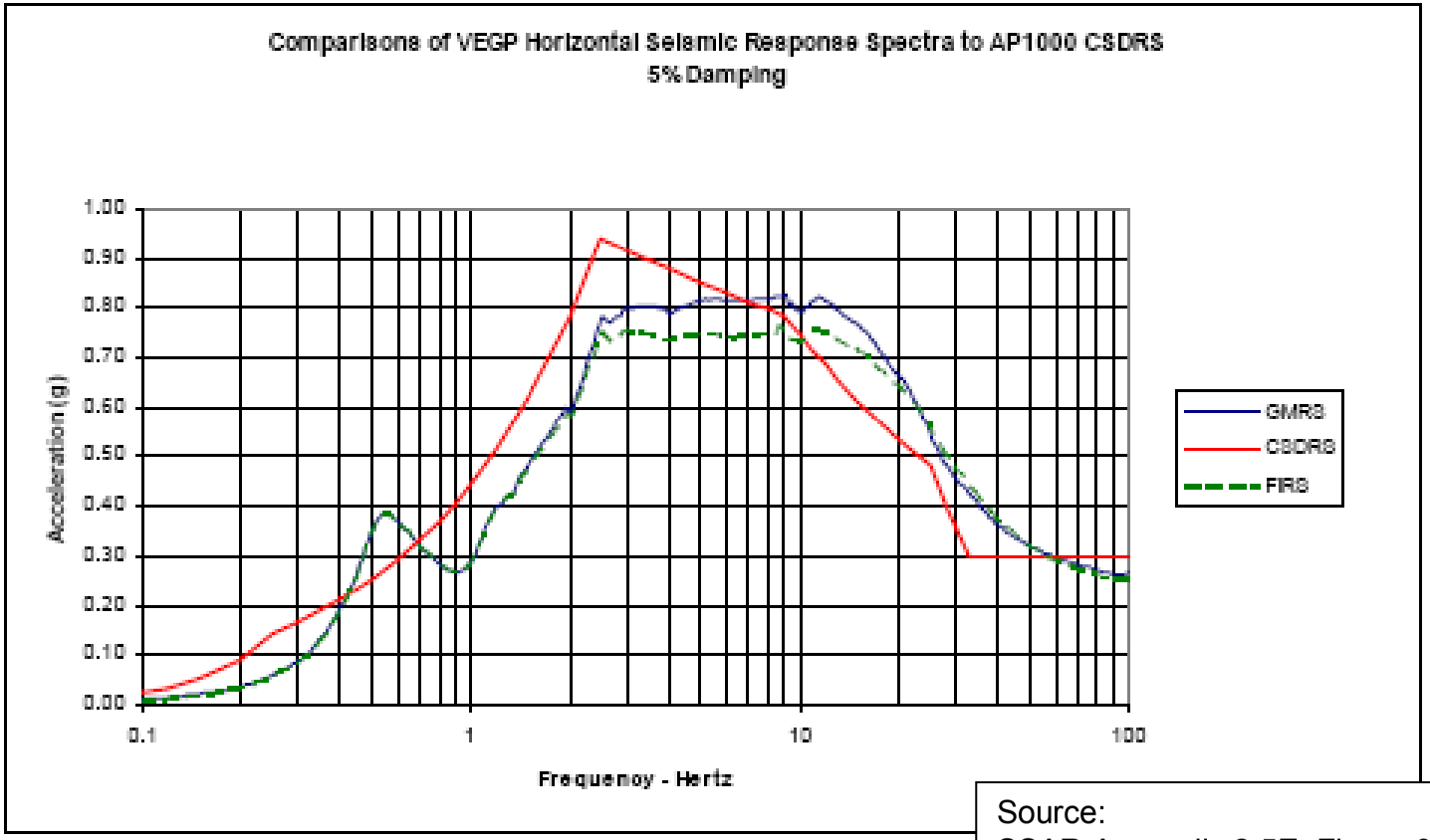
SER Section 3.7.1
Seismic Design Parameters

