From:	Shea, James
Sent:	Tuesday, August 10, 2021 9:36 AM
To:	GEH-BWRX-300RAIsPEm Resource
Subject:	FW GEH BWRX-300 LTR NEDO-33914, Revision 0, Advanced Civil Construction and Design Approach, Final Approved RAI Letter 17 eRAI9859
Attachments:	GEH BWRX-300 Request for Additional Information Letter No. 17 Advanced Civil Construction and Design Approach LTR eRAI 9859-Final.pdf

---

From: Shea, James
Sent: Tuesday, August 10, 2021 9:27 AM
To: 'Schichlein, Lisa (GE Power Portfolio)' <lisa.schichlein@ge.com>
Cc: 'Wadkins, George (GE Power Portfolio)' <George.Wadkins@ge.com>; Schiller, Alina <Alina.Schiller@nrc.gov>; Dudek, Michael <Michael.Dudek@nrc.gov>; Tabatabai, Omid <Omid.Tabatabai-Yazdi@nrc.gov>; Ghosh, Amitava <Amitava.Ghosh@nrc.gov>; Colaccino, Joseph <Joseph.Colaccino@nrc.gov>; GEH-BWRX-300DocsPEm Resource <GEH-BWRX-300DocsPEm.Resource@usnrc.onmicrosoft.com>
Subject: RE: GEH BWRX-300 LTR NEDO-33914, Revision 0, Advanced Civil Construction and Design Approach, Final Approved RAI Letter 17 eRAI9859

Lisa,

By letter dated January 20, 2021 (Agencywide Documents Access and Management System Accession No. ML21020A135), GE-Hitachi Nuclear Energy Americas, LLC (GEH) submitted Licensing Topical Report NEDO-33914, Revision 0, "BWRX-300 Advanced Civil Construction and Design Approach," to the U.S. Nuclear Regulatory Commission (NRC) staff for its BWRX-300 small modular reactor (SMR) Pre-Application key licensing topics review.

The NRC staff has reviewed the information provided in your application and identified areas where it needs additional information to support its review. The enclosed request for additional information (RAI)[1] is attached and was emailed to GEH in draft form on July 30, 2021 and a clarification call was held on August 4, 2021. The staff requests your response to the 9 RAIs based on the NRC Standard Review Plan Section 02.05.04 – "Stability of Subsurface Materials and Foundations," Attached (eRAI 9859), related to the BWRX-300 Civil Design and Construction, by September 13, 2021 (45 days after the draft copy of the RAI was provided to GEH).

During an email response to the staff on August 3, 2021 and again during the August 4, 2021 draft RAI discussion for clarity, and understanding you confirmed that the RAI contained no GEH proprietary information.

[1]Note: NRC RAI approvals are captured electronically in the electronic RAI system.

James Shea
Senior Project Manager
phone: (301)415-1388
james.shea@nrc.gov

U.S. Nuclear Regulatory Commission
Office of Nuclear Reactor Regulation
Mail Stop O-7D21
Washington, DC, 20555-0001

Hearing Identifier: GEH_BWRX300_RAIs_Public
Email Number: 19

Mail Envelope Properties (BLAPR09MB6899F1F7683290A3809C7EF394F79)

Subject: FW GEH BWRX-300 LTR NEDO-33914, Revision 0, Advanced Civil Construction and Design Approach, Final Approved RAI Letter 17 eRAI9859
Sent Date: 8/10/2021 9:35:40 AM
Received Date: 8/10/2021 9:35:44 AM
From: Shea, James

Created By: James.Shea@nrc.gov

Recipients:
"GEH-BWRX-300RAIsPEm Resource" <GEH-BWRX-300RAIsPEm.Resource@usnrc.onmicrosoft.com>
Tracking Status: None

Post Office: BLAPR09MB6899.namprd09.prod.outlook.com

Files	**Size**	**Date & Time**
MESSAGE	2325	8/10/2021 9:35:44 AM
GEH BWRX-300 Request for Additional Information Letter No. 17 Advanced Civil Construction and Design Approach LTR eRAI 9859-Final.pdf	208968	

