2.5 Geology, Seismology, and Geotechnical Engineering

Geology, seismology, and geotechnical engineering information are specific to the site and region and will be addressed by applicants on a site-specific basis. A range of site conditions which encompasses a number of potential reactor sites throughout the United States has been selected for evaluating the U.S. EPR.

2.5.1 Basic Geologic and Seismic Information

A combined license (COL) applicant that references the U.S. EPR design certification will use site-specific information to investigate and provide data concerning geological, seismic, geophysical, and geotechnical information.

2.5.1.1 Regional Geology

Regional geology is site specific and will be addressed by the COL applicant.

2.5.1.2 Site Geology

Site-specific geology information will be addressed by the COL applicant.

2.5.2 Vibratory Ground Motion

A COL applicant that references the U.S. EPR design certification will review and investigate site-specific details of seismic, geophysical, geological, and geotechnical information to determine the safe shutdown earthquake (SSE) ground motion for the site and compare site-specific ground motion to the Certified Seismic Design Response Spectra (CSDRS) for the U.S. EPR.

The seismic design basis for the U.S. EPR is presented in Section 3.7.1.1.1. As noted therein, the U.S. EPR is designed for three sets of control motions anchored at a peak ground acceleration (PGA) of 0.3g and an additional set of ground motions (horizontal and vertical) with high frequency content. These ground motions are defined as hypothetical free-field outcrop motions at 38ft 10-1/2 in. below grade at the bottom elevation of the foundation basemat for the Nuclear Island (NI) Common Basemat Structures (GDC 2). The CSDRS for the U.S. EPR are shown in Figure 3.7.1-1 and described in Section 3.7.1.1.

Section 3.7.1.3 describes a range of soil profiles and associated dynamic soil properties selected for the design of the U.S. EPR. Table 3.7.1-6 shows the soil layering, the assumed strain-dependent properties, and the CSDRS design control motion associated with the profile. The variation in shear wave velocity in each of the assumed profiles is illustrated in Figure 3.7.1-31 and Figure 3.7.1-32. The soil properties associated with the various shear wave velocities assumed in the soil profiles are discussed further in Section 3.7.2.4.1 and summarized in Table . Section 3.7.1.3 and Section 3.7.2.4.1 discuss that, for soil-structure interaction (SSI) analysis for the U.S. EPR design certification, the assumed shear wave velocities in each profile are taken to be strain-compatible values during seismic events.

Refer to Section 3.7.1 and Section 3.7.2 for additional description of soil-structure interaction analyses performed for the U.S. EPR. Liquefaction of soils and stability of slopes is addressed in Section 2.5.4.8 and Section 2.5.5, respectively.

2.5.2.1 Seismicity

Seismicity is site specific and will be addressed by the COL applicant.

2.5.2.2 Geologic and Tectonic Characteristics of the Site and Region

Geologic and tectonic characteristics are site specific and will be addressed by the COL applicant.

The guidance of RG 1.208 and RG 1.165 will be met, as appropriate, in performing the required studies to determine the SSE using probabilistic seismic hazard analyses.

2.5.2.3 Correlation of Earthquake Activity with Seismic Sources

Correlation of earthquake activity with seismic sources is site specific and will be addressed by the COL applicant, consistent with the guidance of RG 1.208 and RG 1.165, as appropriate.

2.5.2.4 Probabilistic Seismic Hazard Analysis and Controlling Earthquake

The probabilistic seismic hazard analysis is site specific and will be addressed by the COL applicant, consistent with the guidance of NUREG/CR-6372 (Reference 1), RG 1.165, and RG 1.208, as appropriate.

2.5.2.5 Seismic Wave Transmission Characteristics of the Site

Seismic wave transmission characteristics are site specific and will be addressed by the COL applicant.

2.5.2.6 Ground Motion Response Spectrum

A COL applicant that references the U.S. EPR design certification will compare the final strain-dependent soil profile with the U.S. EPR design soil parameters and verify that the site-specific seismic response is enveloped by the CSDRS and the soil profiles discussed in Sections 2.5.2, 2.5.4.7 and 3.7.1 and summarized in Table 3.7.1-6, Table 3.7.1-8 and Table 3.7.1-9. The applicant will develop site-specific ground motion response spectra (GMRS) and foundation input response spectra (FIRS). The FIRS shall be defined using the NEI approach (SHAKE outcrop) of ISG-17. The applicant will also describe site-specific soil conditions and evaluate the acceptability of the U.S. EPR standard design described in Section 3.7.1 for the particular site. In making this comparison, the applicant will refer to Sections 3.7.1 and 3.7.2 for a description of the soil-structure interaction analyses performed for the U.S. EPR in addressing the following evaluation guidelines.