Comparison of Vogtle Horizontal GMRS and FIRS with AP1000 CSDRS



Source:
SSAR Appendix 2.5E, Figure 3-4

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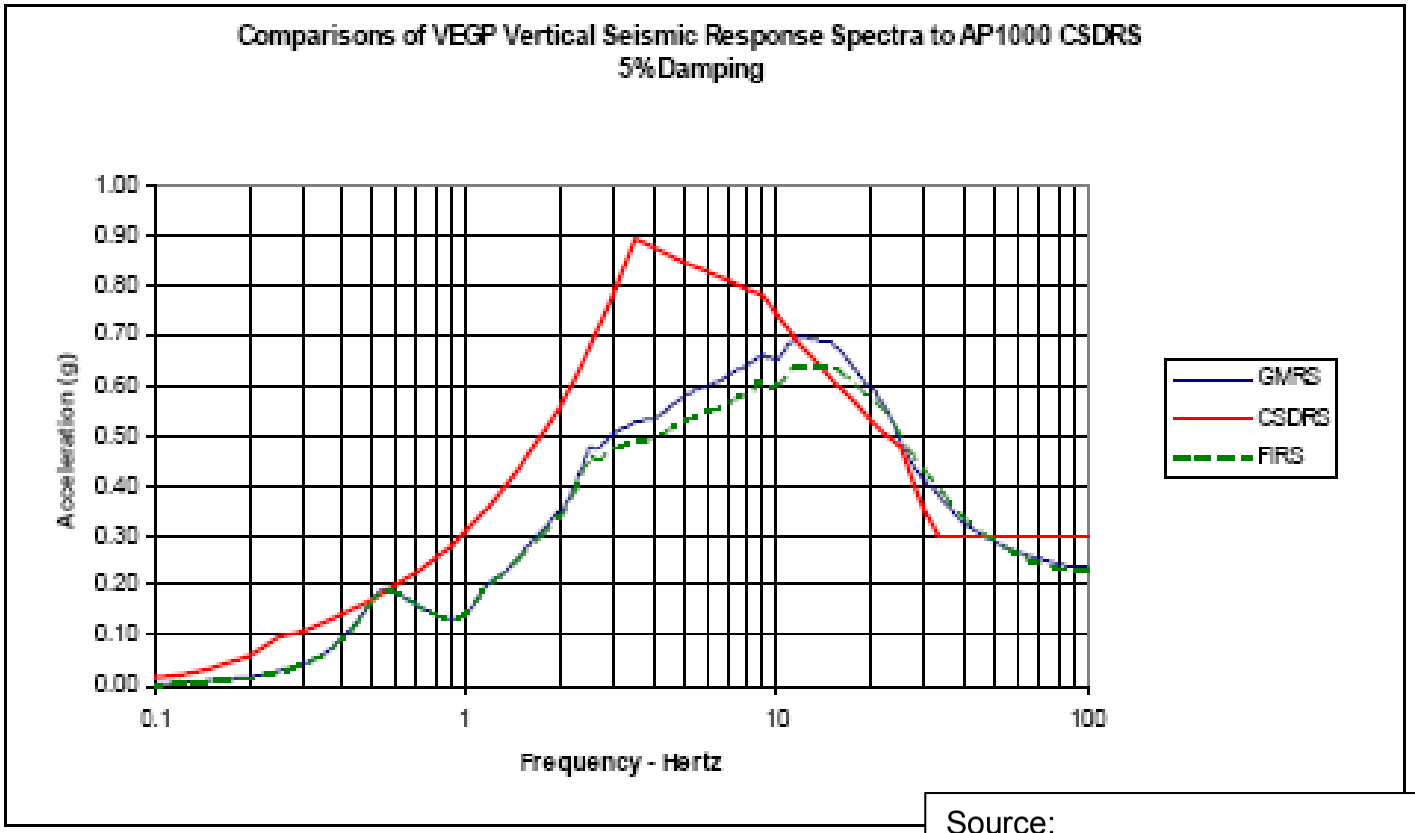
SER Section 3.7.1 Seismic Design Parameters

Comparison of Vogtle Vertical GMRS and FIRS with AP1000 CSDRS



Source:
SSAR Appendix 2.5E, Figure 3-4

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SER Section 3.7.1 Seismic Design Parameters

Technical Evaluation/Findings

Vibratory Ground Motion

- Alternative method was used for developing the FIRS. Review indicates that the method results in a conservative estimate of horizontal seismic demand.

- The FIRS defined as an outcrop motion in the free field satisfied the minimum peak ground acceleration (PGA) value of 0.10g (10 CFR Part 50, Appendix S).

Critical Damping

- The critical structural damping values used in SSI analysis were consistent with damping values provided in RG 1.61.

Supporting Media

- SSI modeling assumptions properly account for site characteristics such as depth of soil over bedrock, soil properties, soil layering characteristics and groundwater elevation.

