2.0 SITE CHARACTERISTICS

This chapter of the North Anna 3 combined license (COL) Final Safety Analysis Report (FSAR) addresses the geological, seismological, hydrological, and meteorological characteristics of the site and vicinity, in conjunction with present and projected population distributions and land use and site activities and controls

2.0.1 Introduction

The site characteristics are used to demonstrate that the applicant has accurately described the site characteristics and site parameters, together with site-related design parameters and design characteristics, in accordance with 10 CFR Part 52. For a COL application referencing a design certification (DC) and an early site permit (ESP), the staff's review focuses on the applicant's demonstration that the site characteristics and site-related design parameters specified in the ESP fall within the site parameters and design characteristics specified in the DC.

2.0.2 Summary of Application

Section 2.0 of the North Anna 3 COL FSAR incorporates by reference Section 2.0 of the Economic Simplified Boiling-Water Reactor (ESBWR) design certification document (DCD), Revision 5. In addition, FSAR Section 2.0 incorporates by reference ESP-003 for the North Anna ESP Site, issued pursuant to 10 CFR 52.24, and documents related thereto (e.g., North Anna ESP Application Site Safety Analysis Report (SSAR), Revision 9).

In addition, in FSAR Section 2.0, the applicant provided the following information:

COL Items

- NAPS COL 2.0-1-A Site Characteristics Demonstration

The applicant provided Table 2.0-201 in response to this COL item. Part 1 of Table 2.0-201 identifies each DCD site parameter value and the corresponding ESP and Unit 3 site characteristic values. In addition, Part 1 provides an evaluation, as applicable, of whether (1) ESP site characteristic values fall within DCD site parameter values; (2) Unit 3 site characteristic values fall within DCD site parameter values; and (3) Unit 3 site characteristic values fall within ESP site characteristic values.

- NAPS COL 2.0-2-A through 2.0-30-A Standard Review Plan Conformance

In response to these COL items, the applicant provided detailed information related to Unit 3 site characteristics in FSAR Sections 2.1 through 2.5, which incorporate by reference the corresponding ESP SSAR sections. In addition, the applicant provided Table 2.0-2R, which brings forward the ESBWR DCD Table 2.0-2, "Limits Imposed on Acceptance Criteria in Section II of SRP by ESBWR Design" and identifies specific COL items. In Table 2.0-2R, the COL Item from the DCD is replaced with information responding to the COL item and identifying the FSAR section that addresses the SRP section invoked by the COL item.

Supplemental Information

- NAPS SUP 2.0-1

The applicant provided Part 2 of Table 2.0-201 as supplemental information. Part 2 of Table 2.0-201 identifies those ESP site characteristics and design parameters for which there is no corresponding DCD site parameter value. Part 2 also evaluates whether the Unit 3 site characteristic or facility design value falls within the ESP site characteristic or ESP design parameter value.

- NAPS SUP 2.0-2

The applicant provided Part 3 of Table 2.0-201 as supplemental information. Part 3 of Table 2.0-201 identifies those site characteristics and design parameters listed in SSAR Table 1.9-1, for which there is not already a comparison to a corresponding DCD or ESP value in the first two parts of Table 2.0-201. Part 3 also evaluates whether the Unit 3 site characteristic or facility design value falls within the SSAR Table 1.9-1 site characteristic or design parameter value.

2.0.3 Regulatory Basis

The applicable regulatory requirements are the following:

- 10 CFR 52.79(a)(1)(i)-(vi) provides the site-related contents of a COL application.

- 10 CFR 52.79(b) applies to a COL referencing an ESP as the COL relates to information sufficient to demonstrate that the design of the facility falls within the site characteristics and design parameters specified in the ESP.

- 10 CFR 52.79(d)(1) applies to a COL referencing a DC as the COL relates to information sufficient to demonstrate that the characteristics of the site fall within the site parameters specified in the DC.

The related acceptance criteria are the following:

- The acceptance criteria associated with specific site characteristics/parameters and site-related design characteristics/parameters are contained in the related sections of SRP Chapter 2 or other referenced SRP sections.

For a COL application referencing an ESP and a DC, acceptance is based on the applicant's demonstration that the site characteristics and site-related design parameters specified in the ESP fall within the site parameters and design characteristics specified in the DC. If the actual site characteristics do not fall within the certified standard design site parameters, the COL applicant should provide sufficient justification (e.g., by request for a variance from the ESP) that the proposed facility is acceptable at the proposed site.

2.0.4 Technical Evaluation

The U.S. Nuclear Regulatory Commission (NRC) staff reviewed Section 2.0 of the North Anna 3 COL FSAR and considered the referenced DCD. The staff's review confirmed that the information contained in the application and incorporated by reference addresses the relevant information related to this introductory section. Section 2.0 of the ESBWR DCD is being reviewed by the NRC staff on Docket No. 52-010. The staff's technical evaluation of the information incorporated by reference will be documented in the corresponding safety evaluation report (SER).

The staff reviewed the information in the COL FSAR. The technical evaluation is provided in Sections 2.1 through 2.5 of this SER.

2.0.5 Post Combined License Activities

There are no post COL activities associated with this section.

2.0.6 Conclusion

NRC staff reviewed the application and considered the referenced ESBWR DCD. The staff's review confirmed that the applicant has addressed the relevant information and no outstanding information is expected to be addressed in the COL FSAR related to this section.

The staff is reviewing the information in DCD Section 2.0 on Docket No. 52-010. The results of the staff's technical evaluation of the information incorporated by reference in the North Anna 3 COL FSAR will be documented in the SER for the ESBWR DC. The SER for the ESBWR is not yet complete and is being tracked as part of **Open Item [1-1]**. The staff will update Section 2.0 of this SER to reflect the final disposition of the DC application.

Conclusions related to the staff's evaluation of information contained in the COL FSAR are provided in Sections 2.1 through 2.5 of this SER.

2.1 <u>Geography and Demography</u>

2.1.1 Site Location and Description

2.1.1.1 *Introduction*

Descriptions of the site area and reactor location are used to assess the acceptability of the reactor site. This review covers the following specific areas: (1) specification of reactor location with respect to latitude and longitude, political subdivisions; and prominent natural and manmade features of the area; (2) site area map to determine the distance from the reactor to the boundary lines of the exclusion area, including consideration of the location, distance, and orientation of plant structures with respect to highways, railroads, and waterways that traverse or lie adjacent to the exclusion area; and (3) any additional information requirements prescribed within the "Contents of Application" sections of the applicable subparts to the Title of the 10 *Code of Federal Regulations* (CFR) Part 52. The purpose of the review is to ascertain the accuracy of the applicant's description for use in independent evaluations of the exclusion area authority and control, the surrounding population, and nearby manmade hazards.

2.1.1.2 *Summary of Application*

This section of the FSAR incorporates by reference ESP SSAR Section 2.1.1 and includes supplemental information. The applicant supplemented the information as follows:

COL Items

- NAPS COL 2.0-2-A Site Location and Description

The North Anna Power Station (NAPS) COL 2.0-2-A resolves DCD COL Item 2.0-2-A by addressing the provision of site specific information related to site location and description, including political subdivisions, natural and manmade features, population, highways, railways, waterways, and other significant features of the area. The site specific information needed to address DCD COL Item 2.0-2-A in the North Anna 3 FSAR is incorporated by reference to ESP SSAR Section 2.1.1.

- NAPS ESP COL 2.1-1 Coordinates of the Unit 3 Reactor Building

The applicant provided supplemental information on the coordinates of the Unit 3 reactor building.

2.1.1.3 *Regulatory Basis*

The regulatory basis for incorporating information by reference into the ESP SSAR is 10 CFR 52.79(b), which states (in part) that if a COL application references an ESP, then the FSAR need not contain information or analyses submitted to the Commission in connection with the ESP, provided that the FSAR must either include or incorporate by reference the ESP SSAR and must contain, in addition to the information and analyses otherwise required, sufficient information to demonstrate that the design of the facility falls within the site characteristics and design parameters specified in the ESP.

The applicable regulatory requirements for identifying the site location and description are:

1. 10 CFR Part 50 and 10 CFR Part 52, as they relate to inclusion in the Safety Analysis Report (SAR) of a detailed description and safety assessment of the site on which the facility is to be located, with appropriate attention to features affecting facility design (10 CFR 50.34(a)(1)) and 10 CFR 52.79(a)(1)).

2. 10 CFR Part 100, as it relates to the following: (1) defining an exclusion area and setting forth requirements regarding activities in that area (10 CFR 100.3); (2) addressing and evaluating factors that are used to determine the acceptability of the site as identified in 10 CFR 100.20(b); (3) determining an exclusion area where certain dose limits would not be exceeded in the event of a postulated fission product release, as identified in 10 CFR 50.34(a)(1) as it relates to site evaluation factors identified in 10 CFR Part 100; and (4) requiring that the site location and the engineered features included as safeguards against the hazardous consequences of an accident, should one occur, should ensure a low risk of public exposure.

The acceptance criteria presented in the ESP SSAR are based on meeting the following relevant requirements of 10 CFR Parts 52 and 100.

The related acceptance criteria are:

1. Specification of Location: The information submitted by the applicant is adequate and meets the requirements of 10 CFR 50.34(a)(1) and 10 CFR 52.79(a)(1) if it describes highways, railroads, and waterways that traverse the exclusion area in sufficient detail to allow the reviewer to determine that the applicant has met the requirements in 10 CFR 100.3.

2. Site Area Map: The information submitted by the applicant is adequate and meets the requirements of 10 CFR 50.34(a)(1) and 10 CFR 52.79(a)(1) if it describes the site location, including the exclusion area and the location of the plant within the area, in sufficient detail to enable the reviewer to evaluate the applicant's analysis of a postulated fission product release, thereby allowing the reviewer to determine (in NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants" (SRP) Sections 2.1.2 and 2.1.3 and Chapter 15) that the applicant has met the requirements of 10 CFR 50.34(a)(1) and 10 CFR Part 100.

2.1.1.4 *Technical Evaluation*

The NRC staff reviewed Subsection 2.1.1 of the North Anna 3 COL FSAR and checked the referenced ESP SSAR. The staff's review confirmed that the information contained in the application and incorporated by reference addresses the relevant information related to site location and description.

The applicant incorporated by reference ESP SSAR Subsection 2.1.1 to resolve DCD COL Item 2.0-2-A, related to the site location and description, including political subdivisions, natural and manmade features, population, highways, railways, waterways, and other significant features of the area included under Section 2.1 of the COL FSAR, along with supplemental information.

- The staff's technical evaluation of this application is limited to reviewing the supplemental information pertaining to NAPS COL Item 2.0-2-A and NAPS ESP COL Item 2.1-1.

The applicant provided the following supplemental information regarding the site location:

- The site layout and boundary for the proposed North Anna Unit 3, shown in Figure 2.1-201 of the COL FSAR, remains within the ESP proposed facility boundary as shown in Figure 2.0-205 of the COL FSAR. The center of the Unit 3 reactor building is approximately 450 meters (1,476 feet) southwest of the center of the Unit 2 Containment Building.

- NRC staff has independently estimated and verified the following latitude and longitude and universal transverse mecator (UTM) coordinates of the proposed NAPS Unit 3 site in the FSAR as summarized in the table below.

UTM coordinates (meters)	Latitude/longitude (degree/minute/second)
Zone 18, North American Datum (NAD) 83; 4,215,999 meters north; 254,783 meters east	38 03 31.01 north; 77 47 41.8 west

On the basis of the staff's confirmatory review of the information addressed in the North Anna 3 COL FSAR, the site location information provided by the applicant is considered adequate and acceptable.

2.1.1.5 *Post Combined License Activities*

There are no post COL activities related to this subsection.

2.1.1.6 *Conclusion*

NRC staff reviewed the application and checked the referenced ESP SSAR. The staff's review confirmed that the applicant has addressed the relevant information and there is no outstanding information expected to be addressed in the COL FSAR related to this subsection.

As set forth above, the applicant presented and substantiated information to establish the site location and description. The staff reviewed the information provided and, for the reasons given above, concluded that the information is sufficient for the staff to evaluate compliance with the siting evaluation factors in 10 CFR 100.3, as well as with the radiological consequence evaluation factors in 10 CFR 52.79(a)(1). The staff further concluded that the applicant had provided sufficient details in the ESP SSAR and FSAR about the site location and description for the staff to evaluate whether the applicant has met the relevant requirements of 10 CFR 52.79(a)(1) and 10 CFR Part 100, with respect to determining the acceptability of the site, as documented in Sections 2.1.2, 2.1.3, and 13.3 and Chapters 11 and 15 of this SER and NUREG-1835. This decision also addresses NAPS COL Information Item 2.0-2-A and NAPS ESP COL Action Item 2.1-1. In conclusion, the applicant has provided sufficient information to satisfy 10 CFR Parts 50, 52, and 100.