1. The applicant will confirm that the peak ground acceleration for the GMRS is less than the PGA for the CSDRS (0.3g or if high frequency content is present, 0.21g and 0.18g for the horizontal and vertical, respectively).

2. The applicant will confirm that the low-strain, best-estimate, value of shear wave velocity below the bottom of the foundation basemat of the NI Common Basemat Structures and other Seismic Category I structures is 1000 fps, or greater. This comparison will confirm that the NI Common Basemat Structures and other Seismic Category I structures are founded on competent material.

3. The applicant will demonstrate that the FIRS for the NI Common Basemat Structures is enveloped by one of the individual design ground motion response spectra, which make up the CSDRS as described in Section 3.7.1.1.1. In addition, the applicant will demonstrate that the input motion, which considers the difference in elevation between each structure and the NI Common Basemat Structures, the embedment of the ESWB, and SSSI effect of the NI Common Basemat Structures is less than the modified CSDRS used for the design of the EPGB and the ESWB (see Section 3.7.1.1.1).

4. The U.S. EPR design is based on analysis that assumes the underlying layer of soil and rock are horizontal with uniform properties. The U.S. EPR analysis assumes backfill is uniform and the lateral extent of the backfill has no influence on the analysis. The applicant will assess lateral uniformity of the site per Section 2.5.4.10.3.

5. The applicant will compare the final site-specific soil characteristics including backfill with the U.S. EPR design soil parameters and demonstrate that the idealized strain-compatible site soil profile is consistent with one of the soil profiles used for the U.S. EPR. The profiles include a range of uniform and layered site conditions. The site soil profile for the backfill and soil columns must be consistent with one of the soil profiles in Tables 3.7.1-6 that has the same CSDRS curve that was used for comparison in step 3 above. Site soil profiles for the EPGB starting at grade elevation must be consistent with one of the soil profiles in Tables 3.7.1-8 associated with the modified CSDRS curve used in step 3 above. Site soil profiles for the ESWB starting at grade elevation must be consistent with one of the soil profiles in Tables 3.7.1-9 associated with the modified CSDRS curve used in step 3 above. The site soil properties for the given soil layer must be consistent with soil properties in Table 3.7.2-9. The applicant also considers the assumptions used in the SSI analyses including embedment and extent of backfill, as described in Section 3.7.1 and Section 3.7.2. The applicant also considers the dynamic bearing capacity requirements as described in Section 2.5.4.10.1.

6. If the conditions of steps one through five are met, the characteristics of the site fall within the site parameters for the U.S. EPR and the site is acceptable.

7. If the conditions of steps one through five are not met, the applicant will demonstrate by other appropriate means that the U.S. EPR is acceptable at the proposed site. The applicant may perform intermediate-level additional studies to demonstrate that the particular site is bounded by the design of the U.S. EPR. An example of such studies is to show that the site-specific motion at top-of-basemat level, with consideration of the range of structural frequencies involved, is bounded by the U.S. EPR design.

8. If the evaluations of step 7 are not sufficient, the applicant will perform detailed site-specific SSI analyses with the soil column properties for the particular site. This site-specific evaluation will include dynamic seismic analyses and development of in-structure response spectra (ISRS) for comparison with ISRS and zero period accelerations (ZPAs) for the U.S. EPR at key locations in the U.S. EPR structure. Key locations are selected based on the location of major equipment (reactor pressure vessel supports, steam generator supports, emergency diesel generator foundation) and at high elevations in the structure where the ISRS is expected to be amplified. These analyses will be performed in accordance with the methodologies described in Section 3.7.1 and Section 3.7.2. Results from this comparison will be acceptable if the amplitude of the site-specific ISRS do not exceed the ISRS for the U.S. EPR as shown in the figures indicated for each location below. The NI site-specific ZPAs for these same locations also need to be enveloped by any one of the individual soil cases in Table 3.7.2-10. The EPGB and ESWB site-specific ZPAs need to be bounded by the envelopes provided in Table 3.7.2-28 and Table 3.7.2-29, respectively. Comparisons will be made at the following key locations, defined in Section 3.7.2:

   – Reactor Building Internal Structures (RBIS)—Reactor Vessel Support at elevation +16 ft, 10-3/4 in (Figures 3.7.2-74, 3.7.2-75, and 3.7.2-76) and steam generator supports at elevation +63 ft, 11-3/4 in (Figures 3.7.2-77, 3.7.2-78, and 3.7.2-79).