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SER Section 3.7.2 Seismic Systems Analysis

Summary of Application

- Developed 2D site-specific SSI models for evaluating NI sliding and overturning stability.
- Seismic Model Description
  - 2D SASSI stick models for NI and adjacent buildings.
  - Models accounted for 40 ft embedment of NI foundation below soil surface.
- Soil-Structure Interaction Analysis
  - Three orthogonal directions assessed (2 horizontal, vertical).
  - Used lower bound, best-estimate, and upper bound soil profiles to address uncertainty in SSI calculations.
  - Compared in-structure responses at 6 key locations in the AP1000 NI.
  - Computed maximum seismic shear forces for use in NI stability and dynamic bearing pressure evaluations.

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SER Section 3.7.2 Seismic Systems Analysis

Technical Evaluation/Findings

Seismic Model

- The use of 2D SASSI models is acceptable for the evaluation of sliding stability and bearing pressure demands.

Soil-Structure-Interaction Analysis

- Staff compared the analysis results (e.g., zero period acceleration values near the NI center-of-gravity) with the AP1000 DCD soft soil case and found them to be similar.

- Maximum seismic base shear forces are acceptable based on staff independent calculations.

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SER Section 3.8.5 Foundations

Summary of Application

- Waterproofing membrane ITAAC

Waterproof Membrane Inspections, Tests, Analyses, and Acceptance Criteria (SSAR Table 3.8.5.1-1)		
Design Commitment	**Inspections, Tests, Analyses**	**Acceptance Criteria**
The friction coefficient to resist sliding is 0.7 or higher	Testing will be performed to confirm that the mudmat-waterproofing-mudmat interface beneath the Nuclear Island basemat has a minimum coefficient of friction to resist sliding of 0.7.	A report exists and documents that the as-built waterproof system (mudmat-waterproofing-mudmat interface) has a minimum coefficient of friction of 0.7 as demonstrated through material qualification testing.

- Test data of waterproofing membrane indicate a coefficient of friction of 0.7 between the membrane and the concrete mudmat.
- Test data indicate a coefficient of friction of 0.45 for soil immediately below mudmat.
- Soil test data indicate a bearing capacity of 42 ksf.

SER Section 3.8.5 Foundations

Technical Evaluation/Findings

NI Structure Stability Analysis

- Staff reviewed the maximum horizontal seismic forces and maximum friction forces below the basemat.

Maximum NI Seismic Forces

Reaction	Vogtle Lower Bound	Vogtle Best Estimate	Vogtle Upper Bound
Seismic Shear NS	78.3 E3 kips	82.5 E3 kips	89.0 E3 kips
Seismic Shear EW	88.9 E3 kips	89.8 E3 kips	95.8 E3 kips
Friction Force	117.3 E3 kips	116.7 E3 kips	116.4 E3 kips

- The NI structure will not slide during the SSE, because the frictional force is greater than the inertial force.

SER Section 3.8.5 Foundations

Technical Evaluation/Findings (Continued)

Bearing Capacity

- The maximum dynamic bearing pressure on soils for the NI, radwaste, annex, and turbine buildings are 17.95 ksf, 1.68 ksf, 7.20 ksf, and 2.54 ksf, respectively, during the SSE.

- The minimum factor of safety with respect to a failure of the dynamic soil bearing capacity during the SSE is 2.34 (42 ksf divided by 17.95).

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Summary Findings

SRP Section 3.7.1 Seismic Design Parameters

- The applicant adequately developed seismic design parameters and has met the applicable regulatory requirements.

SRP Section 3.7.2 Seismic Systems Analysis

- The applicant adequately performed site-specific 2D SSI analysis for the purpose of determining the maximum seismic demands and has met the applicable regulatory requirements.
- Staff's evaluation of in-structure response will be done as part of the SCOL review.

SRP Section 3.8.5 Foundations

- The applicant has demonstrated that the mudmat and the waterproofing membrane are adequate and that the NI foundation is stable during an SSE.
- The applicant's proposed mudmat and waterproofing membrane design meet the applicable regulatory requirements.

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Vogtle ESP Mandatory Hearing

March 23-25, 2009

NRC Staff Presentation Topic #7

Seismic Evaluation:

Environmental Review

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Presenter:

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NRO/DSER/RAP1

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Seismic Evaluation: Outside Scope of Environmental Review

- NEPA reviews focus on the impact of the proposed action on the environment.

- By contrast, seismic analysis is a safety review focused on the potential impact of the environment (seismic characteristics of the site) on the proposed facility.

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Seismic Evaluation: Outside Scope of Environmental Review

- NUREG-1555, Environmental Standard Review Plan (ESRP), does not contain guidance for the environmental review of seismic information.

- Instead, the ESRP (Section 2.6) guides the environmental staff to refer seismological analyses and evaluations to the SSER or SER.

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