2.1.2 Exclusion Area Authority and Control

2.1.2.1 *Introduction*

The descriptions of exclusion area authority and control are used to verify the applicant's legal authority to determine and control activities within the designated exclusion area, as provided in the application, and are sufficient to enable the reviewer to assess the acceptability of the reactor site. The review covers the following specific areas as to the establishment of (1) the applicant's legal authority to determine all activities within the designated exclusion area, (2) the applicant's authority and control to exclude or remove personnel and property in the event of an emergency, (3) verification that proposed or permitted activities in the exclusion area unrelated to operation of the reactor do not result in a significant hazard to public health and safety, and (4) verification related to any additional information requirements prescribed within the "Contents of Application" sections of the applicable subparts to 10 CFR Part 52.

2.1.2.2 *Summary of Application*

This section of the COL FSAR addresses the need for exclusion area authority and control. The applicant addressed the information as follows:

COL Items

- NAPS COL 2.0-3-A Site Specific Exclusion Area Authority and Control

NAPS COL Item 2.0-3-A resolves DCD COL Item 2.0-3-A by addressing the provision of site specific information related to exclusion area authority and control, including the size of the area and activities that may be permitted within the designated exclusion area. The site specific information needed to address DCD COL Item 2.0-3-A in the North Anna 3 FSAR is incorporated by reference to ESP SSAR Subsection 2.1.2.

- NAPS ESP COL 2.1-2

The applicant provided supplemental information to satisfy the requirements of NAPS ESP COL Action Item 2.1-2.

- NAPS ESP Permit Condition 3.E(1)

The applicant provided supplemental information to address NAPS ESP Permit Condition 3.E(1). The information emphasizes that the applicant maintains current control of the NAPS site and exclusion area under an existing agreement with ODEC, so no approvals are required by State law for shared control of the exclusion area. As the owners of the NAPS, Dominion and ODEC possess the right to implement the site redress plan.

2.1.2.3 *Regulatory Basis*

The regulatory basis for incorporating information by reference to the ESP SSAR is 10 CFR 52.79(b), which states (in part) that if a COL application references an ESP, then the FSAR need not contain information or analyses submitted to the Commission in connection with the ESP, provided that the FSAR must either include or incorporate by reference the ESP SSAR and must contain, in addition to the information and analyses otherwise required, information sufficient to demonstrate that the design of the facility falls within the site characteristics and design parameters specified in the ESP.

The regulatory basis for the information presented in the ESP SSAR is addressed in the SER related to the ESP SSAR (i.e., NUREG-1835).

The applicable regulatory requirements for verifying exclusion area authority and control are:

1. 10 CFR Parts 50 and 52, as they relate to the inclusion in the SAR of a detailed description and safety assessment of the site on which the facility is to be located, with appropriate attention to features affecting facility design (10 CFR 50.34(a)(1), 10 CFR 52.17(a)(1), and 10 CFR 52.79(a)(1)).

2. 10 CFR Part 100, as it relates to (1) defining an exclusion area and setting forth requirements regarding activities in that area (10 CFR 100.3); (2) addressing and evaluating factors that are used to determine the acceptability of the site as identified in 10 CFR 100.20(b); and (3) determining an exclusion area so that certain dose limits will not be exceeded in the event of a postulated fission product release, as identified in 10 CFR 50.34(a)(1) and as it relates to site evaluation factors identified in 10 CFR Part 100.

The acceptance criteria presented in the ESP SSAR are based on meeting the following relevant requirements of 10 CFR Parts 52 and 100.

The related acceptance criteria are as follows:

1. Establishment of Authority: The information submitted by the applicant is adequate and meets the requirements of 10 CFR 50.33, 10 CFR 50.34(a)(1), 10 CFR 52.79, and 10 CFR Part 100 if it provides sufficient detail to enable the staff to evaluate the applicant's legal authority within the designated exclusion area.

2. Exclusion or Removal of Personnel and Property: The information submitted by the applicant is adequate and meets the requirements of 10 CFR 50.33, 10 CFR 50.34(a)(1), 10 CFR 52.79, and 10 CFR Part 100 if it provides sufficient detail to enable the staff to evaluate the applicant's legal authority for the exclusion or removal of personnel or property from the exclusion area.

3. Proposed and Permitted Activities: The information submitted by the applicant is adequate and meets the requirements of 10 CFR 50.33, 10 CFR 50.34(a)(1), 10 CFR 52.79, and 10 CFR Part 100 if it provides sufficient detail to enable the staff to evaluate the applicant's legal authority over all activities within the designated exclusion area.

2.1.2.4 *Technical Evaluation*

NRC staff reviewed Subsection 2.1.2 of the North Anna 3 COL FSAR and checked the referenced ESP SSAR. The staff's review confirmed that the information contained in the application and incorporated by reference addresses the relevant information related to exclusion area authority and control.

The staff's technical evaluation of this application is limited to reviewing the supplemental information pertaining to NAPS COL Item 2.0-3-A and NAPS ESP COL Action Item and Permit Condition 3.E(1).

The staff reviewed the resolution to DCD COL Item 2.0-3-A, related to exclusion area authority and control addressed by the applicant in ESP COL Action Item 2.1-2 and ESP COL Permit Condition 3.E(1).

- NAPS COL 2.0-3-A Site Specific Exclusion Area Authority and Control

The applicant incorporated by reference ESP SSAR Subsection 2.1.2 to address DCD COL Item 2.0-3-A. The staff finds the information incorpated by reference in the ESP acceptable because the information provided and reviewed in the ESP are still releveant and applicable to this COL application.

- NAPS ESP Permit Condition 3.E(1)

The applicant supplemented Section 2.1.2.1 of the ESP SSAR with the information to address the authority of the COL applicant, as described below.

Since Dominion submitted the ESP application, the Commonwealth of Virginia has passed legislation re-regulating the electric power industry in Virginia. The State Corporation Commission has determined that Dominion should be the COL applicant. In addition, ODEC has elected to participate in the ownership of Unit 3. As a result, rather than Dominion's purchasing or leasing the ESP site, Dominion and ODEC will continue to jointly own the entire NAPS site, including Unit 3. Dominion will continue to maintain sole control of the existing exclusion area as a single exclusion area and single restricted area for all reactor units located within the NAPS property, including Unit 3.

To resolve NAPS ESP Permit Condition 3.E(1), the applicant stated that Dominion currently controls the NAPS site and exclusion area under Dominion's existing agreement with ODEC, and no approvals are required by state law to share control of the exclusion area.

In addition, as the owners of NAPS, Dominion and ODEC possess the right to implement the site redress plan.

Lastly, the applicant states that recreational use of the lake is consistent with lake access and control practices in effect for Units 1 and 2 and will be maintained for Unit 3.

NRC staff reviewed the applicant's supplemental information regarding exclusion area authority. On the basis of this supplemental information, the staff concluded that the applicant has resolved NAPS ESP Permit Conditions 3.E(1) pertaining to exclusion area authority and control and the site redress plan.

- NAPS ESP COL 2.1-2

ESP COL Action Item 2.1-2 requires the applicant to address arrangements for controlling the portions of Lake Anna and the waste heat treatment facility (WHTF) that are within the exclusion area. To resolve ESP COL Action Item 2.1-2, the applicant supplemented the ESP SSAR with a description of the arrangements made with the appropriate agencies for emergencies. The information states that under the Commonwelath of Virginia's Radiological Emergency Response Plan (COVRERP), the Virginia Department of Game and Inland Fisheries (VDGIF) is responsible for warning people in boats and assisting with the traffic control of boats on Lake Anna in the vicinity of NAPS. This arrangement is documented in the COVRERP Appendix 1.

Since the supplemental information from the applicant addressed arrangements for controlling only Lake Anna, the NRC staff requested additional information on controls for the WHTF to resolve ESP COL Action item 2.1-2. The applicant responded by stating that Lake Anna consists of both the WHTF and North Anna Reservoir, which are within the NAPS exclusion area, and the VDGIF is responsible for controlling the portions of Lake Anna and the WHTF that are within the exclusion area.

Based on the staff's review of the supplemental information provided, the staff concludes that the applicant has appropriately resolved the action items.

2.1.2.5 *Post Combined License Activities*

There are no post COL activities related to this subsection

2.1.2.6 *Conclusion*

NRC staff reviewed the application and checked the referenced ESP SSAR. The staff's review confirmed that the applicant has addressed the relevant information and there is no outstanding information expected to be addressed in the COL FSAR related to this subsection.

As set forth above, the applicant has provided and substantiated information concerning the plan to obtain legal authority over and control of all activities within the designated exclusion area. The staff reviewed the information provided in the ESP SSAR and FSAR pertaining to exclusion area authority and control. The staff concluded that the applicant's plan for the exclusion area is acceptable and meets the requirements of 10 CFR 50.34(a)(1), 10 CFR 52.79(a)(1), 10 CFR Part 100, and 10 CFR 100.3 with respect to determining the acceptability of the site. This conclusion is based on appropriate descriptions from the applicant of the plant exclusion area; the controlling authority for all activities within the exclusion area; the methods for the relocation or abandonment of public roads that lie within the proposed exclusion area, if necessary; and the methods for controlling access to and occupancy of the exclusion area during normal operation and in the event of an emergency condition. In addition, the applicant has assumed responsibility for the required authority to control activities within the designated exclusion area, including the exclusion and removal of persons and property, and has established acceptable methods for control of the designated exclusion area. This information addresses NAPS COL Information Item 2.0-3-A, NAPS ESP COL Action item 2.1-2, and NAPS ESP Permit Condition 3.E(1). In conclusion, the applicant has provided sufficient information to satisfy 10 CFR Parts 50, 52, and 100.

2.1.3 Population Distribution

2.1.3.1 *Introduction*

The description of population distribution addresses the need for information about the following: (1) the population in the site vicinity, including transient populations; (2) the population in the exclusion area; (3) whether appropriate protective measures could be taken on behalf of the populace in the specified low-population zone (LPZ) in the event of a serious accident; (4) whether the nearest boundary of the closest population center containing 25,000 or more residents is at least one and one-third times the distance from the reactor to the outer boundary of the LPZ; (5) whether the population density in the site vicinity is consistent with the guidelines in Regulatory Position C.4 of Regulatory Guide (RG) 4.7; and (6) any additional information requirements prescribed within the "Contents of Application" sections of the applicable subparts to 10 CFR Part 52.

2.1.3.2 *Summary of Application*

This section of the COL FSAR addresses the need for a description of population distribution. The applicant addressed the information as follows:

COL Item

- NAPS COL 2.0-4-A Site Specific Population

NAPS COL 2.0-4-A resolves DCD COL Item 2.0-4-A by addressing the provision of site specific information related to population distribution of the site environs. This site specific information needed to address DCD COL Item 2.0-4-A in North Anna 3 FSAR is incorporated by reference to ESP SSAR Section 2.1.3.

2.1.3.3 *Regulatory Basis*

The regulatory basis for incorporating information by reference to the ESP SSAR is 10 CFR 52.79(b), which states (in part) that if a COL application references an ESP, then the FSAR need not contain information or analyses submitted to the Commission in connection with the ESP, provided that the FSAR must either include or incorporate by reference the ESP SSAR and must contain, in addition to the information and analyses otherwise required, information sufficient to demonstrate that the design of the facility falls within the site characteristics and design parameters specified in the ESP.

The regulatory basis for the information presented in the ESP SSAR is addressed in the SER related to the ESP SSAR (i.e., NUREG-1835).

The applicable regulatory requirements for identifying site location and description are:

1. 10 CFR 50.34(a)(1), as it relates to consideration of the site evaluation factors identified in 10 CFR 100.3, 10 CFR Part 100 (including consideration of population density), and 10 CFR 52.79, as it relates to provisions from the applicant in the ESP SSAR of the existing and projected future population profile of the area surrounding the site.

2. 10 CFR 100.20 and 10 CFR 100.21, as they relate to determining the acceptability of a site for a power reactor. In 10 CFR 100.3, 10 CFR 100.20(a), and 10 CFR 100.21(b), the NRC provides definitions and other requirements for determining an exclusion area, LPZ, and population center distance.

The acceptance criteria presented in the ESP SSAR are based on meeting the following relevant requirements of 10 CFR Parts 52 and 100.

The related acceptance criteria are:

1. Population Data: The population data supplied by the applicant in the SAR is acceptable under the following conditions: (1) the SAR contains population data from the latest census and projected population at the year of plant approval and 5 years thereafter, in the geographical format given in Section 2.1.3 of RG 1.70 and in accordance with RG 1.206; (2) the SAR describes the methodology and sources used to obtain the population data, including the projections; (3) the SAR includes information on transient populations in the site vicinity.

2. Exclusion Area: The exclusion area should either not contain any residents, or such residents should be subject to ready removal if necessary.

3. Low-Population Zone: The specified LPZ is acceptable if it is determined that appropriate protective measures could be taken on behalf of the enclosed populace in the event of a serious accident.

4. Nearest Population Center Boundary: The nearest boundary of the closest population center containing 25,000 or more residents is at least one and one-third times the distance from the reactor to the outer boundary of the LPZ.

