ENCLOSURE 1

M220047

Final ACRS Subcommittee Presentation Slides for NEDO-33914, BWRX-300 Advanced Civil Construction and Design Approach Licensing Topical Report

Non-Proprietary Information

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ACRS Subcommittee Presentation

GE Hitachi (GEH)
Licensing Topical Report (LTR) NEDO-33914
BWRX-300 Advanced Civil Construction and Design Approach

March 18, 2022

Agenda

- Licensing Topical Report Purpose and Scope
- Regulatory Basis
- Investigations, Testing, Inspection and Monitoring Programs
- Foundation Interface Analysis
- Design Analyses
- Design Approach for II/I Interaction
- Generic Design Approach

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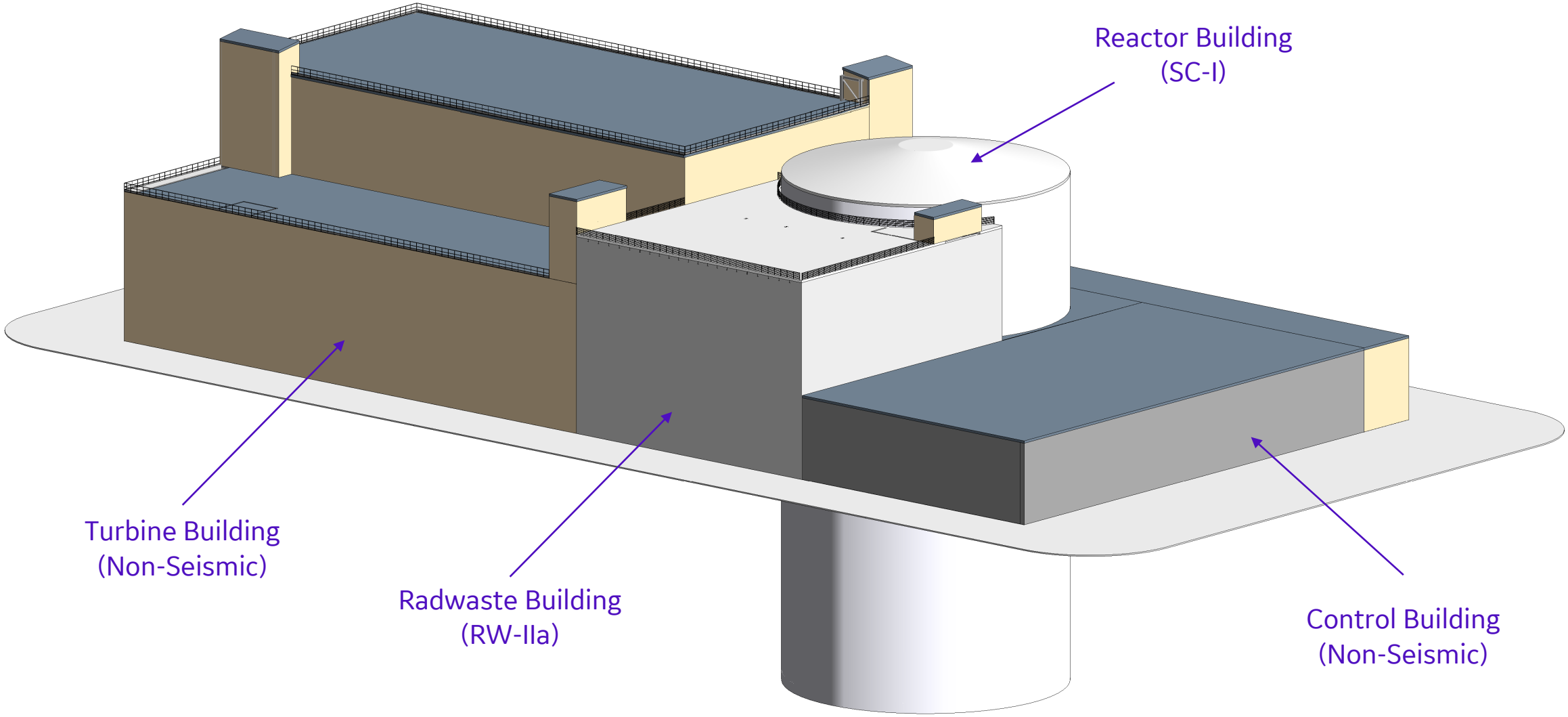
BWRX-300 Buildings and Seismic Classification

