2. SITE ENVELOPE

This chapter discusses the site envelope for the AP1000 design, focusing on the geography and demography, nearby facilities, and postulated site parameters for the design, including meteorology, hydrology, geology, seismology, and geotechnical parameters. An applicant for a combined license (COL) for the AP1000 will establish the actual site characteristics with respect to these matters when it applies for a COL, or it will reference an early site permit (ESP) that reflects such characteristics. In either case, the COL applicant must show that the site parameters postulated for and considered in the AP1000 design adequately reflect the actual site characteristics. Should the postulated site parameters not encompass the actual site characteristics, the COL applicant will need to demonstrate by some other means that the proposed facility is acceptable at the proposed site. This might be done by reanalyzing or redesigning the proposed facility.

The staff of the U.S. Nuclear Regulatory Commission (NRC) based its evaluation of the site envelope on a thorough review of the AP1000 Design Control Document (DCD), Tier 2, Chapter 2, "Site Characteristics," as well as the applicant's responses to the staff's requests for additional information (RAIs).

2.1 Geography and Demography

The applicant stated in DCD Tier 2, Section 2.1, "Geography and Demography," that the geography and demography are site specific and will be defined by the COL applicant. In addition, DCD Tier 2, Section 2.1.1, "Combined License Information for Geography and Demography," states that COL applicants will provide site specific information related to site location and description, exclusion area authority and control, and population distribution. Because this information is site specific and will be provided by the COL applicant, the staff concludes that this is acceptable.

2.1.1 Site Location and Description

NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants," Section 2.1.1, "Site Location and Description," states that the site area which contains the reactors and associated principal plant structures will be reviewed to determine the distance from the reactor to the boundary lines of the exclusion area, including the direction and distance from the reactor to the nearest exclusion area boundary line. The location, distance, and orientation of plant structures, with respect to highways, railroads, and waterways which traverse or lie adjacent to the exclusion area, will be reviewed to ensure that they are adequately described to permit analyses (see Standard Review Plan (SRP) Section 2.2.3, "Evaluation of Potential Accidents") of the possible effects on the plant of accidents along these transportation routes. The description of the restricted area will be reviewed to verify that the information is adequate to determine general population doses from normal liquid and gaseous releases.

The acceptance criteria for site location and description are based on the relevant requirements of Title 10 of the Code of Federal Regulations (10 CFR) Part 20, "Standards for Protection Against Radiation". An applicant for a standard design certification must postulate values for site parameters as a basis for the plant design.

Site Envelope

The applicant stated in DCD Tier 2, Section 2.1.1, that site specific information on any particular site and its location will include political subdivisions, natural and man-made features, population, highways, railways, waterways, and other significant features of the area. The DCD includes this as a COL information item, identifies corresponding information discussed in the SRP, and specifies that it will be addressed by the COL applicant. Therefore, the COL information item is acceptable. This is COL Action Item 2.1.1-1.

2.1.2 Exclusion Area Authority and Control

SRP Section 2.1.2, "Exclusion Area Authority and Control," states that the applicant's legal authority to determine all activities within the designated exclusion area will be reviewed. This review will also establish that proposed activities in the exclusion area unrelated to operation of the reactor do not result in a significant hazard to the public health and safety.

Acceptance criteria are based on the relevant requirements of 10 CFR Part 100, "Reactor Site Criteria," regarding the applicant's legal authority with respect to the designated exclusion area.

The applicant stated in DCD Tier 2, Section 2.1.1, that site specific information on the exclusion area will include the size of the area and the exclusion area authority and control. The discussion will cover activity that may be permitted within the exclusion area. This COL information item identifies corresponding information discussed in the SRP and specifies that it will be addressed by the COL applicant. Therefore, the COL information item is acceptable. This is COL Action Item 2.1.2-1.

2.1.3 Population Distribution

SRP Section 2.1.3, "Population Distribution," states that the staff will review the population data in the site environs, as presented in the DCD, to determine whether the exclusion area boundary (EAB), low population zone (LPZ), and population center distance for the site comply with the requirements of 10 CFR Part 100.

The acceptance criteria are based on the relevant requirements in 10 CFR Part 100.

The applicant stated in DCD Tier 2, Section 2.1.1, that site specific information on population distribution will be included. This COL information item identifies the information discussed in the SRP and specifies that it will be addressed by the COL applicant. Therefore, the COL information item is acceptable. This is COL Action Item 2.1.3-1.

2.2 Nearby Industrial, Transportation, and Military Facilities

In DCD Tier 2, Section 2.2, "Nearby Industrial, Transportation, and Military Facilities," the applicant stated that each COL applicant referencing the AP1000 will provide analyses of accidents external to the nuclear plant. In particular, the applicant stated that COL applicants referencing the AP1000 certified design will provide site specific information related to the identification of potential accidents and verify the hazards in the vicinity of the site, including an

evaluation of potential accidents. The COL applicant will verify that the total annual frequency of a site specific potential hazard leading to severe consequences is less than 1E-6 per year. The COL applicant will identify and evaluate specific site-related hazards, including explosions, flammable vapor clouds, toxic chemicals, fires, and airplane crashes. The staff will not limit site safety reviews to this list of hazards. The staff will consider other site specific hazards, as appropriate, such as nearby marine traffic in the form of barges or other sizeable vessels potentially impacting plant cooling water intakes. The staff will review the analyses submitted by COL applicants using accident frequency and severity review methods and acceptance criteria described in SRP Sections 2.2.1, 2.2.2, "Identification of Potential Hazards in Site Vicinity," and 2.2.3. On this basis, the staff finds the approach described by the applicant for addressing site specific hazards to be acceptable. This is COL Action Item 2.2-1.