5. Population Density: If the population density exceeds the guidelines in Regulatory Position C.4 of RG 4.7, the applicant must give special attention to the consideration of alternative sites with lower population densities.

2.1.3.4 *Technical Evaluation*

NRC staff reviewed Subsection 2.1.3 of the North Anna 3 COL FSAR and checked the referenced ESP SSAR. The staff's review confirmed that the information contained in the application and incorporated by reference addresses the relevant information related to population distribution.

The applicant incorporated by reference ESP SSAR Section 2.1.3 to resolve DCD COL Item 2.0-4-A, related to the population distribution included under Section 2.1 of the NAPS COL.

Under the provisions of 10 CFR 52.79(b), the staff accepted the information incorporated by reference to ESP SSAR Section 2.1.3. Therefore, the staff did not perform any technical evaluation of this FSAR section.

2.1.3.5 *Post Combined License Activities*

There are no post COL activities related to this section.

2.1.3.6 *Conclusion*

NRC staff reviewed the application and checked the referenced ESP SSAR. The staff's review confirmed that the applicant has addressed the relevant information and there is no outstanding information expected to be addressed in the COL FSAR related to this subsection.

As set forth above, the applicant has provided an acceptable description of current and projected population densities in and around the site. The staff reviewed the information provided and, for the reasons given above, concluded that the population data provided is acceptable and meets the requirements of 10 CFR 50.34(a)(1), 10 CFR 52.79(a)(1), 10 CFR 100.20(a), 10 CFR 100.20(b), 10 CFR Part 100, and 10 CFR 100.3. The staff further concluded that the applicant had provided sufficient details in ESP SSAR Section 2.13 about the population distribution to allow the staff to evaluate, as documented in Section 2.1.3 of NUREG-1835, whether the applicant meets the relevant requirements of 10 CFR 52.79(a)(1) and 10 CFR Part 100, with respect to determining the acceptability of the site. This conclusion is based on the applicant's acceptable description and safety assessment of the site that contains present and projected population densities, which are within the guidelines of Regulatory Position C.4 of RG 4.7 and properly specified the distance from the LPZ population center. In addition, the staff reviewed and confirmed the applicant's estimates of the present and projected populations surrounding the site, including transients, by comparison with independently obtained population data. The applicant also calculated the radiological consequences of design-basis accidents at the outer boundary of the LPZ (SRP Chapter 15). The applicant provided reasonable assurance that appropriate protective measures can be taken within the LPZ to protect the population in the event of a radiological emergency. This information addressed NAPS COL Item 2.0-4-A. In conclusion, the applicant has provided sufficient information to satisfy 10 CFR Parts 50, 52, and 100.

2.2 Nearby Industrial, Transportation, and Military Facilities

This section provides information on the site characteristics that could affect the safe design and siting of the plant. The information consists of three subsections: Subsection 2.2.1 provides information on locations and routes; Subsection 2.2.2 describes nearby industrial transportation facilities (airports, airways, roadways, railways, etc.) and military facilities; and Subsection 2.2.3 evaluates potential hazards.

2.2.1 Locations and Routes

The locations of and separation distances from transportation facilities and routes, including airports and airways, roadways, railways, and navigable bodies of water are in ESP SSAR Sections 2.2.1 and 2.2.2, which are incorporated by reference. The staff's review of this information is in the following SER Section 2.2.2.

2.2.2 Descriptions

2.2.2.1 *Introduction*

The description of locations and routes refers to potential external hazards or hazardous materials that are present or may reasonably be expected to be present during the projected lifetime of the proposed plant. The purpose is to evaluate the sufficiency of information concerning the presence and magnitude of potential external hazards so that the reviews and evaluations described in SRP Sections 2.2.3, 3.5.1.5, and 3.5.1.6 can be performed. The review covers the following specific areas: (1) the locations of and separation distances to transportation facilities and routes, including airports and airways, roadways, railways, pipelines, and navigable bodies of water; (2) the presence of military and industrial facilities such as fixed manufacturing, processing, and storage facilities; and (3) any additional information requirements prescribed within the "Contents of Application" sections of the applicable subparts to 10 CFR Part 52.

2.2.2.2 *Summary of Application*

Section 2.2.2 of the FSAR addresses the need for locations and route descriptions and descriptions of nearby industrial and military facilities. The applicant addressed the information as follows:

<u>*COL Items*</u>

- NAPS COL 2.0-5-A

NAPS COL 2.0-5-A resolves DCD COL Item 2.0-5-A by providing information about industrial, military, and transportation facilities and routes to establish the presence and magnitude of potential external hazards. The site specific information needed to address DCD COL Item 2.0-5-A in the North Anna 3 FSAR is incorporated by reference to ESP SSAR Section 2.2.1- 2.2.2.

- NAPS ESP COL 2.2-1

In accordance with RG 1.206 and relevant sections of 10 CFR Parts 50 and 100, the applicant provided supplemental information to address ESP COL Action Item 2.2.-1. The supplemental information identified and addressed the potential hazard facilities and routes within five miles of NAPS, three (3) airports within 10 miles of NAPS, and other significant facilities beyond 5 miles of NAPS.

2.2.2.3 *Regulatory Basis*

The regulatory basis for incorporating information by reference to the ESP SSAR is 10 CFR 52.79(b), which states (in part) that if a COL application references an ESP, then the FSAR need not contain information or analyses submitted to the Commission in connection with the ESP, provided that the FSAR must either include or incorporate by reference the ESP SSAR and must contain, in addition to the information and analyses otherwise required, information sufficient to demonstrate that the design of the facility falls within the site characteristics and design parameters specified in the ESP.

The applicable regulatory requirements for identifying locations and routes are:

1. 10 CFR 100.20(b), which requires that the nature and proximity of human-related hazards (e.g., airports, dams, transportation routes, and military and chemical facilities) be evaluated to establish site parameters used to determine whether the plant's design can accommodate commonly occurring hazards, and whether the risk of other hazards is very low.

2. 10 CFR 52.79(a)(1)(iv), as it relates to the factors to be considered in the evaluation of sites that require the location and description of industrial, military, or transportation facilities and routes.

3. 10 CFR 52.79(a)(1)(vi), as it relates to compliance with 10 CFR Part 100.

The acceptance criteria in the ESP SSAR are based on meeting the following relevant requirements of 10 CFR Parts 52 and 100.

The related acceptance criteria are:

1. Data in the SAR that adequately describe the locations of and distances from the plant of nearby industrial, military, and transportation facilities; and that the data are in agreement with data obtained from other sources, when available.

2. Descriptions of the nature and extent of activities conducted at the site and in its vicinity, including the products and materials likely to be processed, stored, used, or transported; and that they are adequate to permit identification of the possible hazards cited in Subsection III of Section 2.2.1-2.2.2 of NUREG-0800.

3. Sufficient statistical data with respect to hazardous materials that establish a basis for evaluating the potential hazards to the plant or plants considered at the site.

2.2.2.4 *Technical Evaluation*

NRC staff reviewed Subsection 2.2.2 of the North Anna 3 COL FSAR and checked the referenced ESP SSAR. The staff's review confirmed that the information contained in the application and incorporated by reference addresses the relevant information related to identification of potential hazards in the vicinity of the site.

The staff reviewed the resolution to DCD COL Item 2.0-5-A related to identification of potential hazards in the vicinity of the site, including nearby industrial, transportation, and military facilities and NAPS ESP COL Action Item 2.2-1 as follows:

Industrial Facilities

In order to resolve ESP COL Action Item 2.2-1, the applicant stated that since submitting the ESP SSAR, no hazardous industrial facilities have been added to the 620-acre industrial development near the Unit 3 exclusion area boundary (EAB). The industrial site poses no hazard to Unit 3.

Airports

This section of the ESP SSAR is supplemented with information that identifies an additional airport in the vicinity of Unit 3.

A third airport (Seven Gables) within 10 miles of the Unit 3 site opened in 2007. Seven Gables is a private landing strip with an unlighted 1,500-foot turf runway approximately 7.6 miles north-northwest of the site. This airport is not licensed for commercial use and is based with three small aircraft. The airport's location is shown along with other nearby airports in FSAR Figure 2.2-201. Flight operation information is in FSAR Table 2.2-201.

Airways

The supplemental information in this section of the ESP SSAR identifies an additional military training flight airway in the vicinity of NAPS.

One additional airway, VR1755, is identified and shown along with others in FSAR Figure 2.2-201. The center line of this airway is more than 8 miles from Unit 3. On the basis of flight operations data supplied by the U.S. Department of Navy for all four military training routes for the year 2006, the applicant states that the assumed 6,000 flights per year in the ESP SSAR remain bounding.

2.2.2.5 *Post Combined License Activities*

There are no post COL activities related to this subsection.

2.2.2.6 *Conclusion*

NRC staff reviewed the application and checked the referenced ESP SSAR. The staff's review confirmed that the applicant has addressed the relevant information, and there is no outstanding information expected to be addressed in the COL FSAR related to this subsection.

As set forth above, the applicant presented and substantiated information that identified potential hazards in the site vicinity. The staff reviewed the information in the ESP SSAR and supplemented in the FSAR and, for the reasons given above, concluded that the applicant had provided information that identified potential hazards in accordance with the requirements of 10 CFR 52.79(a)(1)(iv) and 10 CFR 52.79(a)(1)(vi) for compliance evaluation. The nature and extent of activities involving potentially hazardous materials that are conducted at nearby industrial, military, and transportation facilities have been evaluated to identify those activities that have the potential for adversely affecting plant safety-related structures. Based on an evaluation of information in the ESP SSAR and FSAR, as well as information that the staff had independently obtained, the staff concluded that all potentially hazardous activities on the site and in the vicinity of the plant have been identified. The hazards associated with these activities have been reviewed and are discussed in Sections 2.2.3, 3.5.1.5, and 3.5.1.6 of this SER. This information addresses NAPS ESP COL Action Item 2.2-1. In conclusion, the applicant has provided sufficient information to satisfy 10 CFR Parts 50, 52, and 100.

2.2.3 Evaluation Of Potential Accidents

2.2.3.1 *Introduction*

The evaluation of potential accidents considers the applicant's probability analyses of potential accidents involving hazardous materials or activities on the site and in the vicinity of the proposed site to confirm that appropriate data and analytical models have been used. This review covers the following specific areas: (1) hazards associated with nearby industrial activities such as manufacturing, processing, or storage facilities; (2) hazards associated with nearby military activities such as military bases, training areas, or aircraft flights; and (3) hazards associated with nearby transportation routes (aircraft routes, highways, railways, navigable waters, and pipelines). Each hazard review area includes consideration of the following principal types of hazards: (1) toxic vapors or gases and their potential for incapacitating nuclear plant control room operators; (2) overpressure resulting from explosions or detonations involving materials such as munitions, industrial explosives, or explosive vapor clouds resulting from the atmospheric release of gases (such as propane and natural gas or any other gas) with a potential for ignition and explosion; (3) missile effects attributable to mechanical impacts such as aircraft impacts, explosion debris, and impacts from waterborne items such as barges; and (4) thermal effects attributable to fires

2.2.3.2 *Summary of Application*

This section of the COL FSAR addresses the need to evaluate potential accidents. The applicant addressed the information as follows:

<u>COL Items</u>

- NAPS COL 2.0-6-A Evaluation of Potential Accidents

NAPS COL 2.0-6-A resolves DCD COL Item 2.0-6-A by addressing the provision for evaluating potential accidents. The site specific information needed to address DCD COL Item 2.0-6-A in North Anna 3 FSAR is incorporated by reference to ESP SSAR Section 2.2.3.

- NAPS ESP COL 2.2-2 Interactions Between the Existing and New Unit

The applicant provided updated site specific supplemental information to address ESP COL Action Item 2.2-2.

2.2.3.3 *Regulatory Basis*

The regulatory basis for incorporating information by reference to the ESP SSAR is 10 CFR 52.79(b), which states (in part) that if a COL application references an ESP, then the FSAR need not contain information or analyses submitted to the Commission in connection with the

ESP, provided that the FSAR must either include or incorporate by reference the ESP SSAR and must contain, in addition to the information and analyses otherwise required, information sufficient to demonstrate that the design of the facility falls within the site characteristics and design parameters specified in the ESP.

The regulatory basis for the information presented in the ESP SSAR is addressed in the SER related to the ESP SSAR (i.e., NUREG-1835).

The applicable regulatory requirements for identifying and evaluating potential accidents are:

- 10 CFR 52.79(a)(1)(iv) as it relates to the factors to be considered in the evaluation of sites, which require the location and description of industrial, military, or transportation facilities and routes.

- 10 CFR 52.79(a)(1)(vi), as it relates to compliance with 10 CFR Part 100.

The acceptance criteria presented in the ESP SSAR are based on meeting the relevant requirements of 10 CFR Parts 52 and 100.