   – Safeguard Building (SB) 1—elevation +26 ft, 7 in (Figures 3.7.2-80, 3.7.2-81, and 3.7.2-82) and +68 ft, 11 in (Figures 3.7.2-83, 3.7.2-84, and 3.7.2-85).

   – SBs 2/3—elevation +26 ft, 7 in (Figures 3.7.2-86, 3.7.2-87, and 3.7.2-88) and +53 ft, 6 in (Figures 3.7.2-89, 3.7.2-90, and 3.7.2-91).

   – SB 4—elevation +68 ft, 11 in (Figures 3.7.2-92, 3.7.2-93, and 3.7.2-94).

   – Reactor Containment Building (RCB)—Polar crane support at elevation +123 ft, 4-1/4 in (Figures 3.7.2-95, 3.7.2-96, and 3.7.2-97) and top-of-dome at elevation +190 ft, 3-1/2 in (Figures 3.7.2-98, 3.7.2-99, and 3.7.2-100).

   – Fuel Building (FB)—elevation +12 ft, 1-3/4 in. (Figures 3.7.2-110, 3.7.2-111, and 3.7.2-112).

   – FB - elevation +48 ft, 6-3/4 in. (Figures 3.7.2-155, 3.7.2-156, and 3.7.2-157).

- Emergency Power Generator Building (EPGB)—center of basemat (Figures 3.7.2-101, 3.7.2-102, and 3.7.2-103) and +51 ft, 6 in. (Figures 3.7.2-148, 3.7.2-149, and 3.7.2-150.

- Essential Service Water Building (ESWB)—Pump Slab on elevation +14 ft, 0 in (Figures 3.7.2-107, 3.7.2-108, and 3.7.2-109) and Fan Deck on elevation +63 ft, 0 in (Figures 3.7.2-104, 3.7.2-105, and 3.7.2-106).

9. Exceedances will require additional evaluation to determine if safety-related structures, systems, and components of the U.S. EPR at the location(s) in question will be affected.

As a result of the reconciliation process described above, the applicant may redesign selected features of the U.S. EPR, as required. Redesigned features will be identified as exceptions to the FSAR and addressed by the COL applicant.

2.5.3 Surface Faulting

No surface faulting is considered to be present under foundations for Seismic Category I structures in the U.S. EPR (GDC 2).

A COL applicant that references the U.S. EPR design certification will investigate site-specific surface and subsurface geologic, seismic, geophysical, and geotechnical aspects within 25 miles around the site and evaluate any impact to the design. The COL applicant will demonstrate that no capable faults exist at the site in accordance with the requirements of 10 CFR 100.23 and of 10 CFR 50, Appendix S. If non-capable surface faulting is present under foundations for safety-related structures, the COL applicant will demonstrate that the faults have no significant impact on the structural integrity of safety-related structures, systems, or components.

2.5.4 Stability of Subsurface Materials and Foundations

The stability of subsurface materials under the foundations for Seismic Category I structures is demonstrated in Section 3.8.5 for the U.S. EPR soil profiles described in Section 3.7.1 and Section 3.7.2. As described in Section 3.8.5, lateral soil pressure loads under saturated conditions are considered for the design of below-grade walls. Soil loads are based on the parameters described in Section 2.5.4.2.

A COL applicant that references the U.S. EPR design certification will present site-specific information about the properties and stability of soils and rocks that may affect the nuclear power plant facilities under both static and dynamic conditions, including the vibratory ground motions associated with the CSDRS and the site-specific SSE.

2.5.4.1 Geologic Features

Geologic features are site specific and will be addressed by the COL applicant.