BWRX-300 Building Seismic Categories



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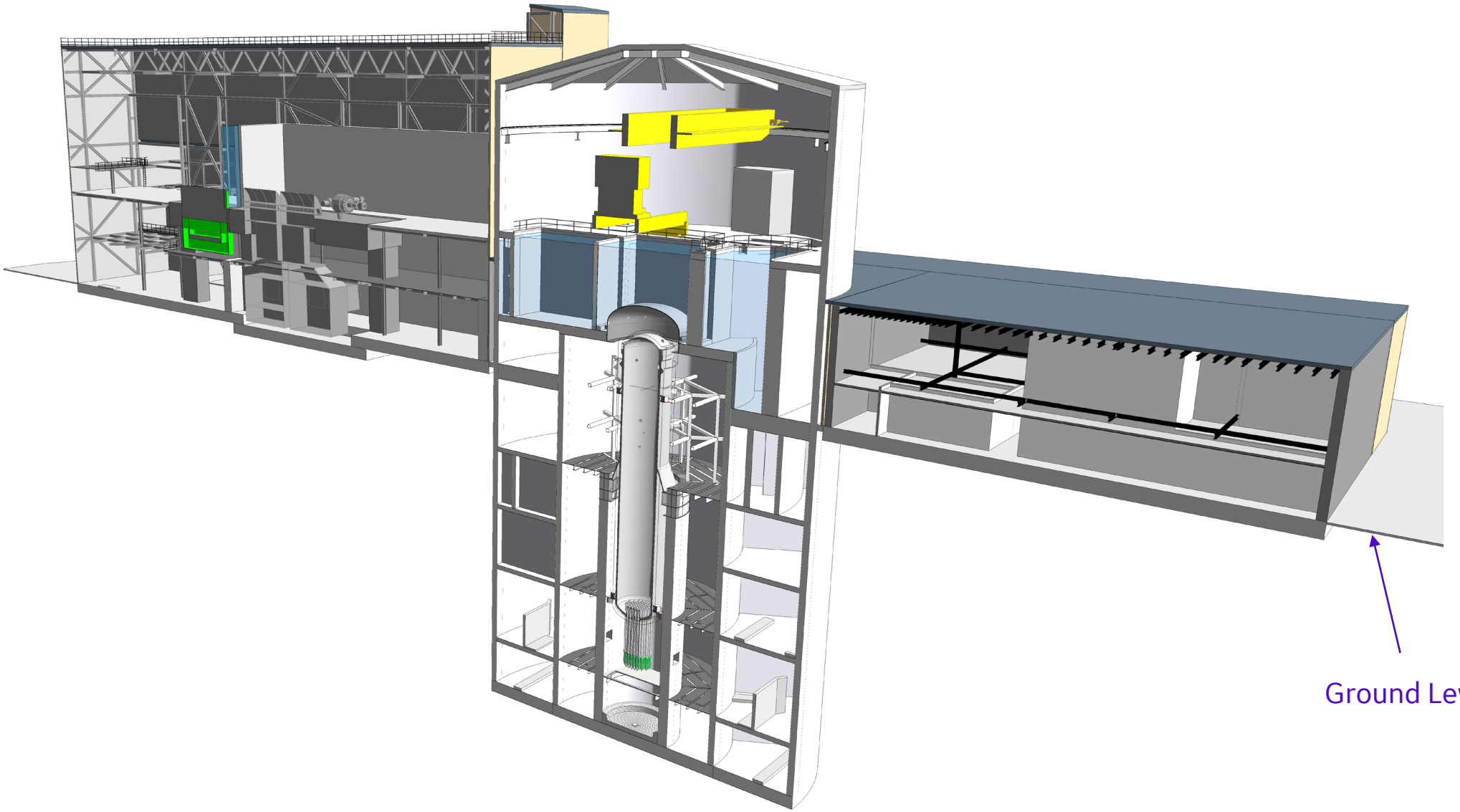
BWRX-300 3D Section View



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Licensing Topical Report Purpose and Scope

Licensing Topical Report Purpose

GEH is seeking NRC approval for the application of an alternative approach to the construction, analyses, and design of the BWRX-300 below-grade Reactor Building.