The related acceptance criteria are:

1. Event Probability: The identification of design-basis events resulting from the presence of hazardous materials or activities in the vicinity of the plant or plants of specified type is acceptable if all postulated types of accidents are included for which the expected rate of occurrence of potential exposures resulting in radiological dose in excess of the 10 CFR 50.34(a)(1) limits, as it relates to the requirements of 10 CFR Part 100, is estimated to exceed the NRC staff objective of an order of magnitude of 10^{-7} per year.

2. Design-Basis Events: The effects of design-basis events have been adequately considered, in accordance with 10 CFR 100.20(b), if analyses of the effects of those accidents on the safety-related features of the plant or plants of specified type have been performed and measures have been taken (e.g., hardening, fire protection) to mitigate the consequences of such events.

2.2.3.4 *Technical Evaluation*

NRC staff reviewed Subsection 2.2.3 of the North Anna 3 COL FSAR and checked the referenced ESP SSAR. The staff's review confirmed that the information contained in the application and incorporated by reference addresses the relevant information related to the evaluation of potential accidents.

The staff's technical evaluation of this application is limited to reviewing the supplemental information pertaining to NAPS COL Item 2.0-6-A, and NAPS ESP COL Action items. The staff reviewed the resolution to DCD COL Item 2.0-6-A, related to the evaluation of potential accidents to be covered under ESP COL Action Item 2.2-2 addressed as follows:

- NAPS COL 2.0-6-A Evaluation of Potential Accidents

The applicant incorporated by reference ESP SSAR Section 2.2.3 to address DCD COL Item 2.0-6-A.

- NAPS ESP COL 2.2-2 Interactions between Existing Units and the New Unit

The applicant supplemented its application with a new section to ESP SSAR Section 2.2.3.1 on the evaluation of potential hazards of onsite chemicals to resolve ESP COL Action Item 2.2-2.

The chemicals stored onsite at Units 1 and 2 and to be stored at Unit 3 are identified in FSAR Table 2.2-202. This table identifies the storage locations and quantities of each chemical. Properties relative to the hazards from each chemical and the results of the screening analyses are in FSAR Table 2.2-203. FSAR Table 2.2-204 provides the safe-separation distances for flammable and explosive chemicals and compares those distances to the actual distance to the nearest safety-related Unit 3 structure, system, or component (SSC).

Explosions

The applicant evaluated hydrogenand Nalco H-130, and hydrazine (for units 1 and 2) for potential explosions resulting in blast overpressure using 1 psi overpressure as a criterion for adversely affecting plant operations or preventing the safe shutdown of the plant. In accordance with RG 1.91, peak-positive incident overpressures below 1 psi are not considered to cause significant damage.

The applicant determined a minimum safe-standoff distance from an in-vessel, confined vapor explosion by conservatively considering a volume of chemical vapor equal to the empty volume of the largest storage vessel that was available for combustion, with an explosion yield factor of 100 percent.

The applicant addressed the potential detonation and deflagration in a plume due to a flammable vapor cloud from the release of chemicals. This evaluation assumed a dispersion downwind toward the NAPS, with a delayed ignition. The vapor dispersion assumed a wind speed of 1 meter per second with an atmospheric stability class F, and a 77 degree Fahrenheit ambient air temperature, a relative humidity of 50 percent, a cloud cover of 50 percent, and an atmospheric pressure condition. The ALOHA computer model (ALOHA, 2007) was used to evaluate the dispersion and detonation of the vapor clouds. Each chemical was analyzed by assuming the maximum volume of the storage vessel leaked to form a 1-centimeter thick puddle, giving significant surface area to maximize evaporation and the formation of a vapor cloud.

NRC staff performed independent calculations using the three chemicals addressed by the applicant that the staff calculations confirmed the applicant’s results. Therefore, the staff concluded that the applicant’s assumptions and methodology are acceptable.

The staff noted that there are two 10,000 gallon underground gasoline storage tanks onsite at Unit 3 as identified in FSAR Table 2.2-202. The applicant did not address the hazards posed by these tanks from either a confined vapor explosion or a flammable vapor cloud explosion. The staff requested additional information from the applicant in a request for additional information (RAI) **RAI 2.2.3-1**, which asked the applicant to address the potential hazards of these tanks from the perspective of fuel storage and onsite delivery of fuel to the tanks. The applicant provided the information in an FSAR update and calculated the probability of 7.8×10^{-7} for an explosion from a gasoline tanker truck delivery resulting in an overpressure of 1 psi at the nearest Unit 3 safety-related structure.

The staff reviewed the methodology, assumptions, and data the applicant had used to determine the event probability. The staff considered the applicant's approach reasonable and the conclusion acceptable. The staff considers **RAI 2.2.3-1** resolved.

Toxic Chemicals

The applicant identified the onsite storage of chemicals for Unit 3 in FSAR Table 2.2-203 and considered the potential for impacting control room habitability. In FSAR Section 2.2.3.1.3, the applicant stated that the effects of toxic vapors or gases and their potential for incapacitating Unit 3 control room operators were evaluated. The results are in FSAR Section 6.4. However, in FSAR Section 6.4 under NAPS COL 6.4-2-A, the applicant conclusively stated, "The results of the analysis, when compared to the toxicity limits given in RG 1.78 and National Air Quality Standards, show hazardous concentrations of toxic gas in the control room are not reached." The applicant has not provided the bases and methodology for calculating the toxic chemical concentrations at the intake of the control room, and potential toxic chemical concentrations inside the control room with potential air flow rates. The modeling assumptions and inputs for accidental chemical release scenarios and evaporation characteristics, dispersion and transport mechanisms, and resulting concentrations are not provided. NRC staff requested this information in **RAIs 2.2.3-2 and 2.2.3-3**. The applicant's response identified two chemicals requiring control room habitability analyses that were reviewed by the staff and evaluated in Section 6.4 of this SER. The applicant identified eight additional chemicals that are stored onsite, but the applicant provided no rationale as to why those chemicals are not a hazard to the control room. The staff issued a subsequent **RAI 2.2.3-5** requesting the applicant to provide a rationale for screening out those chemicals. This issue is **Open Item 2.2.3-5**. As a follow-up to the applicant's response to **RAI 2.2.3-2 and 2.2.3-3**, the staff issued **RAI 2.2.3-7** requesting a revised response regarding the modeling details for its conclusions. This RAI is being tracked as **Open Item 2.2.3-7**.

The staff noted that the quantity of sodium hydroxide in FSAR Table 2.2-202 (180 gallons for Unit 3 and 700 gallons for Units 1 and 2) was not analyzed for toxicity, whereas Units 1 and 2 UFSAR Version 42 (Table 6.4-1) identifies a sodium hydroxide quantity of 55 gallons, which was analyzed for toxicity. The staff requested clarification in **RAI 2.2.3-4**. The applicant's response stated that the existing Unit 1 and 2 analyses were overly conservative, and assumed that all sodium hydroxide is volatile. However, based on the low volatility of sodium hydroxide, no significant concentrations would accumulate even with the higher quantities. Based on the staff's independent review and confirmatory calculations, the staff considers the applicant's response acceptable and RAI 2.2.3-4 resolved.

Airways

Supplemental information to Section 2.2.3.2.2 of the ESP SSAR modified the evaluation results on effective plant areas for Unit 3. NRC staff finds that the modification is acceptable and would not change the original conclusion that the two accident probabilities are within the NUREG-0800 guideline of less than 10^{-7} per year.

Fires

FSAR Section 2.2.3.4 included supplemental information regarding fires. The applicant performed an analysis of a wildfire near Unit 3 using methodology in NUREG-1805 to determine the incident heat flux on Unit 3. On the basis of a calculated heat flux with conservative assumptions, NRC staff considers the applicant's analysis reasonable and the conclusion acceptable.

Collision with Unit 3 Intake Structure

FSAR Section 2.2.3.5 states that the Unit 3 intake structure is located on Lake Anna in a cove behind a cofferdam that is northeast of the Unit 3 power block area, shown in FSAR Section 2.1-201. Lake Anna has small pleasure boats used solely for recreation; there are no large boats or barges on the lake. The area around the Unit 3 intake structure is managed by Dominion as a part of the exclusion area. The cofferdam prevents a potential collision between a boat on Lake Anna and the Unit 3 intake structure. Even if there is such a collision, the Unit 3 intake structure is not a safety-related structure, and therefore the staff concluded that the collision would not affect the safety of the plant.

Liquid Spills near the Intake Structure

FSAR Section 2.2.3.6 states that although small quantities of motor oil and gasoline may be spilled from the pleasure boats in Lake Anna, such spills would not affect the safe operation or shutdown of Unit 3. The NRC staff considers agrees with the applicant's assessment that minor spills into the lake will not affect safe operation or shutdown of the proposed unit.

2.2.3.5 *Post Combined License Activities*

There are no post COL activities related to this subsection.

2.2.3.6 *Conclusion*

NRC staff reviewed the application and checked the referenced ESP SSAR. The staff specified **Open Item 2.2.3-7,** regarding the hazards posed by chemicals stored on-site. The staff outlined additional information that needs to be reflected in sections of the FSAR, as appropriate. The staff's review of FSAR Section 2.2.3 will be complete after this open item has been resolved.

2.3 Meteorology

To ensure that a nuclear power plant or plants can be designed, constructed, and operated on an applicant's proposed site in compliance with the Commission's regulations, NRC staff evaluates regional and local climatological information, including climate extremes and severe weather occurrences that may affect the design and siting of a nuclear plant. The staff reviews information on the atmospheric dispersion characteristics of a nuclear power plant site to determine whether the radioactive effluents from postulated accidental releases, as well as routine operational releases, are within Commission guidelines. The staff has prepared Sections 2.3.1 through 2.3.5 of this SER in accordance with the review procedures described in NUREG-0800, using information presented in Section 2.3 and Appendix 2A of Revision 1 to the FSAR (which references Revision 5 to the Econimic Simplified Boiling-Water Reactor (ESBWR) Design Control Document (DCD)), responses to staff RAIs, and generally available reference materials (as cited in applicable sections of NUREG-0800).

2.3.1 Regional Climatology

2.3.1.1 *Introduction*

Subsection 2.3.1, "Regional Climatology," of the North Anna 3 COL FSAR addresses averages and extremes of climatic conditions and regional meteorological phenomena that could affect the safe design and siting of the plant, including information describing the general climate of the region, seasonal and annual frequencies of severe weather phenomena, and other meteorological conditions to be used for design- and operating-basis considerations.

2.3.1.2 *Summary of Application*

This subsection of the North Anna 3 COL FSAR addresses site specific information on the regional climatology. The applicant addressed the information as follows:

<u>COL Item</u>

- NAPS COL 2.0-7-A Regional Climatology

This COL information item states that the COL applicant supply site specific information in accordance with SRP Section 2.3.1;[1] that is, the COL applicant should describe averages and extremes of climatic conditions and regional meteorological phenomena that could affect the safe design and siting of the plant. In response to this COL information item, the applicant incorporated by reference Revision 9 to the ESP SSAR Subsection 2.3.1, with supplements (1) providing additional information about temperature extremes, (2) addressing wind speeds used for the design of non-safety-related structures not included as part of the certified design, and (3) stating that the design features that demonstrate acceptable roof structure performance to address ice and winter precipitation for Unit 3 safety-related structures are described in DCD Appendix 3G.

2.3.1.3 *Regulatory Basis*

The regulatory basis for incorporating information by reference to the ESP SSAR is 10 CFR 52.79(b), which states (in part) that if a COL application references an ESP, then the FSAR need not contain information or analyses submitted to the Commission in connection with the ESP, provided that the FSAR must either include or incorporate by reference the ESP SSAR and must contain, in addition to the information and analyses otherwise required, information sufficient to demonstrate that the design of the facility falls within the site characteristics and design parameters specified in the ESP.

The regulatory basis for the information presented in the ESP SSAR Subsection 2.3.1 is addressed in the SER related to the ESP SSAR (i.e., NUREG-1835). The acceptance criteria for the additional regional climatic information presented in the North Anna 3 COL FSAR, beyond that presented in the ESP SSAR, are based on meeting the following relevant requirements of 10 CFR Parts 52 and 100:

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1 The wording presented here for COL Information Item NAPS COL 2.0-7-A differs from that presented in Revision 5 to the ESBWR DCD. The wording presented here, which is based on the response from General Electric-Hitachi (GEH) to ESBWR DCD RAI 2.0-2 dated October 23, 2008, should appear in a future revision to the ESBWR DCD.

- 10 CFR 52.79(a)(1)(iii), as it relates to identifying the most severe of the natural phenomena that have been historically reported for the site and surrounding area and with a sufficient margin for the limited accuracy, quantity, and time in which the historical data have been accumulated.

- 10 CFR 100.20(c)(2) and 10 CFR 100.21(d), with respect to the consideration given to the regional meteorological characteristics of the site.

