2.0 Site Characteristics

2.5 Geological, Seismological, and Geotechnical Engineering

2.5.1 Regulatory Criteria

The ABWR design is certified for plants founded on soil deposits up to 91.5 m (300 ft.), in addition to rock sites. Therefore, there is a potential that larger differential settlements may occur for a deep soil site due to the geologic variation of subsurface materials and non-uniform loading distribution. The applicant added dynamic bearing capacity and differential site parameters to the ABWR DCD in order to ensure that the soil under the foundation and the foundation itself will be able to withstand the foundation dynamic pressure resulting from the combination of all possible loadings. These parameters are needed to demonstrate compliance with 10 CFR 52.47(a)(1)(iii), 10 CFR Part 50, Appendix A, and 10 CFR Part 100, Appendix A, Section V.(d). Therefore, this design change is a "modification," as that term is defined in Chapter 1 of this supplement, and will correspondingly be evaluated using the regulations applicable and in effect at the initial ABWR certification.

The applicable regulatory requirements for evaluating the proposed GEH ABWR DCD modifications related to geology, seismology, and geotechnical engineering design parameters are as follows:

- 10 CFR 52.47(a)(1)(iii) (1997) requires design certification applicants to provide postulated site parameters, and an analysis and evaluation of the design in terms of such parameters.

- 10 CFR Part 50, Appendix A, General Design Criterion (GDC) 2, "Design Bases for Protection Against Natural Phenomena," (1997) with respect to structures, systems, and components (SSC) important to safety being 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 functions.

- 10 CFR Part 100, Appendix A,[1] Section V.(d) (1997), requires that each applicant determine whether there will be soil instability due to vibratory ground motion associated with the Safe Shutdown Earthquake.

2.5.2 Summary of Technical Information

Geology, seismology, and geotechnical engineering related design parameters and associated COL information items are presented in GEH ABWR DCD, Revision 6, Tier 1, Section 5.0, "Site Parameters;" Tier 2, Section 2.0, "Site Characteristics;" and Tier 2, Section 2.3, "COL License Information".

Seismic design parameters that include Safe Shutdown Earthquake (SSE) ground motion, bearing capacity, and settlement are described in GEH ABWR DCD, Revision 6, Tier 2, Section 2.3.1.2, "Seismic Design Parameters". COL information requirements for basic geologic and seismic information, vibratory ground motion, surface faulting, stability of subsurface material and foundation, site and facilities, field investigations, laboratory investigations,

1 The requirements of 10 CFR Part 100, Appendix A, apply here because 10 CFR Part 100, Subpart B, applies only to applications submitted on or after January 10, 1997.

subsurface conditions, excavation and backfilling for foundation construction, effect of groundwater, liquefaction potential, response of soil and rock to dynamic loading, minimum soil bearing capacity, earth pressures, soil properties for seismic analysis of buried pipes, static and dynamic stability of facilities, subsurface instrumentation, stability of slopes, and embankments and dams are described in GEH ABWR DCD, Revision 6, Tier 2, Section 2.3.2.21 to Section 2.3.2.39.

The applicant proposed additional information that is related to geology, seismology, and geotechnical engineering design parameters to the GEH ABWR DCD. The additional information (represented below with italicized text) in Revision 6 of the GEH ABWR DCD is:

Tier 1, 5.0 Site Parameters

Table 5.0 ABWR Site Parameters

Minimum Dynamic Bearing Capacity: 2,700 kPa [392 psi]
Maximum Settlement(9): 75mm [2.95 in.]
Maximum Foundation Angular Distortion: 1/750(10)

Note: (9) Settlement is long term (post construction) value.
(10) Angular distortion is defined as the slope between two adjacent columns. Angular distortion is long term (post construction) value.

Tier 2, 2.0 Site Characteristics

Table 2.0-1 Envelope of ABWR Standard Plant Site Design Parameters

– Maximum Dynamic Bearing Capacity: 2,700 kPa [392 psi]
– Maximum Settlement: 75mm [2.95 in.] †††
– Maximum Foundation Angular Distortion: 1/750 ‡‡‡

Note: ††† Settlement is long term (post construction) value.
‡‡‡ Angular distortion is defined as the slope between two adjacent columns. Angular distortion is long term (post construction) value.