Options
Priority: Normal
Return Notification: No
Reply Requested: No
Sensitivity: Normal
Expiration Date:

Request for Additional Information Letter No. 17 (eRAI 9859)
Issue Date: 07/30/2021
Application Title: GEH BWRX-300 Pre-Application Licensing Topical Reports (LTRs)
GEH BWRX-300 LTR NEDO-33914, Advanced Civil Construction and Design Approach
Operating Company: GE Hitachi Nuclear Energy (Wilmington, NC)
Docket No. 99900003

QUESTIONS:

Review Section: 02.05.04 - Stability of Subsurface Materials and Foundations

02.05.04-01

LTR Application Sections: TR NEDO-33914 Sections 3.1.1, 3.1.2, 3.1.3, and 4.3.1.2

Requirements:

General Design Criterion (GDC) 2 requires that structures, systems, and components (SSCs) important to safety shall be designed to withstand the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, floods, tsunami, and seiches without loss of capability to perform their safety function. GDC 2 also specifies that the design bases for these SSCs shall reflect the importance of the safety functions to be performed.

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.

Standard Review Plan (SRP) NUREG-0800, Section 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.

Issue:

Figure 4-2 shows the rheological model of an interface to be used in the Foundation Interface Analysis (FIA) with several parameters, such as, $k_n, \sigma_t, \tau_{max}, k_s, C, C_r, \varphi$. These parameters determine whether the interface slides (shear failure) or dilates (tensile failure) under the imposed loads including the load from the safe shutdown earthquake (SSE). The response of both soil and rock media surrounding the Reactor Building (RB) shaft to the imposed loads significantly affects the loads imposed on the RB walls. In addition, the loads imposed on the RB wall may not be symmetric around the shaft walls, especially in the rock medium.

Section 4.3.1.2, Fault or Joint Planes or Interfaces Between Bedding Units in a Geologic Formation, states that the nonlinearity and behavior of the joints are analyzed throughout the life stages of a reactor and the same interface model would be used in modeling the joints, bedding planes, and faults in the rock mass as part of the FIA model. The properties assigned to the interface elements along a rock discontinuity are to be obtained from laboratory or field testing (Sections 3.1.1 and 3.1.2). In addition, Section 4.3.1.2 states that the parameters representing slip of the interface model may be estimated based on properties of the weakest interface materials.

It is not clear from the discussions given in Site Investigation Program (Section 3.1.1) and Laboratory Testing Program (Section 3.1.2) whether a specific program would be developed to collect the necessary samples at the site and conduct specific tests at the laboratory to determine the parameters of the FIA model, as shown in Figure 4-2, or any other model to be used to represent the interfaces. It is also not clear how the weakest plane (interface) would be identified at a given site with its strength properties.

Request:

The staff requests GEH to identify the sample collection and testing programs that would be used to determine the parameters necessary to model the behavior of all interfaces (RB Wall/Soil, RB Wall/Rock, Soil/Rock, and Rock/Rock for joints/bedding planes), as appropriate. Modify the TR as necessary.

02.05.04-02

LTR Application Sections: TR NEDO-33914 Sections 3.1.1, 3.1.3, 3.2.1, 4.2.2, and 5.2.1.2

Requirements:

General Design Criterion (GDC) 2 requires that structures, systems, and components (SSCs) important to safety shall be designed to withstand the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, floods, tsunami, and seiches without loss of capability to perform their safety function. GDC 2 also specifies that the design bases for these SSCs shall reflect the importance of the safety functions to be performed.

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.

Standard Review Plan (SRP) NUREG-0800, Section 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.

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.

RG 1.138, "Laboratory Investigations of Soils and Rocks for Engineering Analysis and Design of Nuclear Power Plants," Revision 3, 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.