NUREG-0800, Section 2.3.1 specifies, in part, that an application meets the above requirements if the application satisfies the following criteria:

- Data on severe weather phenomena should be based on standard meteorological records from nearby representative National Weather Service (NWS), military, or other stations recognized as standard installations that have long periods of data on record. The applicability of these data to represent site conditions during the expected period of reactor operation should be substantiated.

- Ambient temperature and humidity statistics should be derived from data recorded at nearby representative climatic stations or obtained from appropriate standards with suitable corrections for local conditions.

- The information should be presented and substantiated in accordance with acceptable practice and data as promulgated by the U.S. National Oceanic and Atmospheric Administration, industry standards, and regulatory guides.

2.3.1.4 *Technical Evaluation*

NRC staff reviewed Subsection 2.3.1 of the North Anna 3 COL FSAR and checked the referenced ESP SSAR. The staff's review confirmed that the information in the North Anna 3 COL application and incorporated by reference to Subsection 2.3.1 of the ESP SSAR, Revision 9, addresses the relevant information related to the regional meteorology. The staff's technical evaluation of the information incorporated by reference to the ESP SSAR related to regional climatology is documented in the corresponding SER (i.e., NUREG-1835).

The staff's technical evaluation of this application subsection is limited to reviewing (1) the resolution of COL information item NAPS COL Item 2.0-7-A, and (2) whether the Unit 3 climatic site characteristics fall within the ESBWR DCD climatic site parameter values.

<u>*COL Item*</u>

- NAPS COL 2.0-7-A Regional Climatology

NRC staff reviewed the resolution to DCD COL 2.0-7-A related to regional climatology. The staff found that the applicant had appropriately supplied site specific regional climatological information by incorporating by reference Revision 9 to the ESP SSAR Subsection 2.3.1, except as discussed below.

Revision 0 to North Anna 3 COL FSAR Table 2.0-2R stated that the wind speed used in the design of non-safety-related structures that are not included as part of the ESBWR standard plant design is 40 meters per second (90 miles per hour). Neither ESP SSAR Subsection 2.3.1 nor Revision 0 to North Anna 3 COL FSAR Subsection 2.3.1 provided the basis for this wind speed value. The staff issued **RAI 2.3.1-1** and asked the applicant to provide the basis for the FSAR Table 2.0-2R wind speed value of 90 miles per hour, which is to be used in the design of non-safety-related structures that are not included as part of the ESBWR standard plant design.

The applicant's response to **RAI 2.3.1-1,** dated August 28, 2008, stated that Section 6 of the American Society of Civil Engineers (ASCE) Standard Number 7 (ASCE 7-02) provided the basis for the 90 miles per hour design-basis wind speed for the non-safety-related Unit 3 structures that are not included as part of the ESBWR standard plant design. Figure 6.1 of ASCE 7-02 provides a map of the continental United States showing contours of basic wind speeds for design-basis wind loading. These basic wind speeds are 3-second gust values at 33 feet (10 meters) in exposure category C and represent 50-year return periods.[2] Figure 6.1 of ASCE 7-02 shows a basic wind speed of 90 miles per hour for the portion of the United States that includes the proposed North Anna 3 site. The applicant stated that the use of ASCE 7-02 to derive the design-basis wind speed for non-safety-related structures is in accordance with the Virginia Construction Code, Part I of the Virginia Uniform Statewide Building Code. Therefore, the staff concluded that a site characteristic basic wind speed value of 90 miles per hour for non-safety-related structures is acceptable. The applicant revised North Anna 3 COL FSAR Subsection 2.3.1 in Revision 1 to incorporate the applicant's response to **RAI 2.3.1-1,** as discussed above. Therefore, the staff considers **RAI 2.3.1-1** to be resolved.

Evaluation of Site Parameters and Site Characteristics

Section 2.0 of the North Anna 3 COL FSAR evaluates whether the North Anna 3 site characteristics fall within the ESBWR DCD site parameter values. A comparison of ESBWR DCD climatic site parameters with the North Anna 3 climatic site characteristics is in North Anna 3 COL FSAR Table 2.0-201. Unless noted otherwise in FSAR Table 2.0-201, the Unit 3 site characteristics are the same values listed as site characteristics in the ESP SSAR. These values are acceptable to the staff because SRP Section 2.3.1 states that a COL application referencing an ESP need not include a reinvestigation of the site characteristics that were previously accepted in the referenced ESP. The staff found that the applicant had appropriately compared the ESBWR DCD site parameter values with the North Anna 3 site characteristics, except as discussed below.

Revision 0 of North Anna 3 COL FSAR Table 2.0-201 compared ESBWR 0 percent exceedance (i.e., historic high and low) ambient design temperature site parameters (e.g., maximum dry-bulb, coincident wet bulb, and non-coincident wet bulb temperature and minimum dry-bulb temperature values) with corresponding 0 percent exceedance North Anna 3 site characteristics. 10 CFR 52.79(a)(1)(iii) states that COL applications must identify the meteorological characteristics of the proposed site with appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area and with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated. Temperatures based on a 100-year return period are considered to provide sufficient margin for the limited accuracy, quantity, and period of time in which historical data have been accumulated.

In order to comply with 10 CFR 52.79(a)(1)(iii), the higher of either the 100-year return period or the historic maximum dry-bulb temperature, the coincident wet bulb temperature, and non-coincident wet bulb temperature values should be compared to the corresponding ESBWR 0

[2] ASCE 7-02 defines exposure category C as open terrain with scattered obstructions of heights generally less than 30 feet (9.1 meters). This category includes flat, open country grasslands and all water bodies in hurricane-prone regions. This exposure category conservatively describes the North Anna Unit 3 site.

percent exceedance maximum ambient design temperature site parameters. Similarly, the lower of either the 100-year return period or the historic minimum dry-bulb temperature should be compared to the ESBWR 0 percent exceedance minimum ambient design temperature site parameter. Consequently, the staff asked the applicant in **RAI 2.3.1-2** to compare the higher of either the 100-year return period or the historic maximum North Anna 3 site characteristic values with the corresponding ESBWR 0 percent exceedance maximum ambient design temperature site parameter values.

The applicant's response to **RAI 2.3.1-2** dated August 28, 2008, provided a 100-year return period maximum dry bulb, coincident wet bulb, and non-coincident wet bulb temperature and minimum dry bulb temperature values for the North Anna 3 site. The applicant chose the higher of either the 100-year return period or the historic maximum North Anna 3 site characteristic values for comparison with the corresponding ESBWR 0 percent exceedance maximum ambient design temperature site parameter values. The staff reviewed the applicant's response to **RAI 2.3.1-2** as follows:

- ESP SSAR Table 2.3-18 presented a 100-year return period maximum dry bulb temperature value of 109 degrees Fahrenheit using a linear regression based on 30 years (1973–2002) of Richmond, Virginia, hourly data. This value is higher than the extreme maximum temperature recorded in the site region as reported in the ESP SSAR (107 degrees Fahrenheit in Charlottesville, Virginia, in 1954), and it bounds a 100-year return period value calculated by the staff using Equation 1 from Chapter 27 of the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) *2001 ASHRAE Handbook—Fundamentals*, using 1972–2001 statistical data (i.e., mean and standard deviation of annual extreme maximum dry-bulb temperatures) for Richmond, as reported in the CD-ROM accompanying Chapter 28 of the *2005 ASHRAE Handbook—Fundamentals*. For these reasons, the staff accepts 109 degrees Fahrenheit as an appropriate North Anna 3 maximum dry bulb site characteristic value for comparison with the ESBWR 0 percent exceedance maximum dry bulb site parameter value of 117 degrees Fahrenheit.

- The applicant derived a 100-year return period, maximum coincident wet bulb temperature value of 76 degrees Fahrenheit by extrapolating a curve of Richmond's dry bulb temperatures, plotted with their maximum observed coincident wet bulb temperatures, to the 100-year return period maximum dry bulb temperature value of 109 degrees Fahrenheit. NRC staff believes the resulting 76 degrees Fahrenheit concurrent wet bulb value does not appear to be conservative. The CD-ROM accompanying Chapter 28 of the *2005 ASHRAE Handbook—Fundamentals*, provides a joint frequency matrix of Richmond, Virginia, dry bulb temperatures and mean coincident wet bulb temperatures for the period of 1972–2001. A linear trend line through the last five data points in this joint frequency matrix, extrapolated out to a dry bulb temperature of 109 degrees Fahrenheit, projects a mean coincident wet bulb temperature of approximately 78 degrees Fahrenheit. Nonetheless, the staff accepts the applicant's 76 degrees Fahrenheit as the mean coincident wet bulb value because both the applicant's value and the staff's value of 78 degrees Fahrenheit are below the ESBWR DCD site parameter value of 80 degrees Fahrenheit.

- ESP SSAR Table 2.3-18 presented a 100-year return period maximum noncoincident wet bulb temperature value of 88 degrees Fahrenheit using a linear regression based on 30 years (1973–2002) of Richmond, Virginia, hourly data. This value is higher than the extreme maximum temperature recorded in the site region, as reported in the ESP

SSAR (84.9 degrees Fahrenheit) and bounds a 100-year return period value calculated by the staff, as discussed in the North Anna ESP SER (NUREG-1835). For these reasons, the staff accepts 88 degrees Fahrenheit as an appropriate North Anna 3 maximum noncoincident wet bulb site characteristic value for comparison with the ESBWR 0 percent exceedance maximum noncoincident wet bulb site parameter value of 88 degrees Fahrenheit.

- ESP SSAR Table 2.3-18 presented a 100-year return period minimum dry bulb temperature value of -19 degrees Fahrenheit using the same technique described above for the 100-year return period maximum dry bulb temperature value. This value bounds a 100-year return period value calculated by the staff using the same technique discussed above for the 100-year return period maximum dry bulb temperature. However, the extreme minimum temperature recorded in the site region as reported in the ESP SSAR (-21 degrees Fahrenheit in Louisa, Virginia, in 1996) is more severe and was therefore chosen by the applicant as the Unit 3 historic minimum temperature site characteristic. For these reasons, the staff accepts -21 degrees Fahrenheit as an appropriate North Anna 3 minimum dry bulb site characteristic value for comparison with the ESBWR 0 percent exceedance minimum dry bulb site parameter value of -40 degrees Fahrenheit.

The applicant revised the North Anna 3 FSAR Table 2.0-201 and Subsection 2.3.1 in Revision 1 to incorporate the response to **RAI 2.3.1-2** as discussed above. Therefore, the staff considers **RAI 2.3.1-2** to be resolved.

North Anna 3 COL FSAR Table 2.0-201 shows that all the North Anna 3 climatic site characteristics fall within the ESBWR DCD climatic site parameters. Therefore, the staff found that the applicant had appropriately demonstrated that the North Anna 3 site characteristics fell within the ESBWR DCD site parameter values.

The staff acknowledges that long-term climatic changes resulting from human or natural causes may introduce changes into the most severe natural phenomena reported for the site. However, no conclusive evidence or consensus of opinion is available on the rapidity or nature of such changes. Currently, the staff is unaware of any reliable climate models capable of modeling design-basis climate extremes at a particular location. There is a level of uncertainty in projecting future conditions because the assumptions regarding the future level of emissions of heat trapping gases depend on projections of population, economic activity, and choice of energy technologies. North Anna 3 COL FSAR Table 2.0-201 shows that there is a margin between most of the ESBWR DCD climatic site parameters and the North Anna 3 climatic site characteristics. If it becomes evident that long-term climatic change is influencing the most severe natural phenomena reported at the site, the COL holders have a continuing obligation to ensure that their plants stay within the licensing basis.

2.3.1.5 *Post Combined License Activities*

There are no post COL activities associated with this subsection.

2.3.1.6 *Conclusion*

NRC staff reviewed the application and checked the referenced ESP SSAR. The staff's review confirmed that the applicant has addressed the relevant information and there is no outstanding information expected to be addressed in the COL FSAR related to this subsection.

The staff concluded that the information pertaining to North Anna 3 COL FSAR Subsection 2.3.1 is within the scope of the ESP SSAR and adequately incorporates by reference Subsection 2.3.1 of the ESP SSAR. The information is thus acceptable. In addition, the staff compared the additional COL information in the application to the relevant NRC regulations and acceptance criteria defined in NUREG-0800, Section 2.3.1. The staff concluded that the applicant is in compliance with the relevant requirements of 10 CFR Parts 52 and 100. COL Information Item 2.0-7-A has been adequately addressed by the applicant and can be considered closed.

2.3.2 Local Meteorology

2.3.2.1 *Introduction*

Subsection 2.3.2, "Local Meteorology," of the North Anna 3 COL FSAR addresses the local (site) meteorological characteristics, the assessment of the potential influence of the proposed plant and its facilities on local meteorological conditions, the impact of these modifications on the plant design and operations, and a topographical description of the site and its environs.