2.3 Meteorology

2.3.1 Regional Climatology

In DCD Tier 2, Table 2-1, "Site Parameters," and DCD Tier 2, Section 3.3, "Wind and Tornado Loadings," and DCD Tier 1, Table 5.0-1, "Site Parameters," the applicant specified meteorological parameters, such as air temperatures, humidity, precipitation, snow, wind, and tornado limits, for which the AP1000 is designed. In an RAI, the staff asked the applicant for references for the meteorological data used in the analyses that resulted in the selection of the site parameter values. In response, Westinghouse referenced the Electric Power Research Institute (EPRI) Advanced Light-Water Reactor (ALWR) Utility Requirements Document (URD). In a subsequent RAI, the staff asked the applicant for the technical basis for its selection of the values and the deviation of the tornado parameter from the recommendations of Regulatory Guide (RG) 1.76, "Design Basis Tornado for Nuclear Power Plants." The applicant responded that the deviation from RG 1.76 was based on SECY-93-087, "Policy, Technical, and Licensing Issues Pertaining to Evolutionary and Advanced Light-Water Reactor (ALWR) Designs," dated April 2, 1993.

The NRC staff acknowledges that the AP1000 is designed to the values referenced above, but does not claim that they are representative of any particular percentile of possible sites in the United States, nor does the staff assert the acceptability of the basis for the choice of the values with respect to siting. For example, the AP1000 is designed for a tornado wind speed of 134.1 m/sec (300 mph), as discussed in SECY-93-087. The staff notes that a letter dated March 25, 1988, from the NRC to the ALWR Utility Steering Committee identifies site specific design-basis wind speeds higher than 134.1 m/sec (300 mph) in some areas of the United States. Thus, a particular site may potentially be characterized by tornado wind speeds greater than 134.1 m/sec (300 mph). Therefore, the AP1000 design tornado wind speed may not apply for all sites.

In SRM SECY-03-0227, Review Standard RS-002, "Processing Applications for Early Site Permits," dated March 15, 2004, the Commission directed the staff to update the review guidance, including RG 1.76, to reflect more recent tornado wind speed data. This activity does not affect the design certification review of the AP1000. However, a COL applicant may have to

reconcile a particular site tornado wind speed if it is greater than the tornado wind speed used in the AP1000 design.

The applicant specified in DCD Tier 2, Sections 2.3.1, "Regional Climatology," and 2.3.6.1, "Regional Climatology," that the regional climatology is site specific and will be addressed by the COL applicant. This should include the provision of information sufficient to demonstrate that the design of the AP1000 falls within the site parameters specified by the siting review. The staff finds this acceptable. This is COL Action Item 2.3.1-1.

2.3.2 Local Meteorology

The applicant specified in DCD Tier 2, Sections 2.3.2, "Local Meteorology," and 2.3.6.2, "Local Meteorology," that the local meteorology is site specific and will be addressed by the COL applicant. This should include the provision of information sufficient to demonstrate that the design of the AP1000 falls within the site parameters specified by the siting review. The staff finds this acceptable. This is COL Action Item 2.3.2-1.

2.3.3 Onsite Meteorological Measurements Program

The applicant specified in DCD Tier 2, Sections 2.3.3, "Onsite Meteorological Measurement Programs," and 2.3.6.3, "Onsite Meteorological Measurements Program," that the onsite meteorological measurements program is site specific and will be addressed by the COL applicant. The staff finds this acceptable. This is COL Action Item 2.3.3-1.

2.3.4 Short-Term (Accident) Atmospheric Relative Concentration

In lieu of site-specific meteorological data, the applicant provided a set of hypothetical reference short-term atmospheric relative concentration (χ/Q) values for the AP1000 design for the control room, EAB, and LPZ, as specified in DCD Tier 2, Tables 2-1, 15A-5, "Offsite Atmospheric Dispersion Factors (χ/Q) for Accident Dose Analysis," and 15A-6, "Control Room Atmospheric Dispersion Factors (χ/Q) for Accident Dose Analysis," and DCD Tier 1, Table 5.0-1. The applicant stated that the EAB and LPZ values are representative of the 70^{th}–80^{th} percentile of operating U.S. nuclear power plant sites. The staff acknowledges that the AP1000 is designed to these values, but does not certify that they are representative of any particular percentile of possible sites in the United States. The χ/Q values for the EAB and LPZ are not based on any AP1000 design or operation inputs. Therefore, the COL review will address the methodology and all inputs and assumptions. For a selected site with any of the χ/Q values in excess of the bounding χ/Q values, the COL applicant will address how the radiological consequences associated with all design-basis accidents continue to meet the radiological dose consequence criteria given in 10 CFR 50.34(a)(1)(ii)(D)*(1) and (2)*. This is COL Action Item 2.3.4-1.

The control room χ/Q values shown in DCD Tier 2, Tables 2-1 and 15A-6, and DCD Tier 1, Table 5.0-1, are also not based on any AP1000 design or operation inputs. The staff initially asked the applicant if the methodology and all inputs and assumptions would be evaluated as part of the COL review. The applicant provided a detailed response stating that the COL

applicant would provide the methodology, inputs, and assumptions, as well as additional information about the analysis. The staff issued a second RAI to inquire if the applicant was seeking certification of any of the AP1000 design values used as inputs to the control room χ/Q calculations. The applicant subsequently provided certain design-specific information that was used as an input to the assessment and for which it was seeking certification. The staff identified unresolved issues related to adequate justification for assuming a diffuse release, estimation of initial sigma values, other release assumptions, building cross-sectional areas, and distances between release/receptor pairs. This was Open Item 2.3.4-1 in the draft safety evaluation report (DSER).