The purpose of the LTR was to present design, analysis, and monitoring guidelines and requirements to support the request for NRC approval of the innovative and comprehensive construction approach for the construction of the below grade BWRX-300 small modular reactor (SMR) Reactor Building (RB) vertical right cylinder shaft (LTR Sections 1.3 and 1.4).

The following criteria, methodologies, recommendations, and approaches are addressed:

- Requirements and recommendation for site investigation and subsurface materials lab testing programs (LTR Section 3.1)
- Inspection and monitoring programs (LTR Sections 3.2 and 3.3)
- Compression strength testing program for safety-related concrete (LTR Section 3.2.2.1)
- Field monitoring program (LTR Section 3.4)
- Methods and approaches for non-linear Foundation Interface Analyses (FIA) (LTR Section 4.0)
- Requirements and recommendations for implementing a one step approach for static and seismic Soil Structure Interaction (SSI) analyses (LTR Section 5.1)

Licensing Topical Report Purpose

- Deterministic and probabilistic evaluation approaches to ensure the one step approach provides conservative design demands on the deeply embedded RB structure (LTR Sections 5.1.3 and 5.1.4)
- Approaches for developing equivalent linear static and dynamic subgrade properties used as inputs to the one step design analysis model (LTR Sections 5.2.1 and 5.2.4)
- Requirements and methodologies for developing Safe Shutdown Earthquake (SSE) design ground spectra to define the design ground motion along the depth of the RB embedment (LTR Section 5.2.2)
- Additional requirements for generating acceleration time histories for use as input to the seismic SSI analyses (LTR Section 5.2.3)
- Seismic SSI analysis approach that provides demands for seismic design and qualification of structures, systems and components (SSCs) for all frequencies of interest and adequately captures the effects of structure-soil-structure interaction (SSSI) for the deeply embedded RB with adjacent structures and foundations (LTR Sections 5.3, 5.3.2, and 5.3.7)
- Different approaches for demonstrating consistency between the results from the deterministic SSI analyses of the RB structure with the results from the probabilistic site response analyses (SRA) (LTR Section 5.3.4)

Licensing Topical Report Purpose

- Approaches for sensitivity evaluations from the effects of concrete cracking, soil structure interface conditions, soil separation and groundwater variations on the seismic response and design of the deeply embedded RB structure. (LTR Sections 5.3.5, 5.3.8, 5.3.9 and 5.3.10)
- Comprehensive approach for evaluating the effects of non vertically propagating seismic waves on the design ground motion and seismic response of the deeply embedded RB structure (LTR Section 5.3.3)
- Different approaches for considering Equipment Structure Interaction (ESI) for developing in structure seismic response demands for equipment design and qualification (LTR Section 5.3.6)
- Recommendations for performing non-linear seismic SSI analyses for sensitivity evaluations (LTR Section 5.3.11)
- Graded approach for the design of structures adjacent to the deeply embedded RB that includes Seismic Category II/I interactions (LTR Section 6.0)
- Methodology for developing generic seismic and geotechnical design parameters (LTR Section 7.0)

Licensing Topical Report Scope

This request was supported by the following information in the LTR:

- Regulatory basis specific for the innovative approaches implemented for analysis, design and construction (LTR Section 2.0)
- Guidelines and requirements for characterizing subsurface conditions, including geotechnical site investigations and laboratory testing programs, as well as the inspection and monitoring programs performed during excavation, construction, and operation (LTR Section 3.0)
- Requirements and guidelines for performing FIA to ensure the stability of both structure and the in-situ soil and/or rock during and after construction (LTR Section 4.0)
- Design requirements, acceptance criteria and guidelines for the analysis and design of the deeply embedded RB, including the development of site specific geotechnical and seismic design parameters (LTR Section 5.0)
- An approach for addressing Seismic Category (SC) II/I interaction between the SC I RB and surrounding structures and foundations (LTR Section 6.0)
- Generic seismic and geotechnical design parameters (LTR Section 7.0)