2.3.2.2 *Summary of Application*

This subsection of the North Anna 3 COL FSAR addresses site specific information on the local meteorology. The applicant addressed the information as follows:

<u>COL Items</u>

- NAPS COL 2.0-8-A Local Meteorology

This information item states that the COL applicant supply site specific information in accordance with SRP Section 2.3.2; that is, the COL applicant should provide summaries of the local (site) meteorological characteristics, an assessment of the potential influence of the proposed plant and its facilities on local meteorological conditions, the impact of these modifications on plant design and operation, and a topographical description of the site and its environs. The applicant's response to this COL information item incorporated by reference Revision 9 to the ESP SSAR Subsection 2.3.2, with a supplement stating that increases in overall ambient temperature beyond the North Anna 3 site boundary resulting from the operation of the Unit 3 cooling towers would be minimal.

- NAPS ESP COL 2.3-1 Cooling Tower-Induced Effects on Temperature, Moisture, and Salt Deposition

This COL action item states that the COL applicant consider as part of detailed engineering the potential impact on the design or operation of the proposed unit(s) of any cooling tower-induced local increase in (1) ambient air temperature, (2) ambient air moisture content, or (3) moisture and salt deposition. The applicant responded to this COL action item by providing supplemental information on the potential impact of the Unit 3 cooling towers on Unit 3 plant design and operation due to salt deposition, fogging, icing, and local ambient air temperature increases.

2.3.2.3 *Regulatory Basis*

The regulatory basis for incorporating information by reference to the ESP SSAR is 10 CFR 52.79(b), which states (in part) that if a COL application references an ESP, then the FSAR need not contain information or analyses submitted to the Commission in connection with the ESP, provided that the FSAR must either include or incorporate by reference the ESP SSAR and must contain, in addition to the information and analyses otherwise required, information sufficient to demonstrate that the design of the facility falls within the site characteristics and design parameters specified in the ESP.

The regulatory basis for the information presented in the ESP SSAR is addressed in the SER related to the ESP SSAR (i.e., NUREG-1835).

The acceptance criteria for the additional local meteorological information presented in the North Anna 3 COL FSAR beyond that presented in the ESP SSAR are based on meeting the following relevant requirements of 10 CFR Parts 52 and 100:

- 10 CFR 52.79(a)(1)(iii), as it relates to identifying the most severe of the natural phenomena that have been historically reported for the site and surrounding area and with sufficient margins for the limited accuracy, quantity, and time in which the historical data have been accumulated.

- 10 CFR 100.20(c)(2) and 100.21(d), with respect to the consideration that has been given to the local meteorological and air quality characteristics of the site and other physical characteristics of the site that can influence the local meteorology.

NUREG-0800, Section 2.3.2, specifies (in part) that an application meets the above requirements if the application satisfies the following criteria:

- A discussion and evaluation of the influence of the plant and its facilities on the local meteorological and air quality conditions should be provided. Applicants should identify potential changes in the normal and extreme values resulting from plant construction and operation.

2.3.2.4 *Technical Evaluation*

NRC staff reviewed Subsection 2.3.2 of the North Anna 3 COL FSAR and checked the referenced ESP SSAR. The staff's review confirmed that the information contained in the North Anna 3 COL application and incorporated by reference to Subsection 2.3.2 of the ESP SSAR, Revision 9, addresses the relevant information related to the local meteorology. The staff's technical evaluation of the information incorporated by reference to the ESP SSAR related to local meteorology is documented in NUREG-1835.

The staff's technical evaluation of this application subsection is limited to reviewing (1) the resolution of COL Information Item NAPS COL 2.0-8-A, and (2) the resolution of COL Action Item NAPS ESP COL 2.3-1. There are no site parameters or site characteristics associated with this FSAR subsection.

<u>*COL Item*</u>

- NAPS COL 2.0-8-A Local Meteorology

NRC staff reviewed the resolution to NAPS COL 2.0-8-A related to local meteorology. The staff found that the applicant had appropriately supplied site specific local meteorological information by incorporating by reference Revision 9 to the ESP SSAR Subsection 2.3.2. The staff's review of the applicant's supplemental information regarding the Unit 3 cooling tower impact on North Anna 3 plant design and operation is discussed below.

- NAPS ESP COL 2.3-1 Cooling Tower-Induced Effects on Temperature, Moisture, and Salt Deposition

NRC staff reviewed the resolution to NAPS ESP COL 2.3-1, related to the potential impact on the design or operation of North Anna 3 of any cooling tower-induced local increase in (1) ambient air temperature, (2) ambient air moisture content, or (3) moisture and salt deposition. In a supplement to the ESP SSAR, Revision 0 to North Anna 3 COL FSAR Subsection 2.3.2 stated that the impact on the design and operation of Unit 3 from any cooling tower-induced increase in local ambient temperature, moisture content, and salt deposition has been considered in the location and separation of wet cooling towers relative to electrical transmission lines, electrical equipment, and heating, ventilating, and air conditioning (HVAC) intakes and the chosen site layout ensured that such impacts would be minimal. The staff subsequently asked the applicant in **RAI 2.3.2-1** to describe the quantitative analysis used to evaluate the potential impacts of the Unit 3 cooling tower on Unit 3 plant design and operation. The staff also asked the applicant to discuss the effects of local increases in ambient temperature, humidity, and salt and moisture deposition due to the cooling tower on electrical transmission lines and other electrical equipment, including transformers and the switchyard, and HVAC intakes. In a letter responding to **RAI 2.3.2-1** dated April 25, 2008, the applicant described the potential effects of increases in ambient air temperature, moisture, and salt deposition on Unit 3 plant design and operation.

The applicant's response to **RAI 2.3.2-1** addressed potential impacts on Unit 3 plant design and operation due to salt deposition, fogging, and icing from the plant service water system (PSWS) mechanical draft plume abated cooling tower and from the circulating water system (CIRC) hybrid cooling tower using the Seasonal/Annual Cooling Tower Impact (SACTI) computer code. The applicant stated that the highest predicted salt deposition rate is not expected to adversely affect any electrical equipment at the North Anna site, because several months of buildup would be needed before such deposits would be classified as a medium contamination level per the Institute of Electrical and Electronics Engineers (IEEE) Standard C57.19.100-1995. The applicant also predicted that a maximum of 9.5 hours of fogging per year would occur at any location, mostly during the winter months, but no icing was predicted to occur.

The staff reviewed the SACTI computer code inputs provided by the applicant; and executed the code using meteorological data from Richmond, Virginia. The staff generated results similar to the applicant's. Because the control room HVAC intakes, onsite transmission lines, switchyard equipment, and transformers are designed for outdoor operations that include environmental conditions such as rain, fog, and snow, the applicant stated that added fog and moisture from cooling tower plumes are not expected to adversely affect these plant features. The staff concurred with this conclusion.

The applicant stated that the PSWS mechanical draft cooling tower produces higher salt deposition rates than the CIRC hybrid cooling tower. The staff asked the applicant in **RAI 2.3.2-2** to explain why the PSWS cooling tower produces higher salt deposition rates than the CIRC cooling tower, even though the CIRC cooling tower is modeled with a higher drift rate. In a letter responding to **RAI 2.3.2-2** dated August 28, 2008, the applicant stated that the main difference contributing to the higher salt deposition rates for the PSWS cooling tower is the difference in drift particle size between the two cooling towers. Based on the information obtained from manufacturers of cooling towers typical of those to be used at North Anna 3, the applicant noted that the particle sizes emitted by the PSWS are larger than those from the CIRC cooling tower. This explanation as to why the PSWS cooling tower produces higher salt deposition rates appears reasonable to the staff. Therefore, the staff considers **RAI 2.3.2-2** to be resolved.

The applicant's response to **RAI 2.3.2-1** also addressed potential impacts on Unit 3 plant design and operation due to local ambient air temperature increases from the PSWS mechanical draft cooling tower, the CIRC hybrid cooling tower, and the CIRC dry cooling tower.

Because the exhaust temperature of the PSWS cooling tower will be no greater than the maximum inlet water temperature of 39 degree Celsius (103 degrees Fahrenheit), and because this value is less than the ESBWR DCD zero exceedance ambient design temperature site parameter value (47.2 degrees Celsius [117 degrees Fahrenheit]), the applicant stated that the exhaust from the PSWS cooling tower will not adversely affect Unit 3 due to increases in surrounding ambient air temperature.

The applicant also stated that the exhaust temperatures of the CIRC hybrid and dry cooling towers will be no greater than the maximum inlet water temperature of 51.6 degrees Celsius (125 degrees Fahrenheit). Because cooling tower plume temperatures are higher than the local ambient air temperatures, buoyancy will cause the cooling tower plumes to rise under low wind conditions. Because the exhaust plenums of the cooling towers are already at higher elevations compared to the Unit 3 control room HVAC intakes and the Unit 3 outdoor electrical equipment, such as transformers and switchyard equipment, the buoyant plume rise will direct the plume away from the Unit 3 control room HVAC intakes and outdoor electrical equipment. The high wind conditions that could direct the plumes toward the Unit 3 control room HVAC intakes and outdoor electrical equipment would result in a rapid dispersion and mixing that cools the plume. Because of the margin between the ESBWR DCD zero exceedance ambient design temperature site parameter value (47.2 degrees Celsius [117 degrees Fahrenheit]) and the Unit 3 100-year return period maximum dry-bulb temperature site characteristic value (42.8 degrees Celsius [109 degrees Fahrenheit]), the thermal plumes from the CIRC hybrid and dry cooling towers are not expected to increase the surrounding ambient air temperature significantly to adversely affect Unit 3.

The staff concurred with the applicant's assessment that local ambient air temperature increases from the PSWS mechanical draft cooling tower, the CIRC hybrid cooling tower, and the CIRC dry cooling tower will not adversely affect Unit 3 plant design and operation. The applicant revised the North Anna 3 FSAR Subsection 2.3.2 in Revision 1 to incorporate the applicant's response to **RAI 2.3.2-1,** as discussed above. Therefore, the staff considers **RAI 2.3.2-1** to be resolved.

2.3.2.5 *Post Combined License Activities*

There are no post COL activities associated with this subsection.

2.3.2.6 *Conclusion*

NRC staff reviewed the application and checked the referenced ESP SSAR. The staff's review confirmed that the applicant has addressed the relevant information and there is no outstanding information expected to be addressed in the COL FSAR related to this subsection.

The staff concluded that the information pertaining to North Anna 3 COL FSAR Subsection 2.3.2 is within the scope of the ESP and adequately incorporates by reference Subsection 2.3.2 of the ESP SSAR. The information is thus acceptable. In addition, the staff compared the additional COL information in the application to the relevant NRC regulations and acceptance criteria defined in NUREG-0800, Section 2.3.2, and concluded that the applicant is in compliance with the relevant requirements of 10 CFR Parts 52 and 100. COL information item NAPS COL 2.0-8-A and COL Action Item NAPS ESP COL 2.3-1 have been adequately addressed by the applicant and can be considered closed.

2.3.3 Onsite Meteorological Measurement Programs

2.3.3.1 *Introduction*

Subsection 2.3.3, "Onsite Meteorological Measurements Program," of the North Anna 3 COL FSAR addresses the onsite meteorological monitoring program and the resulting data.

2.3.3.2 *Summary of Application*

This subsection of the North Anna 3 COL FSAR addresses site specific information on the onsite meteorological measurement program. The applicant addressed the information as follows:

<u>*COL Item*</u>

- NAPS COL 2.0-9-A Onsite Meteorological Measurements Programs

This COL information item states that the COL applicant supply site specific information in accordance with SRP Section 2.3.3; that is, the COL applicant should describe its onsite meteorological measurements program and provide a copy of the resulting meteorological data. The applicant responded to this COL information item by referencing the onsite meteorological program description provided in Subsection 2.3.3 of the ESP SSAR and the 1996–1998 onsite hourly database submitted in support of the North Anna ESP application. The applicant also provided supplemental information addressing the adequacy of distances from North Anna 3 to the onsite meteorological measurements program.

2.3.3.3 *Regulatory Basis*

The regulatory basis for incorporating information by reference to the ESP SSAR is 10 CFR 52.79(b), which states (in part) that if a COL application references an ESP, then the FSAR need not contain information or analyses submitted to the Commission in connection with the ESP, provided that the FSAR must either include or incorporate by reference the ESP SSAR and must contain, in addition to the information and analyses otherwise required, information sufficient to demonstrate that the design of the facility falls within the site characteristics and design parameters specified in the ESP.

The regulatory basis for the information presented in the ESP SSAR is addressed in the SER related to the ESP SSAR (i.e., NUREG-1835).

The acceptance criteria for the adequacy of distances from the North Anna 3 to the onsite meteorological measurements program are in RG 1.23, "Meteorological Monitoring Programs for Nuclear Power Plants." NUREG-0800, Section 2.3.3, states that guidance on a suitable onsite meteorological monitoring program is in RG 1.23.