The applicant subsequently provided revised design information and assumptions in DCD Tier 2, Table 15A-7, "Control Room Source/Receptor Data for Determination of Atmospheric Dispersion Factors," and Figure 15A-1, "Site Plan with Release and Intake Locations." This information included the release and receptor heights and the distances between the release and receptor locations. The NRC staff reviewed this information and concluded that it was acceptable. Therefore, Open Item 2.3.4-1 is resolved.

The staff notes that all other inputs and assumptions related to the control room χ/Q values will be addressed by the COL applicant and reviewed by the staff. For a selected site with χ/Q values in excess of the bounding χ/Q values, the COL applicant will address how the radiological consequences associated with all design-basis accidents will stay within the control room operator dose limits given in General Design Criteria (GDC) 19, "Control Room," using site specific χ/Q values. This is COL Action Item 2.3.4-2.

The staff notes that the COL applicant may need to address additional short-term χ/Q values (e.g., 50^{th} percentile probability level conditions) assessed as part of the siting review. This is COL Action Item 2.3.4-3.

The staff concludes that successful completion of the COL action items listed above will demonstrate that the short-term (accident) atmospheric relative concentration estimates for the EAB, LPZ, and control room will be acceptable.

2.3.5 Long-Term (Routine) Diffusion Estimates

The applicant stated that the COL applicant referencing the AP1000 certified design will address long-term diffusion estimates and χ/Q values specified in DCD Tier 2, Section 2.3.5, "Long-Term Diffusion Estimates." For a selected site where the χ/Q value at or beyond the site boundary falls outside of the bounds of the site parameter for atmospheric dispersion, the COL applicant will address how the postulated radiological consequences will stay within the dose reference values given in 10 CFR 20.1301, "Dose Limits for Individual Members of the Public," and 50.34a, "Design Objectives for Equipment to Control Releases of Radioactive Material in Effluents-Nuclear Power Reactors," and 10 CFR Part 50, Appendix I, "Numerical Guides for Design Objectives and Limiting Conditions for Operation to Meet the Criterion 'As Low as is Reasonably Achievable' for Radioactive Material in Light-Water-Cooled Nuclear Power Reactor Effluents," using the site specific χ/Q values. This is COL Action Item 2.3.5-1.

Site Envelope

The staff notes that the COL applicant may need to address additional long-term χ/Q values (e.g., annual average values for 16 radial sectors to a distance of 50 miles from the plant) assessed as part of the siting review. This is COL Action Item 2.3.5-2.

The staff concludes that successful completion of the COL action items listed above will demonstrate that the long-term (routine release) relative concentration estimates will be acceptable.

2.4 Hydrologic Engineering

2.4.1 Hydrological Description

The AP1000 is a standard design with a plant configuration that assumes a normal water level at 0.6 m (2 ft) below the grade, and a flood level at the design plant grade of 30.5 m (100 ft). The actual grade level will be a few inches lower to prevent surface water ingress through the doorways. This provision recognizes that the URD states that the maximum flood (or tsunami) level site envelope parameter is 0.3 m (1 ft) below grade. Although the AP1000 design flood level of 30.5 m (100 ft) does not meet the URD flood level criterion explicitly, it does accommodate the intent of the URD.

The staff was concerned about the effect of probable maximum precipitation (PMP) at the plant site. Without adequate site drainage, the design flood level could be exceeded. The plant design is based on a PMP of 49.3 cm/hr (19.4 in./hr) and 16.0 cm/5 min (6 in./5 min). These amounts of local intense precipitation constitute the limit for the AP1000 standard design. Therefore, COL applicants must demonstrate that the PMP at the site does not exceed the design value, and that there is adequate site drainage to prevent the maximum flood level from exceeding the design elevation of 30.5 m (100 ft).

The staff also determined that future COL applicants should indicate whether the proposed PMP drainage system is fed by gravity or will employ active measures to ensure operational safety under the COL. Specifically, COL applicants should propose inspection and maintenance standards for the PMP drainage systems. In response, the applicant reiterated that the COL applicant will provide adequate site drainage because it is a site specific condition. The staff accepts the applicant's justification. The staff also noted that the standard design relies on the adequacy of the local drainage as a safety feature. The normal water level, the PMP, and the maximum flood level provide the design bases for this standard design and are incorporated into the plant postulated site parameter envelope as specified in DCD Tier 2, Table 2-1. The COL applicant will provide detailed site specific information on all other hydrological safety-related issues indicated below, including the effects of intense local precipitation:

- floods
- probable maximum precipitation on streams and rivers
- potential dam failures
- probable maximum surge and seiche flooding

- probable maximum tsunami flooding
- ice effects
- cooling water canals and reservoirs
- channel diversions
- flooding protection requirements
- cooling water supply
- ground water
- accidental releases of liquid effluents in ground and surface waters
- technical specifications and emergency operation requirements

The COL applicant should present the supporting information in accordance with the SRP to demonstrate the suitability of a specific site for the AP1000 design. The flood level and the ground water level design assumptions are practical and reasonable. An applicant for design certification must provide the site parameters used in the design, as well as an analysis and evaluation of the design in terms of these parameters. The information provided in DCD Tier 2 meets the requirements of 10 CFR 52.47(a)(1)(iii). These plant design parameters are compatible with the URD and are suitable for siting at most, but not all, potential sites for future plants in the United States. Accordingly, the staff finds the hydrological information provided by the applicant in the DCD to be reasonable and acceptable. The staff will apply the acceptance criteria from its review standards to any future COL application that references the AP1000 standard design, should it be certified. This is COL Action Item 2.4.1-1.