2.5.4.2 Properties of Subsurface Materials

The following soil properties are used for design of U.S. EPR Seismic Category I structures:

- Soil density:
  - Saturated soil = 134 lb/ft^3.
  - Moist soil = 128 lb/ft^3.
  - Dry soil = 110 lb/ft^3.

  See Section 3.7.1.3 and Table for soil densities used for SSI analysis.
- Angle of internal friction = 26.6 degrees minimum, 30 degrees maximum.
- Coefficient of friction for all interfaces between the foundation basemat and soil for Seismic Category I structures is 0.5 minimum.

For a cohesionless soil site, the soil below and adjacent to the safety-related foundation basemat will have a minimum friction angle of 26.6 degrees. For a cohesive soil site, the soil will have an undrained strength equivalent to or exceeding a drained strength of 26.6 degrees yielding a friction coefficient greater than or equal to 0.5.

The backfill soil adjacent to any safety-related structure will have a maximum angle of internal friction of 30 degrees to limit passive pressure developed on the below grade exterior walls. If the maximum angle of internal friction is higher than 30 degrees, a site-specific analysis will be performed using the site-specific soil parameters and site-specific SSE to demonstrate that the capacity of the below grade walls is not exceeded.

Section 2.5.4.5 discusses the use of mud mats under the foundation basemats to facilitate construction. When used, the governing friction value at the interface zone is determined by a thin soil layer (soil-on-soil) under the mud mat. As indicated above, the underlying soil (expected to be compacted backfill or lean concrete) will have a friction angle greater than 26.6 degrees. Typical values of friction coefficient between concrete and dry soil and rock are in the range of approximately 0.5. Due to the interlock of concrete with soil as the concrete is placed, the friction between the mud mat and underlying soil media is generally higher than the friction resistance of soil-on-soil so that continuity of load transfer across the interface is maintained. Waterproofing systems are addressed in Section 3.4.2.

Earthquake induced soil pressures for the design of the U.S. EPR are developed in accordance with Section 3.5.3 of ASCE 4-98 (Reference 2). Maximum ground water and maximum flood elevations used for determining lateral soil loads for the U.S. EPR are as specified in Table 2.1-1.

A COL applicant that references the U.S. EPR design certification will reconcile the site-specific soil and backfill properties with those used for design of U.S. EPR Seismic Category I structures and foundations described in Section 3.8.

2.5.4.3 Foundation Interfaces

Foundation interfaces with underlying materials are site specific and will be addressed by the COL applicant. The COL applicant will confirm that the site soils and backfill material have (1) minimum sliding coefficient of friction of 0.5, (2) adequate shear strength to provide adequate static and dynamic bearing capacity, (3) adequate elastic and consolidation properties to satisfy the limits on settlement described in Section 2.5.4.10.2, (4) adequate dynamic properties (i.e., shear wave velocity and strain-dependent modulus-reduction and hysteretic damping properties), and (5) properties so that the earthquake design loading on the below grade walls is not exceeded (i.e., the site-specific angle of internal friction, unit soil weight, and seismic wall movements do not cause design limits of the walls to be exceeded because of the passive lateral earth pressure on the walls to support the Seismic Category I structures of the U.S. EPR under earthquake loading.

2.5.4.4 Geophysical Surveys

Geophysical surveys are site specific and will be addressed by the COL applicant.

2.5.4.5 Excavations and Backfill

Excavations and backfill are site-specific and will be addressed by the COL applicant. Additional backfill requirements are identified in Section 3.8.5.4. Mud mats may be provided under foundations for ease of construction. Mud mats may be designed as structural plain concrete elements on a site-specific basis in accordance with ACI 318 (Reference 3).

2.5.4.6 Ground Water Conditions

Ground water conditions are described in Section 2.4 and provided in Table 2.1-1 for the U.S. EPR. Ground water conditions are considered in the structural design of the U.S. EPR, as described in Section 3.8. However, groundwater conditions are not explicitly considered in the SSI analyses described in Section 3.7.1 and Section 3.7.2.

The COL applicant will address site-specific ground water conditions.

2.5.4.7 Response of Soil and Rock to Dynamic Loading

Section 2.5.2 notes that the design of the U.S. EPR is based on the assumption that the shear wave velocities assumed for the soil profiles described in Section 3.7.1.3 are strain-compatible properties. For SSI analysis for the U.S. EPR, assumed relationships to depict the strain-dependent modulus-reduction and hysteretic damping properties are not explicitly considered. The COL applicant will address site-specific response of soil and rock to dynamic loading, including the determination of strain-dependent modulus-reduction and hysteretic damping properties.