Issue:

It is not clear from the discussion given in Section 3.1.3, Characterization of Rock Mass Properties, whether the geological characterization of the rock unit(s) would be adequate to represent the rock mass in the FIA analyses. Discussions on fracture network characterization of the rock mass is mostly limited to collecting 1D information through boreholes. However, rock

fractures are 3D in nature and occur in sets (joint sets). Multiple sets of rock joints can be present in a rock mass creating individual rock blocks. Additionally, the rock mass may be a bedded deposit comprising of multiple rock beds. No discussion is given in Section 3.1.3 how the rock mass fracture network, which can significantly influence the rock pressure of the RB walls, would be characterized.

Additionally, Section 3.1.3, Characterization of Rock Mass Properties, discusses the use of rock mass classification systems (e.g., the Rock Mass Rating (RMR) system, the Geological Strength Index (GSI) system) to develop an estimate of the stress-strain behavior of rock (Section 4.2.2, Rock Constitutive Model) and rock mass stiffness properties (Section 5.2.1.2, Rock Mass Equivalent Linear Properties). The RMR system specifically requires information of the rock discontinuity spacing, orientation, and conditions. The GSI system requires information on at least J_r (joint roughness number) and J_a (joint alteration number) parameters to determine the specific GSI value of the rock mass. It is not clear how these parameters would be determined based on discussion given in Section 3.1.1, Site Investigation Program. Additionally, it is not clear what inspection and verification programs would be used during the Construction Phase (Section 3.2.1, Excavation and Foundation Inspections and Testing) to verify the assumptions made about the rock mass (e.g., rock fracture network, joint strength, etc.) before the excavation commences.

Request:

The staff requests GEH to identify the plan(s) and program(s) for characterizing the rock fracture network and determining the necessary parameters for the rock mass classification system used to determine the rock mass stress-strain behavior. The staff is also requesting GEH to identify the program(s) to verify the assumptions made of the rock and soil media surrounding the RB shaft as the excavation progresses. Modify the TR, as necessary.

02.05.04-03

LTR Application Sections: TR NEDO-33914 Sections 3.2, 3.3, 3.4, and 4.1

Requirements:

General Design Criterion (GDC) 2 requires that structures, systems, and components (SSCs) important to safety shall be designed to withstand the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, floods, tsunami, and seiches without loss of capability to perform their safety function. GDC 2 also specifies that the design bases for these SSCs shall reflect the importance of the safety functions to be performed.

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.

Standard Review Plan (SRP) NUREG-0800, Section 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.

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.

RG 1.138, "Laboratory Investigations of Soils and Rocks for Engineering Analysis and Design of Nuclear Power Plants," Revision 3, 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.

Issue:

Section 4.1, Foundation Interface Analysis Model, states that a numerical model of the interfaces would be developed that examines the response of the BWRX-300 and its surrounding media due to alterations of in-situ subgrade conditions. The responses would be monitored, both through the FIA model response and field measurements. The numerical FIA model will also be calibrated using the field measurements to predict future response of the structure. It is not clear from the discussions in Sections 3.2, 3.3, and 3.4 how the predicted interface behavior would be compared against physical observations from the monitoring programs. Sections 3.2, 3.3, and 3.4 do not discuss any plan or program to monitor the shear and normal displacements along an interface, as shown in Figure 4-1.

Request:

The staff requests GEH to identify the plan(s) or program(s) to monitor the response of the BWRX-300 and its surrounding media and comparing them with predictions using the FIA model for calibrating the numerical FIA model. Additionally, this process should verify that the structural and site responses are within the design bounds. Modify the TR as necessary.

02.05.04-04

LTR Application Section: TR NEDO-33914 Section 5.1.2

Requirements:

General Design Criterion (GDC) 2 requires that structures, systems, and components (SSCs) important to safety shall be designed to withstand the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, floods, tsunami, and seiches without loss of capability to perform their safety function. GDC 2 also specifies that the design bases for these SSCs shall reflect the importance of the safety functions to be performed.

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.

Standard Review Plan (SRP) NUREG-0800, Section 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.

Standard Review Plan (SRP) NUREG-0800, Section 3.7.1, provides regulatory guidance for the development of site design ground motion acceleration response spectra and time histories.