Regulatory Evaluation

Regulatory Basis – Defining Site Subsurface Conditions

The approach used for defining and evaluating site subsurface conditions complies with the following:

- 10 CFR 100 requires the consideration of site physical characteristics, including seismology and geology.
- 10 CFR 100.20(c)(1) and 10 CFR 100.23 establish requirements for conducting site investigations for nuclear power plant license applications.
- IAEA Safety Guide NS-G-6 provides guidance on the methods and procedures for analyses to support the assessment of the geotechnical aspects for the design of nuclear power plants.
- NUREG-0800 (SRP) 2.5.4 provides regulatory guidance for the investigation and reporting site specific geologic features and characteristics of ground materials, including static and dynamic engineering properties and groundwater conditions (LTR Sections 3.1, 3.2, 3.3, 3.4, 4.0)
- RG 1.132, “Site Investigations for Foundations of Nuclear Power Plants,” Revision 2 describes methods acceptable to the NRC staff for conducting field investigations to acquire the geological and engineering characteristics of the site and provides recommendations for developing site specific guidance for conducting subsurface investigations. (LTR Sections 3.1, 3.1.1)
- RG 1.138 describes laboratory investigations and testing practices for determining soil and rock properties and characteristics needed for engineering analysis and design of foundations and earthworks for nuclear power plants. (LTR Section 3.1)

Regulatory Basis – Site Design Parameters

The approach for defining and evaluating design parameters complies with the following:

- 10 CFR 100.23(d)(1) specifies the requirements for defining the safe shutdown earthquake (SSE) ground motion for the site and the need for addressing result uncertainties in the site investigation performed (LTR Section 2.1)
- NUREG-0800 (SRP) 3.7.1 provides regulatory guidance for the development of site design ground motion acceleration response spectra and time histories (LTR Section 5.2.3)
- RG 1.208, “A Performance Based Approach to Define the Site-Specific Earthquake Ground Motion,” Revision 0, specifies the performance-based approach Chapters 1 and 2 of ASCE/SEI 43 05 standard as an acceptable approach for defining the SSE Ground Motion Response Spectra (GMRS) that satisfies the requirements of 10 CFR 100.23.
- Interim Staff Guidance (ISG) DC/COL-ISG-017 “Interim Staff Guidance on Ensuring Hazard Consistent Seismic Input for Site Response and Soil Structure Interaction Analyses”, specifies the requirements for ensuring the inputs used for the deterministic SSI analysis of embedded structures are consistent with the results of probabilistic SRA used to develop Foundation Input Response Spectra (FIRS) and Performance Based Surface Response Spectra (PBSRS) (LTR Section 5.3.4)

Regulatory Basis – Seismic Analysis

The seismic analysis complies with the following:

- 10 CFR 50 Appendix S, Earthquake Engineering Criteria for Nuclear Power Plants
- SSI analyses:
  - SRP 3.7.2
  - DC/COL-ISG-01
  - ASCE/SEI 4-16, Section 5
- Finite Element (FE) Models:
  - SRPs 3.7.1 and 3.7.2
  - RG 1.61, “Damping Values for Seismic Design of Nuclear Power Plants,” Revision 1
  - ASCE/SEI 4-16 Section 3 (LTR Section 5.1) and ASCE/SEI 43-05
- Effects of structure soil structure interaction (SSSI) of the RB with surrounding foundations:
  - ASCE/SEI 4-16 Section 5.1.5 (LTR Section 5.3.7)
  - SRP 3.7.2 Subsection II.3.B (LTR Section 5.3.6)
- Effects of non vertically propagating seismic waves, soil separation, concrete cracking and soil secondary non-linearity on the seismic response and design of the RB:
  - ASCE/SEI 4-16, Section 5.1 (LTR Sections 5.3.3, 5.3.5, 5.3.8, 5.3.9, 5.3.10 and 5.3.11)