2.5.4.8 Liquefaction Potential

The design of the U.S. EPR assumes that the plant is not founded on liquefiable materials (GDC 2).

The COL applicant will address site-specific liquefaction potential. As stated in Section 3.7.1, the evaluation of liquefaction is performed for the seismic level of the site-specific SSE.

2.5.4.9 Earthquake Site Characteristics

Section 3.7.1 describes the seismic design basis for the U.S. EPR. Section 2.5.2 presents a brief summary of the seismic design basis.

Site-specific earthquake site characteristics will be described by the COL applicant.

2.5.4.10 Static Stability

Static stability pertaining to bearing capacity and settlement for the U.S. EPR is described in the following section. Additional information is provided in Section 3.8.5 for the foundations of Seismic Category I structures.

2.5.4.10.1 Bearing Capacity

The maximum bearing pressure under static loading conditions for the foundation basemat beneath the Seismic Category I structure basemats is 23,100 lbs/ft^2, which includes the dead weight of the structure and components and 25 percent of the live load. The maximum bearing pressure under safe shutdown earthquake loads combined with static loads, as described in Section 3.8.5, is 38,000 lbs/ft^2 for soft soil, 48,000 lbs/ft^2 for medium soil, and 60,000 lbs/ft^2 for hard soil. If a site with shear wave velocity between soft and medium soil conditions or between medium and hard soil conditions, the maximum dynamic bearing pressure demand is the larger of the two values. The shear wave velocities (strain compatible best estimate average values directly beneath the foundation basemat) of soft, medium, and hard soils are 1000 ft/sec, 1640 ft/sec, and greater than or equal to 6601 ft/sec, respectively. For sites not meeting the soil property requirements, a site-specific analysis is required. Refer to Appendix 3E for details of these bearing pressures under the basemat (GDC 2).

A COL applicant that references the U.S. EPR design certification will verify that site-specific foundation soils beneath the foundation basemats of Seismic Category I structures have the capacity to support the bearing pressure with a factor of safety of 3.0 under static conditions, or 2.0 under dynamic conditions, whichever is greater.

A COL applicant that references the U.S. EPR design certification will perform a site-specific analysis to determine the bearing pressure demand and peak displacement of the NAB. The foundation soils beneath the NAB foundation basemat shall have the capacity to support the bearing pressure with a factor of safety of 3.0 under static conditions, or 2.0 under combined static and dynamic conditions, whichever is greater. The minimum required separation distance is a factor of two times the calculated absolute sum of the maximum combined site-specific NAB and U.S. EPR NI design displacements, but not less than 30 inches.

2.5.4.10.2 Settlement

Safety-related structures, systems and components are housed primarily in structures supported by the foundation basemat for the NI Common Basemat Structures and independent foundation basemats for the EPGBs and the ESWBs.

Total settlement and differential settlement is dependent on site-specific conditions, construction sequence, loading conditions, and excavation and dewatering plans. It is expected that all elastic settlement and most of the consolidation settlement will occur by the time of completion of construction. There are limited interfaces between systems located on different basemats. The effects of total settlement and differential settlement will be considered where these interfaces occur. As described in Section 3.8.4.1.8 and Section 3.8.4.1.9, the design of safety-related buried conduits and piping is site-specific. These features will be designed for site-specific values of total settlement and differential settlement expected at the interface with the foundation basemat after connections are made. Alternatively, site-specific structural features such as tunnels may be used to limit the imposition of differential settlement.

A COL applicant that references the U.S. EPR design certification will provide an assessment of predicted settlement values across the basemat of Seismic Category I structures during and post construction. The assessment will address both short term (elastic) and long term (heave and consolidation) settlement effects with the site-specific soil parameters, including the soil loading effects from adjacent structures.

Site-specific considerations for the predicted short and long term effects of settlement will be taken into account. Site-specific considerations include the effects of dewatering, excavation, foundation material preparation, umbilical connections, sequence of placement of the basemat, and site-specific construction sequence of the superstructure.