Standard Review Plan (SRP) NUREG-0800, Section 3.7.2, states for the seismic design of nuclear power plants, it is customary to specify earthquake design ground motions that are exerted on the plant structures and used in soil-structure interaction (SSI) analyses.

Issue:

In Section 5.1.2, Soil-Structure Interaction Modeling Assumptions, the rock mass is assumed to be continuous, and the presence of cavities, fracture zones, joints, bedding planes, discontinuities, and other weak zones is neglected. It is not clear from the discussion whether their effects on the rock mass properties (e.g., rock mass modulus, strength) would be incorporated through equivalent rock mass properties so that the calculated loads on the RB walls are realistic. It is also not clear whether an isotropic assumption of the equivalent material properties would be made. Rock fractures have specific orientations in the 3D space and make the rock mass properties anisotropic.

Request:

The staff requests GEH to provide a discussion in the TR how the effects of rock fractures etc. would be incorporated in the SSI modeling.

02.05.04-05

LTR Application Section: TR NEDO-33914 Section 5.1.2

Requirements:

General Design Criterion (GDC) 2 requires that structures, systems, and components (SSCs) important to safety shall be designed to withstand the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, floods, tsunami, and seiches without loss of capability to perform their safety function. GDC 2 also specifies that the design bases for these SSCs shall reflect the importance of the safety functions to be performed.

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.

Standard Review Plan (SRP) NUREG-0800, Section 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.

Standard Review Plan (SRP) NUREG-0800, Section 3.7.1, provides regulatory guidance for the development of site design ground motion acceleration response spectra and time histories.

Standard Review Plan (SRP) NUREG-0800, Section 3.7.2, states for the seismic design of nuclear power plants, it is customary to specify earthquake design ground motions that are exerted on the plant structures and used in soil-structure interaction (SSI) analyses.

Issue:

Section 5.1.2, Soil-Structure Instruction Modeling Assumptions, states that "Strong rock without disadvantageous fracture zones, joints, bedding planes, discontinuities and other zones of weakness will frequently be self-supporting even if some reinforcement is required to ensure a safe excavation." It is not clear what is meant by disadvantageous fracture zones, joints, bedding planes, discontinuities, and other zones of weakness, and how they will be identified at a site.

It is further stated that "Joints and other weak planes may create isolated blocks that are unstable; however, these blocks are not typically large relative to the area of the structure and would be unlikely to produce significant loads on the exterior of the structure compared to other loads (e.g., hydrostatic). These blocks would also not be able to create a cascading failure once the structure is in place." It is not clear what are the basis for the assumption that unstable blocks would be isolated. It is also not clear why the unstable blocks would not produce significant loads on the RB structure. The unstable blocks could impose concentrated load(s) with significantly higher magnitude than the hydrostatic load on the RB walls (e.g., the scenario shown in Figure 5-1). It is also not clear from the discussion how the design of the RB structure would account for such large rock mass failure.

Request:

The staff requests GEH to provide an approach to identify the disadvantageous fracture zones, joints, bedding planes, discontinuities, and other zones of weakness at a site. The staff also requests GEH to provide rationale why the unstable blocks would not produce significant loads on the RB structure and explain how the design of the RB structure would account for such load. Modify the TR as necessary.

02.05.04-06

LTR Application Section: TR NEDO-33914 Section 5.1.2

Requirements:

General Design Criterion (GDC) 2 requires that structures, systems, and components (SSCs) important to safety shall be designed to withstand the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, floods, tsunami, and seiches without loss of capability to perform their safety function. GDC 2 also specifies that the design bases for these SSCs shall reflect the importance of the safety functions to be performed.

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.

Standard Review Plan (SRP) NUREG-0800, Section 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.

Standard Review Plan (SRP) NUREG-0800, Section 3.7.1, provides regulatory guidance for the development of site design ground motion acceleration response spectra and time histories.

Standard Review Plan (SRP) NUREG-0800, Section 3.7.2, states for the seismic design of nuclear power plants, it is customary to specify earthquake design ground motions that are exerted on the plant structures and used in soil-structure interaction (SSI) analyses.