Tier 2, 2.3 COL License Information

2.3.1.2 Seismic Design Parameters

(2) Bearing Capacity

The site soil static bearing capacity at the foundation level of the reactor and control building is 718.20 kPa [104 psi] minimum. *The maximum static bearing demand is compared with the site-specific allowable static bearing pressure, which is obtained by dividing the ultimate soil bearing capacity by a factor of safety appropriate for the design load combination. The maximum dynamic bearing demand is compared with the site-specific allowable dynamic bearing pressure, which is obtained by dividing the ultimate soil bearing capacity by a factor of safety appropriate for the design load combination.*

The site soil dynamic bearing capacity at the foundation level of the reactor and control building is 2,700 kPa [392 psi] minimum.

(3) Settlement

The maximum settlement of the reactor and control building foundations is 75mm [2.95 in.]. The maximum angular distortion of the reactor and control building is 1/750.

2.5.3 Technical Evaluation

The staff reviewed the proposed modifications related to geology, seismology, and geotechnical engineering design parameters in the GEH ABWR DCD and associated sections in NUREG–1503 and its supplement. The staff's technical evaluation focused on the technical basis of the proposed design parameters and the adequacy of associated COL information requirements.

As dynamic bearing capacity and differential settlement site parameters are important design requirements to ensure the stability of foundation and structure for a nuclear power plant, in RAI Question 02.05.04-1, the staff asked the applicant to add these site parameters to the DCD and to provide details on how the dynamic bearing capacity and differential settlement site parameters were determined, including the model(s), assumptions and input parameters used in analyses and calculations, and justifications for site parameter value determinations. In the July 24, 2015 (ADAMS Accession No. ML15209A561), November 13, 2015 (ADAMS Accession No. ML15317A092) and May 31, 2016 (ADAMS Accession No. ML16152A512) responses to this RAI, the applicant provided additional site parameters with detailed descriptions and justifications. The applicant also proposed revisions of the GEH ABWR DCD to incorporate all proposed changes. This includes correcting Table 2.0-1 to reflect that the 2,700 kPa (392 psi) value represents the minimum dynamic bearing capacity site parameter. These proposed revisions are being tracked as **Confirmation Item 02.05.04-1**

The applicant stated that since the site parameter for minimum static bearing capacity in the originally certified DCD was determined by adding a margin factor to the calculated maximum static foundation pressure value, the same approach was used in the determination of the minimum dynamic bearing capacity site parameter. The calculated maximum dynamic bearing pressure for the GEH ABWR Reactor Building (the heaviest building) was 2,336 kPa (339 psi), as documented in GEH ABWR DCD, Tier 2, Section 3H.1.5.6 (unchanged from the originally certified DCD). Based on this calculation, the applicant specifies the minimum dynamic bearing capacity site parameter as 2,700 kPa (392 psi) to provide some margin. The applicant further specifies that the site-specific dynamic bearing capacity determined at the COL application stage should be obtained by dividing the ultimate soil bearing capacity by a factor of safety appropriate for the design load combination, which is described in its proposed revised COL Information Item 2.3.1.2 (2) in GEH ABWR DCD, Revision 6, Tier 2, Section 2.3.1.2.

The staff reviewed the RAI responses and related documents. First, the staff reviewed the GEH ABWR DCD, Revision 6, Tier 2, Section 3H.1.5.6 and confirmed that the calculated maximum foundation bearing pressure under the combination of seismic and other loads was specified as 2,336.0 kPa (339 psi), which is the same as that in the certified ABWR DCD, Revision 4. Second, the applicant specifies the minimum dynamic bearing capacity site parameter as 2,700 kPa (392 psi), which is about 15 percent higher than the calculated maximum foundation bearing pressure value. Third, the DCD requires a factor of safety appropriate for the design load combinations to be used when determining site specific soil dynamic bearing capacity. The

combination of the higher site parameter value than the calculated one and the requirement of an appropriate factor of safety to be used when determining the site specific soil dynamic bearing capacity will provide an adequate safety margin that accounts for the variability and uncertainties of subsurface materials and dynamic/seismic loadings. The staff therefore concludes that the specified dynamic bearing capacity site parameter is adequate because it will provide a design basis for subsurface material underneath the structure foundations to withstand maximum foundation pressure generated by the structure's response to the combination of designed dynamic/seismic and dead loadings.

The applicant proposed a total long term (post construction) settlement of 75mm (2.95 in.) as a site parameter based on ABWR construction experience. The staff concludes that the long term settlement limit of 75 mm (2.95 in.) is reasonable for the GEH ABWR structures because total settlements up to 125 mm (4.92 in.) can be tolerated without damage for buildings constructed on reinforced concrete mat or raft foundation according to the commonly accepted industrial guidance (e.g. engineering manual of the U.S. Army Corps of Engineers) and engineering practices.