A COL applicant that references the U.S. EPR design certification will verify that the predicted tilt settlement value of ½ inch per 50 feet in any direction across the foundation basemat of a Seismic Category I structure is not exceeded. Settlement values larger than this may be demonstrated acceptable by performing additional site-specific evaluations.

Tilt settlement of the building is controlled to 1/2 inch in 50 ft such that equipment can be installed and operated as designed.

Section 3.8.5.4 addresses the analyses performed for settlement loading on the Seismic Category I structures. Section 3.8.5.5addresses the acceptance criteria for settlement on Seismic Category I structures. Section 3.8.5.7 addresses settlement monitoring.

2.5.4.10.3 Uniformity and Variability of Foundation Support Media

The U.S.EPR design considers a broad range of subsurface conditions, and the effects of these various conditions were evaluated by an extensive series of SSI analyses which addressed subsurface stratigraphy, depth-to-bedrock, shear wave velocity, and its variation with depth. While the U.S. EPR design is intended to cover a broad range of soil conditions, it is recognized that it is impractical to address all possible subsurface variations. For this reason site specific subsurface conditions will be evaluated for applicability to the U.S. EPR.

The design of the U.S. EPR is based on analyses that assume the underlying layers of soil and rock are horizontal with uniform properties. The U.S. EPR analysis assumes backfill is uniform and the lateral extent of the backfill has no influence on the analysis. Furthermore, the U.S. EPR is designed for application at a site where the foundation conditions do not have extreme variation within the foundation footprints. However, the design does have margin that allows for adaptation to many sites that might be classified as non-uniform or having highly variable properties.

A COL applicant that references the U.S. EPR design certification will investigate and determine the uniformity of the soil layer(s) underlying the foundation basemats of Seismic Category I structures.

Soil structure interaction analysis, settlement analysis, and bearing pressure analysis for the U.S. EPR assume that the soil layers are horizontal and effects of non-horizontal layering are ignored. However, the layers of soil and rock beneath a specific site may dip with respect to the horizontal. If the dip is less than or equal to 20 degrees, the layer is defined as horizontal and analyses using horizontal layers are applicable, as described in NUREG/CR-0693 (Reference 4).

Guidance for performing a site-specific evaluation of uniformity for soil profiles under the Seismic Category I structures is provided below. Alternate site-specific methodologies may be used with appropriate technical justification.

Uniformity within the layer may be checked by determining from the boring logs a series of “best-estimate” planes beneath the foundation footprint that define the top (and bottom) of each layer. Depending on specific site conditions, the planes can be based on stratigraphy, lithology, unconformities, intrusives, weathering, other geologic/geotechnical properties or characteristics or combinations of the above. The site-specific evaluation will take into account the sensitivity of the seismic and settlement analysis to the soil parameters. Uniformity and best estimate shear wave velocity within the layer will be established for all layers to a minimum depth of approximately 1.5 times an equivalent radius or no more than 1.0 times the maximum foundation basemat dimension. Typically this will be no less than 200 feet below the bottom of the foundation basemat. If the site can be classified as laterally uniform, it is satisfactory for the U.S. EPR based on analyses and evaluations performed to support design certification, provided that additional site-specific analyses are not required to consider differences in analytical modeling assumptions between the U.S. EPR design and those appropriate to the specific site.

If the site is found to have a dip angle greater than 20 degrees, or the site is found to have non-uniform soil conditions within a profile, site-specific analysis will be performed. This site-specific analysis may involve soil structure interaction analysis and/or an analysis that demonstrates that the foundation basemat stresses resulting from the variation of subgrade modulus or shear wave velocity across the footprint are within the design margin for the U.S. EPR foundation basemats. In addition, these considerations may be assessed with the information developed in accordance with RG 1.132 and RG 1.138 to determine if additional site investigation measures are necessary or if site improvement measures should be undertaken.

2.5.4.10.4 Site Investigation for Uniform Sites

For sites that are expected to be uniform, RG 1.132, Appendix D, provides guidance on the spacing and depth of borings of the geotechnical investigation for Seismic Category I structures. Specific language in the Regulatory Guide indicates a spacing of 100 feet supplemented with borings on the periphery and at the corners for favorable, uniform geologic conditions.