Issue:

Section 5.1.2, Soil-Structure Instruction Modeling Assumptions, assumes that the rock is self-supporting. It is not clear whether the BWRX-300 reactor system cannot be installed in a rock mass that is not self-supporting, e.g., rock mass with poor rock quality.

Request:

The staff requests GEH to clarify whether a site requiring significant permanent support system(s) to keep the surrounding media stable would be unsuitable for siting a BWRX-300 reactor. Modify the TR as necessary.

02.05.04-07

LTR Application Section: TR NEDO-33914 Section 4.3.3

Requirements:

General Design Criterion (GDC) 2 requires that structures, systems, and components (SSCs) important to safety shall be designed to withstand the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, floods, tsunami, and seiches without loss of capability to perform their safety function. GDC 2 also specifies that the design bases for these SSCs shall reflect the importance of the safety functions to be performed.

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.

Standard Review Plan (SRP) NUREG-0800, Section 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.

Issue:

Section 4.3.3, Fluid-Soil Interaction, states that the 3D model of BWRX-300 may have hydraulic interface(s) to simulate the effects of pore water during excavation, construction, loading, and operation phases of the reactor. In rock, flow through the rock fracture network can be the dominant flow mechanism. It is not clear what approaches would be taken to deal with fracture flow if it is present.

Request:

The staff requests GEH to clarify the approach to account for fracture flow. Modify the TR as necessary.

02.05.04-08

LTR Application Section: TR NEDO-33914 Section 3.1.1

Requirements:

General Design Criterion (GDC) 2 requires that structures, systems, and components (SSCs) important to safety shall be designed to withstand the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, floods, tsunami, and seiches without loss of capability to perform their safety function. GDC 2 also specifies that the design bases for these SSCs shall reflect the importance of the safety functions to be performed.

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.

Standard Review Plan (SRP) NUREG-0800, Section 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.

Issue:

The TR does not state whether there would be a program to measure the in-situ stress field at the site. In Section 3.1.1, Site Investigation Program, the maximum required drilling depth is set at 120 m because the expected change in stresses due to excavation of the shaft would be less than 10% from the original in-situ stress field. It is not clear how this can be set without knowing the in-situ stress field. The stress distribution around the RB shaft could be quite different if horizontal stresses are larger than the vertical stress affecting the loads on the RB shaft walls.

Request:

The staff requests GEH to clarify whether there will be process to measure the in-situ state of stresses at the site and incorporate the stress field in the analyses. Modify the TR as necessary.

02.05.04-09

LTR Application Section: TR NEDO-33914 Section 5.1.4

Requirements:

General Design Criterion (GDC) 2 requires that structures, systems, and components (SSCs) important to safety shall be designed to withstand the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, floods, tsunami, and seiches without loss of capability to perform their safety function. GDC 2 also specifies that the design bases for these SSCs shall reflect the importance of the safety functions to be performed.

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.

Standard Review Plan (SRP) NUREG-0800, Section 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.

Standard Review Plan (SRP) NUREG-0800, Section 3.7.1, provides regulatory guidance for the development of site design ground motion acceleration response spectra and time histories.

Standard Review Plan (SRP) NUREG-0800, Section 3.7.2, states for the seismic design of nuclear power plants, it is customary to specify earthquake design ground motions that are exerted on the plant structures and used in soil-structure interaction (SSI) analyses.

Issue:

Section 5.1.4, Probabilistic Earth Pressure Analyses, presents an approach as an example to account for the uncertainties in the estimated value of the load on the RB shaft walls in a soil medium. It is not clear whether similar approaches would be used to account for uncertainties in at least important parameters significant to the reactor design; for example, the estimated rock mass modulus estimated using various empirical equations from different measured and inferred parameters (indirect estimation).

Request:

The staff requests GEH to clarify whether there will be a plan to account for the uncertainties in other site-related parameters with potential to significantly affect the reactor design. Modify the TR as necessary.