Regulatory Basis – II/I Interactions

The approach used for evaluating the seismic category two over one interactions complies with the following:

- SRP 3.7.2 (LTR Section 6.0)
- SRP 3.3.2 (LTR Section 6.0)
- ASCE/SEI 43-05 (LTR Sections 6.2 and 6.3)

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Regulatory Basis – Testing, Inspection and Monitoring

The approach used for performing the testing, inspection, and monitoring complies with the following:

- 10 CFR 50 Appendix A GDC 1 inspection and testing requirements met by
  - RG 1.142, “Safety-Related Concrete Structures for Nuclear Power Plants (Other than Reactor Vessels and Containments)”
  - RG 1.136, “Design Limits, Loading Combinations, Materials, Construction, and Testing of Concrete Containments,”
  - NRC Inspection Manuals 88131 (geotechnical and foundation), 88132 (structural concrete), and 55100 (structural welding)
- 10 CFR 50.65 requirements met by (LTR Section 3.3):
  - RG 1.160, “Monitoring the Effectiveness of Maintenance at Nuclear Power Plants,”
  - NUMARC 93-01 “Industry Guideline for Monitoring the Effectiveness of Maintenance at Nuclear Power Plants”
- RG 1.132 and RG 1.138 (LTR Sections 3.1, 3.1.3, and 3.2)
- NUREG/CR-5738 (LTR Section 3.1.3)
- RG 1.142 (LTR Section 3.2.2)

Regulatory Basis – Summary

- The design and analyses described in the LTR comply with all applicable regulatory requirements and guidance as written.
- The implemented innovative approaches meet the intent of the current regulatory guidance for large light water reactors and address the specifics related to the seismic and structural design of deeply embedded SMRs (LTR Section 2.0).
- GEH is not requesting NRC approval for exemptions from any regulatory requirements or any exceptions to any regulatory guidance.
- The methodology in this LTR ensures safe operation of the BWRX-300 for the life of the plant.

Technical Evaluation

Investigations, Testing, Inspection and Monitoring Programs

- Innovative property characterization and monitoring approaches driven by RB structure being deeply embedded
- Investigation, testing, inspection, and monitoring programs, in conjunction with the results of a set of FIA (LTR Section 4.3.4), ensure the safe siting of the BWRX-300 plant:
  - Site investigation program (LTR Section 3.1.1)
  - Subsurface material laboratory testing program (LTR Section 3.1.2)
  - Construction and in-service monitoring programs (LTR Sections 3.2, 3.3, and 3.4)
    - Excavation and foundation inspection and testing programs (LTR Section 3.2.1)
    - Construction inspection and testing program for structural concrete (LTR Section 3.2.2)
    - Compressive strength testing program of SR concrete (LTR Section 3.2.2.1)
    - Structures Monitoring and Aging Management Program (SMAMP) in-service condition monitoring (LTR Sections 3.3.1 and 3.3.2)
    - Field instrumentation plan (LTR Section 3.4)

Foundation Interface Analysis

- To ensure structures and supporting media, soil, and/or rock meet stability requirements of SRP 2.5.4.
- Results of FIA used to evaluate construction plans, including possible ground improvements, excavation support and foundation interface design. Also used for verification of the RB shaft design.
- Non-linear constitutive 3D FIA numerical model (LTR Sections 4.1 and 4.2)
- Analysis approach includes interface modeling, structural modeling, fluid soil interaction, and consideration of all plant life stages (LTR Section 4.3.1 – 4.3.4)

Foundation Interface Analysis

Innovative approach implemented for the BWRX-300 FIA beyond the current regulatory guidance of SRP 2.5.4

- General modeling and analysis requirements for stability evaluations (LTR Section 4.1)
- Guidelines for modeling the non-linear constitutive response of soil and rock including the approach for calibrating the FIA model based on data obtained from field instrumentation (LTR Sections 3.4, 4.2.1 and 4.2.2)
- Guidelines for modeling interfaces, including contacts between structures and the subgrade, as well as interfaces between bedding units and other discontinuities in the geological formation (LTR Section 4.3.1)
- FIA structural modeling requirements, including recommendations for modeling SMR structures and soil stabilizations elements, such as rock anchors, soldier piles, and stabilization walls and liners (LTR Section 4.3.2)