2.3.3.4 *Technical Evaluation*

NRC staff reviewed Subsection 2.3.3 of the North Anna 3 COL FSAR and checked the referenced ESP SSAR. The staff's review confirmed that the information contained in the North Anna 3 COL application and incorporated by reference to Subsection 2.3.3 of the ESP SSAR, Revision 9, addresses the relevant information related to the onsite meteorological measurements program. The staff's technical evaluation of the information incorporated by reference to the ESP SSAR related to the onsite meteorological measurements program is documented in the corresponding SER (i.e., NUREG-1835).

The staff's technical evaluation of this application subsection is limited to reviewing the resolution of COL Information Item NAPS COL 2.0-9-A. There are no site parameters orsite characteristics associated with this FSAR subsection.

COL Item

- NAPS COL 2.0-9-A		Onsite Meteorological Measurements Programs

NRC staff reviewed the resolution to NAPS COL 2.0-9-A related to the onsite meteorological measurements program. The staff found that the applicant had appropriately supplied site specific onsite meteorological measurements program information by incorporating by reference ESP SSAR Subsection 2.3.3.

The staff also reviewed the supplemental information provided by the applicant concerning the distance between the onsite meteorological towers and the Unit 3 structures. The applicant stated that the highest building at the Unit 3 site is the 57.9 meters (190 feet) turbine building, and the primary and backup meteorological towers are approximately 733.4 meters (2,406 feet) and 744 meters (2,440 feet), respectively, from the turbine building. Because the primary and backup meteorological towers are more than 10 building heights away from the tallest building at the Unit 3 site, the applicant concluded that the Unit 3 turbine building does not influence the meteorological measurements. The staff concurred with this assessment because the applicant had met the RG 1.23 criterion. RG 1.23 states that obstructions to wind measurements should be at a distance of at least 10 times their height from the wind sensors.

The staff noted that the CIRC hybrid and the PSWS mechanical draft cooling towers are both lower than the turbine building (i.e., 55 meters and 18.5 meters, respectively) and are located further from the primary and backup meteorological towers. Therefore, the staff concluded that the building wake from these structures would not influence the meteorological measurements.

2.3.3.5 *Post Combined License Activities*

Table 2.3-1 of Part 10 of the COL application contains emergency planning (EP) inspection, test, analysis, and acceptance criteria (ITAAC). The following two EP-ITAAC involve demonstrating that the operational onsite meteorological monitoring program appropriately supports the North Anna 3 emergency plan:

- EP Program Element 6.3: The means exist to continuously assess the impact of the release of radioactive materials to the environment, accounting for the relationship between effluent monitor readings, and onsite and offsite exposures and contamination for various meteorological conditions. The acceptance criterion is that a report exists that confirms a methodology has been provided to establish the relationship between effluent monitor readings and onsite and offsite exposures and contamination for various meteorological conditions.

- EP Program Element 6.4: The means exists to acquire and evaluate meteorological information. The acceptance criterion is that a report exists that confirms the specified meteorological data were available at the control room, technical support center , and emergency operations facility.

EP and EP-ITAAC are addressed in SER Section 13.3, "Emergency Planning."

2.3.3.6 *Conclusion*

NRC staff reviewed the application and checked the referenced ESP SSAR. The staff's review confirmed that the applicant has addressed the relevant information and there is no outstanding information expected to be addressed in the COL FSAR related to this subsection.

The staff concluded that the information pertaining to North Anna 3 COL FSAR Subsection 2.3.3 is within the scope of the ESP SSAR and adequately incorporates by reference Subsection 2.3.3 of the ESP SSAR. The information is thus acceptable. In addition, the staff has compared the additional COL information within the application to the relevant NRC regulations and acceptance criteria defined in NUREG-0800, Section 2.3.3, and concludes that the applicant is in compliance with the relevant requirements of RG 1.23. Therefore, DCD COL Item 2.0-9-A has been adequately addressed by the applicant and can be considered closed.

2.3.4 Short-Term (Accident) Diffusion Estimates (Related To RG 1.206 Section 2.3.4, "Short-Term Atmospheric Dispersion Estimates for Accident Releases")

2.3.4.1 *Introduction*

Subsection 2.3.4, "Short-Term (Accident) Diffusion Estimates," of the North Anna 3 COL FSAR addresses the atmospheric dispersion factor (χ/Q) estimates at the EAB, the outer boundary of the LPZ, the control room, and the TSC for postulated design-basis accidental radioactive airborne releases. This SER subsection also reviews Appendix 2A, "ARCON96 Source/Receptor Inputs," of the North Anna 3 COL FSAR which addresses the use of the ARCON96 atmospheric dispersion model to derive site specific control room and TSC χ/Q values.

2.3.4.2 *Summary of Application*

Subsection 2.3.4 and Appendix 2A of the North Anna 3 COL FSAR address site specific information on short-term atmospheric dispersion estimates for accident releases. The applicant addressed the information as follows:

COL Items

- NAPS COL 2.0-10-A — Short-Term Dispersion Estimates for Accidental Atmospheric Releases

This COL information item states that the applicant supply site specific information, in accordance with SRP Section 2.3.4, to show that the site's meteorological dispersion values—calculated in accordance with RG 1.145 and RG 1.194 and compared to dispersion values in Chapter 15—result in doses less than those stipulated in 10 CFR 52.79(a)(1)(vi) and in the applicable portions of SRP Sections 11 and 15.[3] The applicant responded to this COL information item by referencing the EAB and LPZ χ/Q values presented in the ESP SSAR and by presenting new χ/Q values that were calculated for the control room and the TSC in NAPS FSAR Tables 2.3-201 through 2.3-206. The applicant also demonstrated in North Anna 3 COL FSAR Table 2.0-201 that the North Anna 3 EAB, LPZ, control room, and TSC χ/Q site characteristic values fall within the corresponding ESBWR DCD meteorological dispersion site parameter values, thus ensuring that the applicant's site meteorological dispersion values result in doses less than those stipulated in 10 CFR 52.79(a)(1)(vi) and in the applicable portions of SRP Sections 11 and 15.

- NAPS COL 2A.2-1-A — Confirmation of the ESBWR χ/Q Values

This COL information item states that when referencing the ESBWR DCD to confirm that site characteristics at a given site are bounded by the ESBWR DCD site parameter values per 10 CFR 52.79, the COL applicant shall perform ARCON96 determinations for all source/receptor pairs listed in ESBWR DCD Tables 2A-3 and 2A-4 using site specific meteorological data. The applicant responded to this COL information item by calculating and presenting control room and TSC χ/Q values in NAPS FSAR Tables 2.3-201 through 2.3-206.

- NAPS COL 2A.2-2-A — Confirmation of the Reactor Building χ/Q Values

This COL information item states that if the χ/Q values for a release from any door on the East sides of the reactor building or fuel building are not bounded by the ESBWR χ/Q values for a release in the reactor building, the doors must be administratively controlled prior to movement of irradiated fuel bundles and during movement of irradiated fuel bundles. The administrative controls must be such that the doors and personnel air locks on the East sides of the reactor building or fuel building are promptly closed under conditions indicative of a fuel handling accident. The applicant responded to this COL information item by committing to administratively controlling the doors prior to and during movement of irradiated fuel bundles. The administrative controls are such that the doors and personnel air locks on the East sides of the reactor building or fuel bulding are promptly closed under conditions indicative of a fuel handling accident.

- NAPS ESP COL 2.3-2 — Atmospheric Dispersion Factors for Control Room

This COL action item states that the COL applicant assess the dispersion of airborne radioactive materials to the control room. The applicant responded to this COL action item by

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[3] The wording presented here for COL information item NAPS COL 2.0-10-A differs from that presented in Revision 5 to the ESBWR DCD. The wording presented here, which is based on GEH's response to ESBWR DCD RAI 2.0-2 dated October 23, 2008, should appear in a future revision to the ESBWR DCD.

calculating and presenting new control room χ/Q values in NAPS FSAR Tables 2.3-201 through 2.3-206.

Supplemental information

The applicant provided supplemental information regarding the wake influence zone of tall structures at the Unit 3 site. The applicant stated that the highest building at the Unit 3 site is the turbine building, which is 57.9 meters (190 feet) above plant grade. Because the closest point on the EAB is more than 10 building heights away from the Unit 3 power block buildings, the applicant stated that the entire EAB is located beyond the wake influence zone that can be influenced by the Unit 3 power block buildings, thereby justifying the use of the "wake-credit not allowed" scenario in calculating the EAB χ/Q values presented in ESP SSAR Subsection 2.3.4.

The applicant also provided supplemental information regarding additional dispersion estimates for Unit 1 and 2 airborne radioactive releases to the Unit 3 control room in North Anna 3 COL FSAR Table 2.3-207.

2.3.4.3 *Regulatory Basis*

The regulatory basis for incorporating information by reference to the ESP SSAR is 10 CFR 52.79(b), which states (in part) that if a COL application references an ESP, then the FSAR need not contain information or analyses submitted to the Commission in connection with the ESP, provided that the FSAR must either include or incorporate by reference the ESP SSAR and must contain, in addition to the information and analyses otherwise required, information sufficient to demonstrate that the design of the facility falls within the site characteristics and design parameters specified in the ESP.

The regulatory basis for the information presented in the ESP SSAR is addressed in the SER related to the ESP SSAR (i.e., NUREG-1835).

The acceptance criteria for the additional accidental atmospheric dispersion estimates presented in the North Anna 3 COL FSAR, beyond those presented in the ESP SSAR, are based on meeting the relevant requirements of 10 CFR Part 50. NRC staff considered the following regulatory requirements in reviewing the applicant's discussion of control room atmospheric dispersion analyses:

- 10 CFR Part 50, Appendix A, General Design Criterion (GDC) 19, "Control Room," with respect to the meteorological considerations used to evaluate the personnel exposures inside the control room during radiological accident conditions.

- 10 CFR Part 50, Appendix E, Paragraph IV.E.8, with respect to providing an onsite TSC from which effective direction can be given and effective control can be exercised during an emergency.

NUREG-0800, Section 2.3.4 specifies (in part) that an application meets the GDC 19 requirements if the application provides the following information:

- A description of the atmospheric dispersion models used to calculate χ/Q values for accidental releases of radioactive materials into the atmosphere.

- Meteorological data used for the evaluation (as input to the dispersion models), which represent annual cycles of hourly values of wind direction, wind speed, and atmospheric stability for each mode of accidental release.

- A discussion of atmospheric diffusion parameters, such as lateral and vertical plume spread (σ_y and σ_z) as a function of distance, topography, and atmospheric conditions, should be related to measured meteorological data.

- Hourly cumulative frequency distributions of χ/Q values from the effluent release point(s) to the EAB and LPZ should be constructed to describe the probabilities of these χ/Q values being exceeded.

- Atmospheric dispersion factors used for the assessment of consequences related to atmospheric radioactive releases to the control room for design-basis and other accidents should be provided.

- For control room habitability analysis, a site plan drawn to scale should be included showing true North and potential atmospheric accidental release pathways, control room intake, and unfiltered inleakage pathways.

NUREG-0800, Section 15.0.3 specifies (in part) that an application meets 10 CFR Part 50, Appendix E TSC radiological habitability requirements if the total calculated radiological consequences for postulated accidents fall within the exposure acceptance criteria specified for the control room.

In addition, the short-term atmospheric dispersion estimates for accidental releases to the control room and the TSC should be consistent with the appropriate sections from the following RGs:

- RG 1.23, “Onsite Meteorological Programs,” provides criteria for an acceptable onsite meteorological measurements program; these data are used as inputs to atmospheric dispersion models.

- RG 1.194, “Atmospheric Relative Concentrations for Control Room Radiological Habitability Assessments at Nuclear Power Plants,” presents criteria for characterizing atmospheric dispersion conditions for evaluating the consequences of radiological releases to the control room.

2.3.4.4 *Technical Evaluation*

NRC staff reviewed Subsection 2.3.4 and Appendix 2A of the North Anna 3 COL FSAR and checked the referenced ESP SSAR. The staff’s review confirmed that the information in the North Anna 3 COL application and incorporated by reference Subsection 2.3.4 of the ESP SSAR, Revision 9, addresses the relevant information related to short-term (accidental) atmospheric dispersion estimates for accidental releases. The staff’s technical evaluation of the information incorporated by reference to the ESP SSAR, related to short-term atmospheric dispersion estimates for accidental releases, is documented in the corresponding SER (i.e., NUREG-1835).

The staff’s technical evaluation of this application Subsection 2.3.4 and Appendix 2A is limited to reviewing (1) the resolution of COL Information Items 2.0-10-A, 2A.2-1-A and 2A.2-2-A, (2) the resolution of ESP COL Action Item 2.3-2, (3) supplemental information provided by the applicant regarding the Unit 3 wake influence zone of tall structures, and (4) whether the North Anna 3 accidental atmospheric dispersion site characteristics fall within the ESBWR DCD accidental atmospheric dispersion site parameter values.