2.5 Geological, Seismological, and Geotechnical Engineering

The staff's review of the DCD and the applicant's responses to the related RAIs 241.001 through 241.003 provide the bases for this section of the safety evaluation. The AP1000 standard design is based on seismic and geotechnical design information consisting of the following:

- The free-field peak ground acceleration (PGA) is 0.3 g for the safe-shutdown earthquake (SSE).

- The free-field ground response spectra for both horizontal and vertical directions given in DCD Tier 2, Figures 3.7.1-1, "Horizontal Design Response Spectra Safe Shutdown Earthquake," and 3.7.1-2, "Vertical Design Response Spectra Safe Shutdown Earthquake," characterize the design ground motion.

- The seismic margin earthquake has a free-field peak ground acceleration value of 0.5 g. At this level, there is 95 percent confidence that there is only a 5 percent chance of failure of a structure, system, or component.

- The foundation material for locating the plant must be hard rock to ensure that the nuclear island (NI) structure will behave as though it is fixed at the base during a seismic excitation.

- For the purpose of characterizing hard rock, the material must have a minimum shear wave velocity of 2438 m/sec (8000 ft/sec) based on low strain properties over the entire footprint of the NI at its foundation level.

- The DCD indicates that the average allowable bearing capacity of the foundation material is 402 kPa (8600 psf) under static loading. The applicant's response to the RAIs listed above indicates that the capacity is 21.55 MPa (450,000 psf) for hard rock under dead plus seismic load conditions. The applicant's discussion about the 21.55 MPa (450,000 psf) bearing capacity of hard rock relates to a statement about the general capacity of hard rock material, and it does not imply that this capacity is needed for siting the certified design.

- Based on the calculations reviewed during the audit on April 2–5, 2003, the peak toe pressure at the foundation level is limited to 4.07 MPa (85,000 psf) for the dead plus seismic load conditions when the equivalent static analyses, including calculation of potential liftoff effects, were performed. DCD Tier 2, Section 3.8.5.5.1, "Nuclear Island Maximum Bearing Pressures," indicated that the maximum dynamic pressure from the combined load including the design-basis earthquake is less than 4.07 MPa (85,000 psf). Subsequent, the NRC staff conducted a detailed review of the seismic model and verified the calculations during the audit on October 6–9, 2003. As a result of these detailed reviews, the applicant has revised the maximum dynamic pressure to 5.75 MPa (120,000 psf) in the DCD. This value has been verified by analysis and review and is, therefore, appropriate (see DCD Tier 2, Section 2.5.4.2, "Bearing Capacity," and Table 2-1 under maximum allowable dynamic bearing capacity).

- The site must not have any potential for liquefaction.

The requirements of 10 CFR Part 52, Subpart A, "Early Site Permits," allow applications for an ESP separate from certification of the plant design. The relevant requirements for a COL application are specified in 10 CFR Part 52, Subpart C, "Combined Licenses". A COL applicant holding an ESP for the site at which it proposes to construct an AP1000 plant will have an approved set of site parameters that would be compared against the postulated site parameters used in this certified design. This comparison will demonstrate that the design of the facility falls within the characteristics specified in the ESP. COL applicants without an ESP who reference the AP1000 design will be required to provide site specific information related to basic geological, seismological, and geotechnical characteristics of the site and the region, as discussed in the following sections.

2.5.1 Basic Geologic and Seismic Information

COL applicants without an ESP who reference the AP1000 certified design should provide site specific geological, seismological, and geophysical information related to tectonic or seismic, non-tectonic, deformation conditions caused by human activities in the region of the site and areas local to the site. With respect to site geology, it is necessary to determine whether geologic features underlying the site affect the foundation design in terms of the following:

- dynamic behavior during prior earthquakes
- zones of alteration, irregular weathering, or zones of structural weakness
- unrelieved residual stresses in bedrock
- materials that could be unstable because of their mineralogy or unstable physical properties
- effect of human activities in the area

The DCD Tier 2 information, while listing certain site specific aspects of basic geologic and seismic information to be provided by a COL applicant referencing the AP1000 certified design, does not include some of the attributes discussed above. The staff discussed this issue with the applicant during the audit on April 2–5, 2003. This was Open Item 2.5.1-1 in the DSER.

The applicant addressed this issue in DCD Tier 2, Section 2.5.1, "Basic Geological and Seismic Combined License Information," which included all the attributes of site geology related to geologic features underlying the site and their effects on the foundation design. Therefore, Open Item 2.5.1-1 is resolved. This is COL Action Item 2.5.1-1.

2.5.2 Vibratory Ground Motion

COL applicants without an ESP who reference the AP1000 certified design should provide site specific information related to seismicity, geologic and tectonic characteristics of the site and region, correlation of earthquake activity with seismic sources, probabilistic seismic hazard analysis, controlling earthquakes, seismic wave transmission characteristics of the site, and the SSE ground motion. The DCD Tier 2 information lists a number of these criteria; however, it should include probabilistic seismic hazard analysis, including the definition of controlling earthquakes. The staff discussed this issue with the applicant during the audit on April 2–5, 2003. This was Open Item 2.5.2-1 in the DSER.