…and beyond the current regulatory guidance of SRP 3.8.5

- FIA modeling approach for fluid soil interaction and FIA model calibration using measurements of groundwater elevations and hydrogeological investigations (LTR Sections 3.0 and 4.3.3)
- FIA approaches for the different BWRX-300 life stages, including guidelines for using the measurements from field instrumentation for FIA model calibration and benchmarking FIA results (LTR Sections 3.4 and 4.3.4).

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Design Analysis

- Innovative static and seismic SSI analysis approaches for designing the deeply embedded RB structure (LTR Sections 5.1 and 5.3)
- Requirements, methodologies, and recommendations for developing site specific geotechnical and seismic design parameters are based on the results of site investigations and laboratory testing programs (LTR Sections 3.1 and 5.2)
- Requirements and recommendations ensure the seismic SSI analyses use input motion that is adequate throughout the depth of the RB embedment (LTR Sections 5.2.2 and 5.3.4)
- A comprehensive recommended approach for evaluating the effects of non-vertically propagating seismic waves on the design ground motion and seismic response of the deeply embedded RB structure (LTR Section 5.3.3)
- Recommends approaches for developing in-structure seismic response demands for equipment design and qualification, considering ESI (LTR Section 5.3.6)
- Introduces additional requirements for generating multiple acceleration time histories with refined time steps which ensures the mitigation of uncertainty in the computed structural responses (LTR Section 5.2.3)

Design Approach for II/I Interaction

- Graded approach for the design and II/I interaction evaluations of the structures adjacent to the deeply embedded SC I RB structure.
- Applies to the Control Building (CB), Turbine Building (TB) and Radwaste Building (RwB)
- CB, TB and RwB structures near the SC I RB are designed in accordance with their seismic classification (LTR Section 6.1)
  - CB and TB: Non-seismic (LTR Section 6.1.1) - includes determination of seismic and wind design loads
  - RwB: RW-IIa (LTR Section 6.1.2) – includes the determination of seismic, wind, tornado wind and missile design loads
- Approach for seismic II/I interaction evaluations of CB, TB and RwB structures, including criteria and recommendations for calculations of seismic stress demands and displacements (LTR Section 6.2)
- Approach for II/I interaction evaluations CB, TB and RwB structures for extreme wind loads, including criteria and recommendations for consideration of wind loads displacements (LTR Section 6.3)

BWRX-300 Generic Design Approach

- Methodology for development of generic seismological and geotechnical site parameters for the conceptual design of the BWRX-300 (LTR Section 7.0)
- Overall approach ensures a cost-effective design applicable for a wide range of site conditions (LTR Section 7.1)
  - Use of Generic Design Response Spectra (GDRS) for the conceptual design seismic analyses of the RB (LTR Section 7.2)
  - Use of generic subgrade dynamic properties for the conceptual design seismic analyses of the RB (LTR Section 7.3)
  - Use of generic static properties for different subgrade materials considered for the conceptual design, which are correlated to the generic dynamic subgrade profiles to develop generic profiles of static subgrade properties for use as input for the conceptual design static SSI analyses (LTR Sections 7.4 and 7.5)
  - Use of friction coefficient values and groundwater table elevations for the generic conceptual design evaluations (LTR Sections 7.6 and 7.7)

Conclusion

In summary…

- The design and analyses described in the LTR comply with all applicable regulatory requirements and guidance as written.
- The innovative approaches meet the intent of current regulatory guidance for large light water reactors and address the specifics related to the seismic and structural design of deeply embedded SMRs.
- GEH is not requesting NRC approval for exemptions from any regulatory requirements or any exceptions to any regulatory guidance.
- The methodology in this LTR ensures safe operation of the BWRX-300 for the life of the plant.