As angular distortion, defined as the slope between two adjacent column lines, is one of the foundation differential settlement measurements that affects foundation stability, the applicant specified the maximum angular distortion limit as 1/750. The staff considers this angular distortion limit to be acceptable because the commonly accepted limits for angular distortion are in the range of 1/500 to 1/750 according to industrial guidance and practices (e.g. engineering manual of the U.S. Army Corps of Engineers); therefore the staff concludes that defining the angular distortion limit at 1/750, the lower end of this range, meets the foundation stability requirement and will not have an adverse effect on structures housing equipment sensitive to differential settlement.

Regarding other differential settlement related issues, such as the effect of building settlement on the connection of other components to the buildings, the applicant stated that even with an aggressive 39 month construction schedule, the mechanical and electrical components would be installed at least 12 months after the completion of the foundation basemat, which allows sufficient time for the buildings to settle. The applicant also stated that because the GEH ABWR Primary Containment penetrations sleeves are fixed and some component positions cannot be adjusted after its construction, the GEH ABWR Primary Containment shares a common basemat with the Reactor Building, and openings will be left in exterior walls to allow for the installation of components after construction of the wall and these openings are made large enough to account for expected settlement. The applicant further stated that a design value for the differential settlement between buildings is not needed in the GEH ABWR DCD because the maximum differential settlement is the same as the building's maximum settlement value. The staff considers the applicant's statement that building settlement will not affect the connection of components to the buildings is reasonable because 1) engineering practices have shown that more than 95 percent of total building settlement will occur within 12 months of construction completion for suitable nuclear power plant foundation supporting materials (e.g. well compacted granular materials); and 2) the design and construction procedure of the wall openings for component connections will accommodate the residual long term settlement. The staff therefore concludes that the specified allowable foundation settlement will have no adverse effect on proper component connections to the buildings. Given that the GEH ABWR Primary Containment shares a common basemat with the Reactor Building and, therefore, these two buildings will have the same settlement, and that the design and sequences of building construction and component connection will ensure the proper installation of components between buildings, the staff agrees that no other differential settlement requirement, other than

the angular distortion limit, is needed for the GEH ABWR design.

Based on the above findings, the staff concludes that the applicant adequately addressed the issues related to minimum dynamic bearing capacity and settlement limit requirements, and the proposed modifications related to geology, seismology, and geotechnical engineering design parameters will provide additional assurance of the stability and safety of the nuclear power plant structures. Accordingly, the staff considers the RAI Question 02.05.04-1 resolved.

The staff also reviewed the proposed GEH ABWR DCD revisions and determined that they fully incorporate the proposed site parameter changes and associated COL information items. The staff concludes that those revisions will specify additional design basis requirements and provide site parameter related requirements for COL applicants referencing this design to ensure the stability of foundation and structures for this design. However, the staff needs to confirm all proposed revisions are included in the next revision of the GEH ABWR DCD, which is being tracked as **Confirmation Item 02.05.04-1**.

2.5.4 Conclusion

Based on the review of the applicant's proposed modifications related to the geology, seismology, and geotechnical engineering design presented in GEH ABWR DCD, Revision 6, and the applicant's RAI responses, the staff concludes that the applicant adequately specified additional site parameters that include minimum dynamic bearing capacity, long term settlement limits and angular distortion limit in the GEH ABWR DCD, with associated COL information items. The applicant provided details on how those added site parameters were determined and proposed DCD revisions that incorporate those proposed changes. The added site parameters were determined based on NRC approved analysis procedures and/or in conformance with the commonly accepted industrial guidance and practices, which will provide additional assurance of the foundation and structure stability. The staff also concludes that the new and revised COL information items associated with the added site parameters provide adequate requirements to ensure that the COL applicants referencing the GEH ABWR DCD design meet those site parameter requirements. Therefore, the staff concludes that the proposed DCD modifications related to geology, seismology, and geotechnical engineering design parameters and associated COL application requirements meet the regulatory requirements of 10 CFR 52.47(a)(1)(iii), 10 CFR Part 50, Appendix A, GDC 2, and 10 CFR Part 100, Appendix A, Section V.(d). Inclusion of the proposed changes in the DCD is being tracked by **Confirmation Item 02.05.04-1**.