The staff verified that the DCD was revised to include the need for the COL applicant to conduct site specific probabilistic seismic hazard analysis. Therefore Open Item 2.5.2-1 is resolved. This is COL Action Item 2.5.2-1.

In DCD Tier 2, Section 2.5.2.3, "Sites with Geoscience Parameters Outside the Certified Design," the applicant discussed geoscience parameters outside the certified design. In this section, the applicant indicated the steps that the COL applicant needs to take for conducting site specific soil-structure-interaction analyses and developing in-structure response spectra at specific locations on the NI, and then comparing this information against the corresponding in-structure response spectra at 5 percent damping values from the certified design. The NRC staff determined the specified locations that are critical in terms of the potential for amplification, locations of important equipment, etc. Consistent with the concept of critical locations, the NRC staff also required that the DCD include critical structural details within the certified design, reflecting areas with the highest structural forces and bending moments. The

details of the critical sections are designated as Tier 2* information and cannot be changed without NRC approval. Thus, the DCD describes steps containing applicable criteria from the SRP, and it includes the critical section details. This process should ensure that a COL application for a site outside the site parameters of this certified design could follow well-laid-out steps leading to a safe and acceptable design that adapts the AP1000 design for specific site conditions.

The AP1000 is designed for an SSE defined by a free-field PGA value of 0.3 g, and an associated set of ground motion response spectra for horizontal and vertical directions, as shown in DCD Tier 2, Figures 3.7.1-1 and 3.7.1-2. These response spectra are applied at the foundation level (Elevation 18.3 m (60 ft)) in the free field for the analysis and design of the AP1000. This design ground motion is higher than the SSE for any of the currently licensed nuclear power plants east of the Rocky Mountains. These design ground motion spectra are compatible with the URD and suitable for siting at most, but not all, potential sites for future plants in the United States. COL applicants will compare site specific earthquake ground motions to the ground motions used as input for the design certification. COL applicants will demonstrate that the site specific response spectra at the foundation level (18.3 m (60 ft) below the free surface in the free field) are enveloped by the ground motion spectra used as input for the design certification (as shown in DCD Tier 2, Figures 3.7.1-1 and 3.7.1-2). The site specific response spectra should be developed at 18.3 m (60 ft) below the free surface in the free field, taking into account the site specific soil amplification. In addition, COL applicants should assure that the site specific response spectra at the foundation level 18.3 m (60 ft) below the finished plant grade in the free field are less than or equal to the spectra given in DCD Tier 2, Figures 3.7.1-1 and 3.7.1-2.

COL applicants should also verify that the shear wave velocity of the bedrock is greater than or equal to 2438 m/sec (8000 ft/sec). In addition, COL applicants should demonstrate that the lateral earth pressures from the site specific construction techniques do not exceed the AP1000 certified design values, as specified in the interface requirement (see Open Item 3.8.5.4-2). Section 2.5.4 of this report further discusses this issue.

Based on the resolution of the Open Item 2.5.2-1, and the discussion provided above, the staff concludes that the information provided in the DCD on vibratory ground motion is reasonable and acceptable because it conforms with the probabilistic seismic hazard analysis criteria found in the SRP and RG 1.165, “Identification and Characteristics of Seismic Sources and Determination of Safe-Shutdown Earthquake Ground Motion.” This is COL Action Item 2.5.2-2.

2.5.3 Surface Faulting

The AP1000 DCD Tier 2 information provides for COL applicants referencing the AP1000 certified design to address surface and subsurface geological and geophysical information, including the potential for surface or near-surface faulting affecting the site. The presence or absence of any surface faulting at a specific site will affect its seismic hazard and the basic seismic characteristics of the site. The COL applicant must demonstrate that the proposed site is suitable for siting a specific standard design, in accordance with 10 CFR 52.79, “Contents of Applications; Technical Information.” This regulatory requirement in 10 CFR 52.79(a)(1) states

that, in general, if the application references an ESP, the application need not contain information or analyses submitted to the Commission in connection with the ESP, but must contain, in addition to the information and analyses otherwise required, information sufficient to demonstrate that the design of the facility falls within the parameters specified in the ESP. The AP1000 clearly identifies the site-related parameters for which the design was analyzed and evaluated. These design parameters are reasonable and suitable for most available sites in the United States, and the influence and effects of surface faulting on the controlling site parameters for the AP1000 design are specific to a site. These plant design parameters are compatible with the URD and are suitable for siting at most, but not all, potential sites for future plants in the United States. This is acceptable to the staff. This is COL Action Item 2.5.3-1.

An applicant for design certification must provide the postulated site parameters used in the design, and an analysis and evaluation of the design in terms of these parameters. The information in AP1000 DCD Tier 2 meets this requirement. The NRC staff will apply the acceptance criteria from its review standards to any future COL application that references the AP1000 standard design, should it be certified.