Questions or Comments

Back-up Slides

BWRX-300 Monitoring, Analysis and Design Process

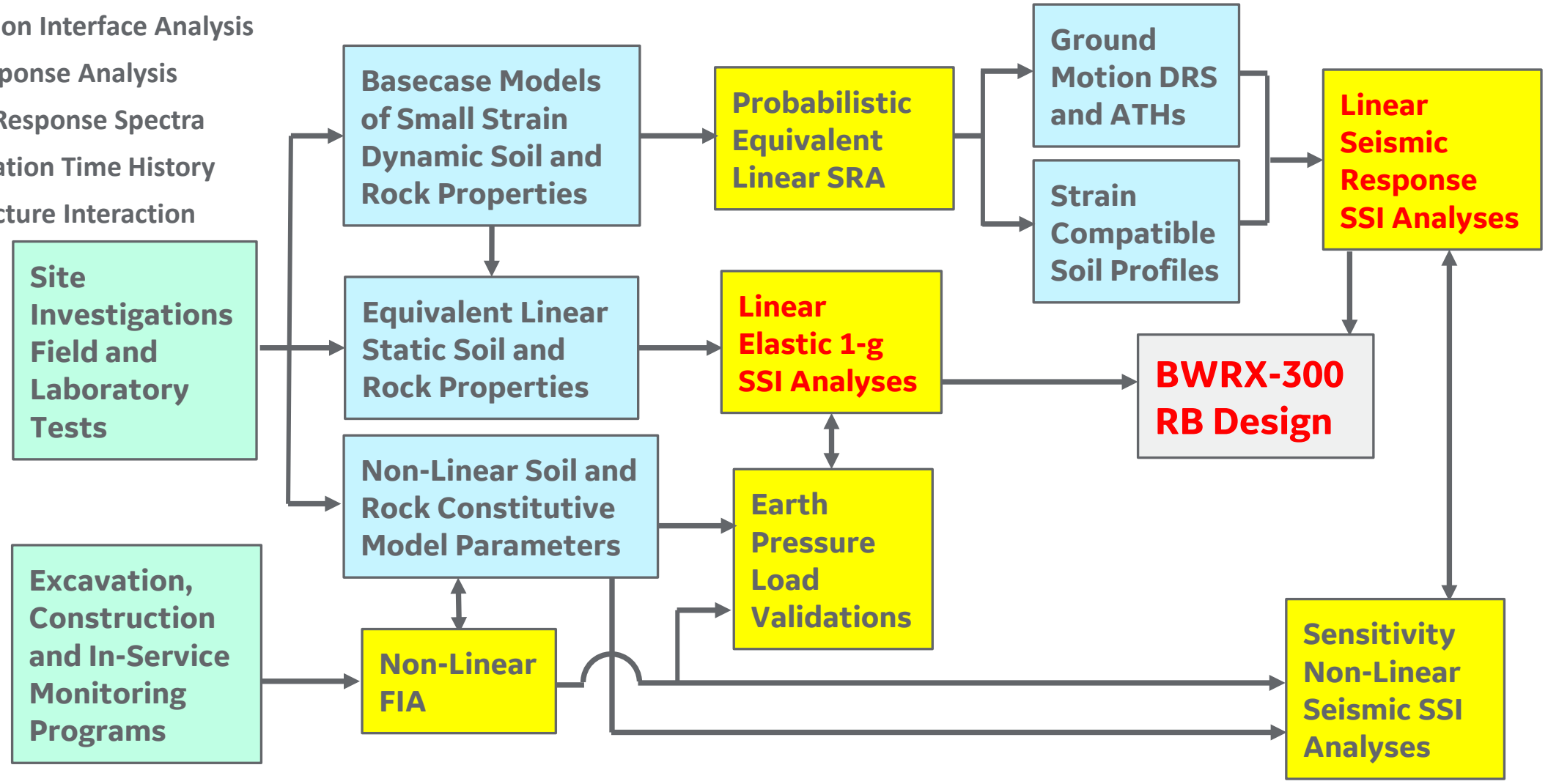
FIA – Foundation Interface Analysis

SRA – Site Response Analysis

DRS – Design Response Spectra

ATH – Acceleration Time History

SSI – Soil-Structure Interaction



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