For foundation engineering purposes, a series of primary borings should be drilled on a grid pattern that encompasses the NI Common Basemat Structures foundation footprint and an area 40 feet beyond the boundaries of the foundation basemat footprint, plus the area that encompasses the other near surface-founded Seismic Category I structures for the U.S. EPR.

The 40-foot extension for the grid of borings is established from a Boussinesq analysis of the zone of influence of the foundation basemat which shows that the net change in the effective vertical overburden stress is less than 7 percent at a distance of 40 feet from the edge of the foundation basemat. The grid need not be of equal spacing in the two orthogonal directions, but it should be oriented in accordance with the true dip and strike of the rock. If geologic conditions are such that true dip and strike are not obvious, or if the dip is practically flat, then the orientation of the grid can be consistent with the major orthogonal lines of the NI Common Basemat Structures.

The depth of borings should be determined on the basis of the geologic conditions. Borings should be extended to a depth sufficient to define the site geology and to sample materials that may swell during excavation, may consolidate subsequent to construction, may be unstable under earthquake loading, or whose physical properties would affect foundation behavior or stability. At least one-fourth of the primary borings should penetrate sound rock or, for a deep soil site, to a maximum depth of 250 feet below the foundation basemat. At this depth of 250 feet, the change in the vertical stress during or after construction for the combined foundation loading is less than 10 percent of the in-situ effective overburden stress. Other primary borings may terminate at a depth of 160 feet below the foundation (i.e., equal to the equivalent radius of the structure). It is recommended that the shear wave velocity should be measured to a depth of 350 ft to 500 ft beneath the foundation basemat of the NI Common Basemat Structures. Thus, a limited number of borings should penetrate significantly deeper than the 250 ft criterion cited above.

2.5.4.10.5 Site Investigation for Non-uniform Sites

At sites that are judged to be non-uniform, potentially non-uniform, highly variable or potentially highly variable based on not meeting the criteria stated in Section 2.5.4.10.3, the investigation effort may have to be extended to determine if the site is acceptable for the U.S. EPR.

The U.S. EPR foundation/structural system for the NI Common Basemat Structures has significant margin. Therefore, it is expected that all but the most variable of sites will meet the criteria stated in Section 2.5.4.10.3. As stated in RG 1.132, where variable conditions are found, the spacing of boreholes should be closer to adequately define the media properties and their variability. Where cavities or other discontinuities of engineering significance may occur, the normal exploratory work should be supplemented by secondary borings or soundings at a spacing close enough to detect such features.

The depth of the secondary borings is 160 feet below the foundation basemat of the NI Common Basemat Structures. At this depth, the maximum change in vertical stress during or after construction is about 11 percent of the in-situ effective overburden stress. The depth of borings should be extended beyond 160 feet if the geologic investigation indicates the possible presence of karst conditions, under-consolidated clays, loose sands, intrusive dikes, or other forms of geologic impacts at depth greater than 160 feet.

2.5.4.11 Design Criteria

Section 3.8.5 provides design criteria and design methods used in analysis and design of foundations, including a description of computer programs used in the analyses and a description of soil loads on embedded walls.

2.5.4.12 Techniques to Improve Subsurface Conditions

Techniques used for improving subsurface conditions are site specific and will be addressed by the COL applicant.

2.5.5 Stability of Slopes

No slope failure potential is considered in the design of safety-related SSC in the U.S. EPR.

A COL applicant that references the U.S. EPR design certification will evaluate site-specific information concerning the stability of earth and rock slopes, both natural and manmade (e.g., cuts, fill, embankments, dams, etc.), of which failure could adversely affect the safety of the plant. As noted in Section 3.7.1, the evaluation of slope stability is performed for the seismic level of the site-specific GMRS.

2.5.6 References

1. NUREG/CR-6372, “Recommendations for Probabilistic Seismic Hazard Analysis: Guidance on Uncertainty and Use of Experts,” U.S. Nuclear Regulatory Commission, November 1997.

2. ASCE 4-98 Standard, “Seismic Analysis of Safety-Related Nuclear Structures and Commentary,” American Society of Civil Engineers, 1999.

3. ACI 318-2005, “Building Code Requirements for Structural Concrete and Commentary,” ACI Committee 318, American Concrete Institute, 2005.

4. NUREG/CR-0693, “Seismic Input and Soil–Structure Interaction,” Final Report, U.S. Nuclear Regulatory Commission, January 1979.