2.5.4 Stability of Subsurface Materials and Foundations

The staff requested the applicant to indicate in the DCD Tier 2 information that the COL applicant will provide site specific information demonstrating that the geotechnical characteristics of the site bound the design analysis assumptions given in DCD Tier 2, Table 2-1. The COL applicant should address the criteria provided in SRP, Section 2.5.4, "Stability of Subsurface Materials and Foundations". The applicant has discussed its standard design attributes related to the following:

- excavation
- bearing capacity
- settlement
- liquefaction
- subsurface uniformity

The DCD describes the need to establish a vertical face below the grade with lateral support of the adjoining undisturbed soil or rock and suggests the use of soil nailing to stabilize the vertical soil surface as an alternative method for achieving this provision. The stability of the nailed soil surface will depend on the length and depth of the soil anchors or nails. One result of this proposed construction technique is that the soil immediately surrounding the NI consists only of natural in situ materials, which have relatively continuous properties in the horizontal and vertical directions. Because this configuration conforms to the assumptions made in the seismic analyses performed to assess the seismic responses of the NI structures, the NRC staff considers the proposed excavation method acceptable. However, during discussions with the applicant in November 2002, the staff noted that the COL applicant should also show that the existing in situ soil satisfies the minimum conditions (in terms of soil parameters) assumed for the design of the AP1000 foundation and exterior walls. In addition, if the in situ soils are not appropriate for the use of soil nailing excavation techniques, the COL applicant should show that any other construction method planned for the excavation satisfies the assumptions of the

NI design. If the COL applicant proposes any other construction technique requiring excavation and backfill of large areas surrounding the NI, the COL applicant should also submit the procedures and criteria for installing the backfill for review and approval by the NRC. In addition, the COL applicant should perform an evaluation of the effect of any alternative construction procedures on the seismic responses of the NI structures. The applicant must specify the amount of lateral passive pressure used in the design of the NI as an interface requirement for the COL applicant. The staff discussed this issue with the applicant during the audit on April 2–5, 2003. This was Open Item 2.5.4-1 in the DSER.

In DCD Tier 2, Section 2.5.4.5, "Combined License Information," the applicant stated the site conditions that the COL applicant must address. The site attributes relate to properties of underlying material, properties of materials adjacent to NI exterior walls, and laboratory investigations of underlying materials. In addition, DCD Tier 2, Section 2.5.4.5.2 discusses the properties of material adjacent to the NI exterior walls and specifies minimum submerged soil density and the angle of internal friction. Because the exterior walls of the NI structure are designed with full passive pressure, the COL applicant need not control the exterior wall pressure as an interface requirement. In addition, DCD Tier 2, Section 2.5.4.5.3 provides requirements for excavation and backfill that the COL applicant must meet regarding static and dynamic engineering properties of materials to be used for the backfill at a specific site, the compaction requirements for fill materials, and the details of a soil retention system, such as the soil nailing method. The NRC staff must approve the methods proposed by the COL applicant. At the COL application review stage, it will be necessary to ensure that the NI exterior walls are not subjected to localized pressure from overburden loads during the construction phase. Additional details on the COL applicant requirements for excavation and backfill were explained in Revision 2 of the applicant's response to RAI 230.23 and in the DCD. Therefore, Open Item 2.5.4-1 is resolved.

The DCD also specifies that the mudmat beneath the foundation mat will be designed as plain concrete, in conformance with the criteria of the American Concrete Institute Standard 318-02, with a minimum compressive strength of 17.24 MPa (2500 psi). Section 3.8.5.1 of this report includes a reference to the mudmat and its strength requirements. The specification of minimum strength for the lean concrete used as a base of the NI basemat is acceptable because it meets a broadly accepted consensus industry standard.

Based on the discussion above, the staff concludes that the information provided in the DCD on the stability of subsurface materials and foundations contains sufficient details to ensure the safe design and construction of a future AP1000 plant at a specific site. The staff finds this reasonable and acceptable. This is COL Action Item 2.5.4-1.

2.5.4.1 Bearing Capacity

The bearing capacity of the subgrade is a fundamental design parameter for this standard design. In the design of the foundation of a large structure, it is important to ensure that, under normal operating conditions, the average pressure on the subgrade is less than the allowable average bearing capacity of the foundation material, and that the peak subgrade pressure caused by the load combination with the SSE imposing the largest toe pressure at the edge of

the foundation is also within the allowable capacity of the subgrade. Settlement or crushing governs the allowable bearing capacity of the subgrade. Under relatively soft soil conditions, short-term soil movement due to water table fluctuation and long-term settlement due to the superimposed loading affect the allowable bearing capacity. Under hard rock subgrade conditions, the bedding direction of rock layers and the level of cracking and other discontinuities in the matrix of the rock material can limit the allowable average and allowable peak bearing capacity. The applicant's response to the staff's RAIs indicates that the bearing capacity at a hard rock site will exceed 21.55 MPa (450,000 psf). During the audit on April 2–5, 2003, the staff requested the applicant to clearly specify, in the DCD, that this standard design is based on an allowable average and an allowable peak bearing capacity. The staff also asked the applicant to specify the value of these parameters. This was Open Item 2.5.4-2 in the DSER.

The applicant revised DCD Tier 2, Section 2.5.4.2, "Bearing Capacity," to specify that the maximum bearing pressure is less than 827.37 MPa (120,000 psi), and DCD Tier 2, Table 2-1 to specify both the average static bearing capacity and the maximum dynamic bearing capacity values. Therefore, Open Item 2.5.4-2 is resolved.

2.5.4.2 Settlement

As stated in DCD Tier 2, Section 3.2, "Classification of Structures, Components, and Systems," the NI is the only seismic Category I structure in the AP1000 standard design. Differential settlement between the NI foundation and the foundations of adjacent buildings does not have any adverse effect on the safety-related functions of structures, systems, and components. Differential settlement under the NI foundation could cause the basemat and the building to tilt. In the narrow direction, the NI foundation width is 49.8 m (163 ft 6 in.) and the height above the bottom of the basemat is 83.3 m (273 ft 3 in.). Assuming a basemat tilt of 10.2 cm (4 in.), the rigid body tilt at the highest point can be 15–18 cm (6–7 in.). Under seismic excitation there will be an elastic deformation relative to the base. The addition of these two effects will diminish the annular space between the shield building and the containment structure and could also affect the functionality of the crane inside the containment and other sensitive components. The DCD does not provide any quantitative justification as to why a basemat tilting of a few inches will not affect functionality of structures, systems, and components. The staff discussed this issue with the applicant during the audit on April 2–5, 2003. This was Open Item 2.5.4-3 in the DSER.

In a subsequent audit (October 6–9, 2003) of the calculations of seismic response of the NI structure, the staff verified the validity of the rigid response characteristics relating to the basemat. This rigidity results from the thick concrete basemat surrounding the bottom of the steel containment and the radial walls of the NI structure; therefore, there will be negligible relative elastic deformation due to seismic excitation. In addition, because the rock formation and the bearing capacity of the subgrade must both be uniform, the NI settlement, if any, should also be uniform. The staff has concluded that overall tilting of the NI due to differential settlement will be minimal, and it should not cause any equipment malfunction by obstruction to freely suspended lifting rigs inside the containment. Therefore, Open Item 2.5.4-3 is resolved.

2.5.4.3 Liquefaction

The DCD clearly states that the COL applicant will demonstrate that the potential for liquefaction is negligible. The design site condition is hard rock with a minimum shear wave velocity of 2438 m/sec (8000 ft/sec) at the foundation level, so the subgrade at the foundation level has no liquefaction potential. The COL applicant must demonstrate that there is negligible soil liquefaction potential at the free-field grade level for the SSE level of 0.3 g PGA, as well as the margin level earthquake of 0.5 g PGA. In DCD Tier 2, Table 2-1, the applicant stated that sites will have no liquefaction potential at the site specific SSE level. This is acceptable to the staff. COL applicants should demonstrate that no liquefaction potential exists at the SSE level for the site for soils under and around all seismic Category I structures. COL applicants should also justify the selection of the soil properties, as well as the magnitude, duration, and number of excitation cycles of the earthquake used in the liquefaction potential evaluation (e.g., laboratory tests, field tests, and published data). COL applicants should demonstrate the testing methods for review and approval by the staff. In addition, COL applicants should perform a soil liquefaction evaluation at 1.67 times the site specific SSE ground motion. This would ensure that any potential failure of the foundations of the turbine building or the waste processing building that are adjacent to the NI would have no adverse impact. The staff finds the information provided by the applicant in the DCD on liquefaction reasonable and acceptable. This is COL Action Item 2.5.4.3-1.

2.5.4.4 Subsurface Uniformity

This standard design is based on the assumption of uniform hard rock conditions with a minimum shear velocity of 2438 m/sec (8000 ft/sec) and negligible liquefaction potential. The AP1000 DCD indicates that the NI structures, consisting of the containment building, shield building, and auxiliary building, are founded on a common 1.8 m (6 ft) thick, cast-in-place, reinforced concrete basemat foundation (see Section 3.8.5 of this report for a discussion of the foundation design). The top of the foundation is specified to be at Elevation 20.3 m (66.5 ft), with the bottom of the basemat at 18.4 m (60.5 ft), assuming a nominal elevation of the free-grade surface of 30.5 m (100 ft).

The AP1000 NI houses all seismic Category I structures and is supported on a single foundation mat with exterior and interior walls rigidly connecting the shield building (including the reactor containment vessel and containment internal structures) and auxiliary buildings to the foundation mat. This system of interconnected vertical shear walls and horizontal floor slabs or diaphragms results in a monolithic reinforced concrete structure design, allowing all loads applied to the structure to engage all parts of the structure. The seismic and dead loads generated from the auxiliary and the shield buildings are then transferred to the foundation mat. The design of critical foundation mat panels is based on the assumption of uniform subgrade reaction.

A fixed-base seismic analysis has been used to analyze the seismic loads and is suitable for hard rock sites with no soil-structure interaction effect. The design of the foundation mat assumes uniformity of the subgrade reaction. Although the DCD specifies a minimum shear

wave velocity of 2438 m/sec (8000 ft/sec), the subgrade reaction values were kept uniform. The mat design does not incorporate any effect of hard spot areas in the subgrade potentially causing higher subgrade reactions during the mat uplift and slapdown under seismic loading. Consequently, the COL applicant should demonstrate that the subgrade is uniform at the foundation level.

The DCD describes in detail the types of investigation that will be necessary on the part of the COL applicant when special site conditions exist, such as sloping bedrock sites, undulating bedrock sites, and geologically impacted sites. This elaboration provides greater assurance of the adequacy of the site characterization necessary for this standard design. Careful consideration has been given to the COL information included in DCD Tier 2, Section 2.5.4.5, to ensure suitability of the subgrade below the foundation mat, as well as the overburden material that will be in contact with the walls below the finished grade. Each attribute of the necessary COL information corresponds to the design assumptions of the AP1000. These standards are in addition to the generic guidelines for site investigation provided in SRP Section 2.5.4.

An applicant for design certification must provide the postulated site parameters used in the design, as well as an analysis and evaluation of the design in terms of these parameters. The AP1000 DCD Tier 2 information meets this requirement. The NRC staff will apply the acceptance criteria from its review standards to any future COL application that references the AP1000 standard design, should it be certified. The staff finds the information provided by the applicant in the DCD on subsurface uniformity reasonable and acceptable because it acknowledges that site parameter information is required to satisfy the regulation.

2.5.5 Stability of Slopes

The AP1000 DCD provides for the COL applicant to address site-specific information about static and dynamic stability of soil and rock slopes, the failure of which could adversely impact the safety of the nuclear island. An applicant for design certification must provide the postulated site parameters used in the design, as well as an analysis and evaluation of the design in terms of these parameters. The AP1000 DCD Tier 2 information meets this requirement. The NRC staff will apply the acceptance criteria from its review standards to any future COL application that references the AP1000 standard design, should it be certified. The staff finds the information provided by the applicant in the DCD on stability of slopes reasonable and acceptable because the standard design application is independent of any site specific condition. This is COL Action Item 2.5.5-1.

2.5.6 Embankments and Dams

The AP1000 DCD provides for the COL applicant to address site-specific information about embankments and dams, the failure of which could adversely impact the safety of the nuclear island. An applicant for design certification must provide the site parameters used in the design, as well as an analysis and evaluation of the design in terms of these parameters. The AP1000 DCD Tier 2 information meets this requirement. The NRC staff will apply the acceptance criteria from its review standards to any future COL application that references the

AP1000 standard design, should it be certified. The staff finds the information provided by the applicant in the DCD on embankments and dams reasonable and acceptable because the standard design application is independent of any site specific condition. This is COL Action Item 2.5.6-1.

2.6 COL Action Items

DCD Tier 2, Sections 2.4.1.1, 2.5.2.3, and 2.5.4.5, include combined license information items in which the staff has determined not be applicable to the design certification review. These items are repeated below.

- Hydrological Description - Combined License applicants referencing the AP1000 certified design will describe major hydrologic features on or in the vicinity of the site including critical elevations of the nuclear island and access routes to the plant. [This is COL Action Item 2.6-1.]

- Geoscience Parameters - Site-specific soil structure interaction analyses must be performed by the Combined License applicant to demonstrate acceptability of sites that have seismic and soil characteristics outside the site parameters in DCD Tier 2, Table 2-1. These analyses would use the site specific soil conditions (including variation in soil properties in accordance with Standard Review Plan 3.7.2). The three components of the site specific ground motion time history must satisfy the enveloping criteria of Standard Review Plan 3.7.1 for the response spectrum for damping values of 2, 3, 4, 5, and 7 percent and the enveloping criterion for power spectral density function. Floor response spectra determined from the site specific analyses should be compared against the design basis of the AP1000 described above. Member forces in each of the sticks should be compared against those given in DCD Tier 2, Tables 3.7.2-11 to 3.7.2-13. These evaluations and comparisons will be provided and reviewed as part of the Combined License application. [This is COL Action Item 2.6-2.]

- The Combined License applicant will establish the properties of the foundation soils to be within the range considered for design of the nuclear island basemat.

  Properties of Underlying Materials - A determination of the static and dynamic engineering properties of foundation soils and rocks in the site area will be addressed. This information will include a discussion of the type, quantity, extent, and purpose of field explorations, as well as logs of borings and test pits. Results of field plate load tests, field permeability tests, and other special field tests (e.g., bore-hole extensometer or pressuremeter tests) will also be provided. Results of geophysical surveys will be presented in tables and profiles. Data will be provided pertaining to site-specific soil layers (including their thicknesses, densities, moduli, and Poisson's ratios) between the basemat and the underlying rock stratum. Plot plans and profiles of site explorations will be provided.

Properties of Materials Adjacent to Nuclear Island Exterior Walls - A determination of the static and dynamic engineering properties of the surrounding soil will be made to demonstrate they are competent and provide passive earth pressures greater than or equal to those used in the seismic stability evaluation for sliding of the nuclear island. Seismic stability requirements are satisfied if the soil layers adjacent to the nuclear island foundation are composed predominantly of rock, or sand and rock (gravel), or sands that can be classified as medium to dense (standard penetration test having greater than 10 blows per foot). If the soil adjacent to the exterior walls is made up of clay, sand and clay, or other types of soil other than those classified above as competent, then the Combined License applicant will evaluate the seismic stability against sliding as described in [DCD Tier 2, Section] 3.8.5.5.3 using the site-specific soil properties, or ensure that the soils have properties that exceed the following:

Submerged soil density of 60 pounds/ft^3
Angle of internal friction of 32 degrees

Laboratory Investigations of Underlying Materials - Information about the number and type of laboratory tests and the location of samples used to investigate underlying materials will be provided. Discussion of the results of laboratory tests on disturbed and undisturbed soil and rock samples obtained from field investigations will be provided. [This is COL Action Item 2.6-3.]

- Bearing Capacity - The Combined License applicant will verify that the site-specific allowable soil bearing capacities for static and dynamic loads are equal to or greater than the values documented in [DCD Tier 2,] Table 2-1, or will provide a site specific evaluation as described in [DCD Tier 2, Section] 2.5.4.2. The acceptance criteria for this evaluation are those of Standard Review Plan 2.5.4 as follows:

  The static and dynamic loads, and the stresses and strains induced in the soil surrounding and underlying the nuclear island, are conservatively and realistically evaluated.

  The consequences of the induced soil stresses and strains, as they influence the soil surrounding and underlying the nuclear island, have been conservatively assessed.

  [This is COL Action Item 2.6-4.]

- Subsurface Instrumentation - Data will be provided on instrumentation, if any, proposed for monitoring the performance of the foundations of the nuclear island. This will specify the type, location, and purpose of each instrument, as well as significant details of installation methods. The location and installation

procedures for permanent benchmarks and markers for monitoring the settlement will be addressed. [This is COL Action Item 2.6-5.]