COL Items

- NAPS COL 2.0-10-A Short-Term Dispersion Estimates for Accidental Atmospheric Releases

NRC staff reviewed the applicant's resolution to NAPS COL 2.0-10-A, related to referencing the EAB and LPZ χ/Q values presented in the ESP SSAR and presenting new χ/Q values in the North Anna 3 COL FSAR that were calculated for the control room and the TSC. The staff also reviewed the applicant's site meteorological dispersion values to ensure that they result in doses less than those stipulated in 10 CFR 52.79(a)(1)(vi) and in the applicable portions of SRP Sections 11 and 15. This review involves demonstrating that North Anna 3 short-term (accidental release) atmospheric dispersion site characteristics fall within the corresponding ESBWR DCD atmospheric dispersion site parameter values. The staff's review of the applicant's resolution to COL Information Item NAPS COL 2.0-10-A is discussed later in this subsection.

- NAPS COL 2A.2-1-A Confirmation of the ESBWR χ/Q Values

NRC staff reviewed the applicant's resolution to NAPS COL 2A.2-1-A, related to generating control room and TSC χ/Q values using the ARCON96 atmospheric dispersion model with site specific meteorological data. The staff's review of the applicant's resolution to COL Information Item NAPS COL 2A.2-1-A is discussed later in this subsection.

- NAPS COL 2A.2-2-A Confirmation of the Reactor Building χ/Q Values

NRC staff reviewed the applicant's resolution to NAPS COL 2A.2-2-A, related to administratively controlling the doors on the East sides of the reactor building and fuel building prior to and during the movement of irradiated fuel bundles. The applicant responded to this COL information item by committing to administratively controlling the doors prior to and during movement of irradiated fuel bundles. The administrative controls are such that the doors and personnel air locks on the East sides of the reactor building and fuel building are promptly closed under conditions indicative of a fuel handling accident. The staff finds this to be acceptable and therefore COL Information Item NAPS COL 2A.2-2-A is considered to be resolved.

- NAPS ESP COL 2.3-2 Atmospheric Dispersion Factors for Control Room

NRC staff reviewed the applicant's resolution to NAPS ESP COL 2.3-2, related to χ/Q values that were calculated for the control room. The staff's review of the applicant's resolution to COL Action Item NAPS ESP COL 2.3-2 is discussed later in this subsection.

Supplemental information

NRC staff reviewed the applicant's supplemental information related to the wake influence zone of tall structures at the Unit 3 site. The staff also reviewed the supplemental information related to additional dispersion estimates for Unit 1 and 2 airborne radioactive releases to the Unit 3 control room.

The applicant's resolutions to NAPS COL 2.0-10-A NAPS COL 2A.2-1-A, and NAPS ESP COL 2.3-2 resulted in the applicant's (1) continuing to use the accident EAB and LPZ χ/Q values from the ESP SSAR, and (2) calculating new accident χ/Q values for Unit 3 releases to the Unit 3 control room and the TSC. The applicant also presented new accident χ/Q values for Unit 1 and 2 releases to the Unit 3 control room. The staff's review of each set of accident χ/Q values is discussed below.

A. EAB and LPZ χ/Q Values

NRC staff reviewed the supplemental information provided by the applicant concerning the wake influence zone of tall structures at the North Anna 3 site. The applicant stated that the highest building at the Unit 3 site is the turbine building, which is 57.9 meters (190 feet) above plant grade. Because the closest point on the EAB modeled in the ESP SSAR (865 meters in the west-southwest sector) is more than 10 building heights away from the Unit 3 power block buildings, the applicant stated that the entire EAB is located beyond the wake influence zone that can be influenced by the Unit 3 power block buildings, thereby justifying the use of the "wake-credit not allowed" scenario in calculating the EAB χ/Q values presented in ESP SSAR Subsection 2.3.4. The staff found that the applicant had made a conservative assumption by ignoring the additional atmospheric turbulence generated by building wake effects. The additional atmospheric turbulence generated by building wakes enhances dispersion and results in lower airborne concentrations (e.g., lower χ/Q values).

The staff found the continued use of the ESP SSAR accident EAB and LPZ χ/Q values acceptable for the following reasons:

- SRP Section 2.3.4 states that a COL application referencing an ESP need not include a reinvestigation of the site characteristics that were previously accepted in the referenced ESP.

- The North Anna 3 plant site shown in North Anna 3 COL FSAR Figure 2.1-201 is within the North Anna ESP proposed facility boundary, as shown in North Anna 3 COL FSAR Figure 2.0-205, and the ESP SSAR accident EAB and LPZ χ/Q site characteristic values were conservatively determined by selecting the shortest distances from any point on the ESP SSAR plant envelope to the EAB and LPZ for each directional sector. Consequently, the downwind distances used in the ESP SSAR to calculate the EAB and LPZ χ/Q site characteristic values bound the corresponding North Anna 3 plant facility distances to the EAB and LPZ.

- The ESP SSAR EAB and LPZ accident χ/Q site characteristic values derived from other input assumptions remain bounding for North Anna 3 (e.g., building wake effects were ignored and all release points were treated as ground-level releases).

The staff concluded that the input assumptions used to model the ESP SSAR accident EAB and LPZ χ/Q values bound the actual North Anna 3 plant and site characteristics, and the use of one set of accident χ/Q values to model all potential accidental release points is appropriate. Therefore, the staff found that the applicant's use of the ESP SSAR EAB and LPZ χ/Q values for North Anna 3 is appropriate.

B. Control Room and TSC χ/Q Values for Unit 3 Releases

Figure 2A-1 in Tier 2 of the ESBWR DCD shows the North Anna 3 onsite release points and control room and TSC intake locations. The release and receptor locations evaluated by the applicant were the same locations used in the ESBWR DCD Chapter 15 dose analyses, as defined in Appendix 2A in Tier 2 to ESBWR DCD. The release locations (e.g., reactor building, turbine building, fuel building, passive containment cooling system vent, and radwaste building) depend on the event, the release pathway, and the event scenario. The applicant considered four control room air intake locations (i.e., one normal, two emergency, and one inleakage location) and two TSC air intake locations, as outlined in DCD Appendix 2A.

The applicant provided χ/Q values in North Anna 3 COL FSAR Tables 2.3-201 through 2.3-206 for use in evaluating potential doses from these North Anna 3 postulated release locations to the North Anna 3 control room and TSC intakes, utilizing the same onsite 1996–1998 meteorological database used in the ESP SSAR for the EAB and LPZ atmospheric dispersion calculations. The applicant stated that the ARCON96 atmospheric dispersion computer code was used in accordance with the guidance in RG 1.194.

RG 1.194 states that the ARCON96 computer code (Revision 1 of NUREG/CR-6330) is an acceptable methodology for assessing control room χ/Q values for use in design-basis accident radiological analyses, subject to the provisions of RG 1.194. The ARCON96 code estimates χ/Q values for various time-average periods ranging from 2 hours to 30 days. The meteorological input to ARCON96 consists of hourly values of wind speed, wind direction, and atmospheric stability class. The χ/Q values calculated through ARCON96 are based on the theoretical assumption that material released into the atmosphere will be normally distributed (Gaussian) about the plume's center line. A straight-line trajectory is assumed between the release points and receptors. The diffusion coefficients account for enhanced dispersion under low wind speed conditions and in building wakes.

Hourly meteorological data are used to calculate hourly relative concentrations. The hourly relative concentrations are then combined to estimate concentrations ranging in duration from 2 hours to 30 days. Cumulative frequency distributions are prepared from the average relative concentrations; the relative concentrations that are exceeded no more than 5 percent of the time are determined for each averaging period.

The diffusion coefficients used in ARCON96 have three components. The first component is the diffusion coefficient used in other NRC models, such as PAVAN (NUREG/CR-2858), which was used in the ESP SSAR to generate EAB and LPZ accident χ/Q values. The other two components are corrections to account for enhanced dispersion under low wind speed conditions and in building wakes. These components are based on an analysis of diffusion data collected in various building wake diffusion experiments under a wide range of meteorological conditions. Because the diffusion occurs at short distances within the plant's building complex, the ARCON96 diffusion parameters are not affected by nearby topographic features such as hills and bodies of water. Therefore, NRC staff found that the applicant's use of the ARCON96 diffusion parameter assumptions is acceptable.

The staff found the applicant's control room and TSC χ/Q values for Unit 3 releases in FSAR Tables 2.3-201 through 2.3-206 acceptable for the following reasons:

- The applicant derived the χ/Q values using the ARCON96 atmospheric dispersion computer code (Revision 1 of NUREG/CR-6330), in accordance with guidance in RG 1.194 and

Appendix 2A in Tier 2 to ESBWR DCD. The staff evaluated the applicability of the ARCON96 model and concluded that there are no unusual sitings, building arrangements, release characterizations, source-receptor configurations, meteorological regimes, or terrain conditions that preclude the use of the ARCON96 model for North Anna 3.

- The applicant derived the χ/Q values using the same onsite 1996–1998 meteorological database used to derive the EAB and LPZ χ/Q values presented in the ESP SSAR. The staff reviewed the 1996–1998 onsite meteorological database in Section 2.3.3 of the ESP SER and concluded that these data are representative of the dispersion conditions at the North Anna ESP site.

- The staff confirmed the applicant's atmospheric dispersion estimates by running the ARCON96 model and generating similar results (within ± 5 percent).

In light of the foregoing, the staff accepted the control room and TSC χ/Q values presented by the applicant.

C. Control Room χ/Q Values for Unit 1 and 2 Releases

NRC staff reviewed the applicant's χ/Q values in North Anna 3 COL FSAR Table 2.3-207 for evaluating the impact of a postulated design-basis accident in North Anna Unit 1 or 2 on the North Anna 3 control room. The applicant explained the generation of these χ/Q values in supplement NAPS SUP 6.4-1 to DCD Section 6.4.5 (i.e., North Anna 3 COL FSAR Subsection 6.4.5). The applicant modeled a bounding case, which the applicant described as a release from the Unit 2 reactor building to the Unit 3 control room. The applicant derived the χ/Q values from assuming a point source, a distance of 400 meters, a release height of 10 meters, and a receptor-to-source direction of 60 degrees.

The staff reviewed the applicant's control room χ/Q values for Unit 1 and 2 releases by executing the ARCON96 atmospheric dispersion model using hourly wind speed, wind direction, and atmospheric stability data based on 1996–1998 onsite meteorological data provided by the applicant in support of the ESP SSAR. The wind data were from the 10-meter and 48-meter levels on the meteorological tower. The stability data were derived from the vertical temperature difference (delta-temperature)—measurements taken between the 48-meter and 10-meter levels on the meteorological tower.

The staff conservatively set (1) the intake height equal to the applicant's assumed release height of 10 meters, and (2) the building area to zero to ignore building wake diffusion. The staff also determined that the 400-meter distance-to-receptor input used by the applicant was appropriate; it represents the shortest distance from either the Unit 1 or 2 reactor building to the Unit 3 control building. The staff's confirmatory analysis produced results similar to the applicant's results (within ± 9 percent). In light of the foregoing, the staff accepted the Unit 1 and 2 release to Unit 3 control room χ/Q values presented in North Anna 3 COL FSAR Table 2.3-207.

Evaluation of Site Parameters and Site Characteristics

NRC staff also reviewed the applicant's resolution to DCD COL 2.0-10-A, related to demonstrating that North Anna 3 short-term (accidental release) atmospheric dispersion site characteristics fall within the corresponding ESBWR DCD atmospheric dispersion site parameter values. Subsection 2.0 of the North Anna 3 COL FSAR evaluated whether the North

Anna 3 site characteristics fall within the ESBWR DCD site parameter values. A comparison of the ESBWR DCD accidental atmospheric dispersion factors with the North Anna 3 accidental atmospheric dispersion factors is in North Anna 3 COL FSAR Table 2.0-201. Smaller χ/Q values are associated with a greater dilution capability, resulting in lower radiological doses. When comparing an ESBWR DCD site parameter χ/Q value and a North Anna 3 site characteristic χ/Q value, the North Anna 3 site is acceptable for the ESBWR design if the North Anna 3 site characteristic χ/Q value is smaller than the ESBWR site parameter χ/Q value. Such a comparison shows that the North Anna 3 site has better dispersion characteristics than the ESBWR reactor design requires.

North Anna 3 COL FSAR Table 2.0-201 shows that North Anna 3 EAB, LPZ, control room, and TSC site characteristic χ/Q values are all less than or equal to the corresponding ESBWR DCD site parameter χ/Q values, thereby demonstrating that site meteorological dispersion conditions result in doses less than those stipulated in 10 CFR 52.79(a)(1)(vi) and in the applicable portions of SRP Sections 11 and 15.

2.3.4.5 *Post Combined License Activities*

There are no post COL activities associated with this subsection.

2.3.4.6 *Conclusion*

NRC staff reviewed the application and checked the referenced ESP SSAR. The staff's review confirmed that the applicant has addressed the relevant information and there is no outstanding information expected to be addressed in the COL FSAR related to this subsection.

The staff concluded that the information pertaining to North Anna 3 COL FSAR Subsection 2.3.4 is within the scope of the ESP and adequately incorporates by reference Subsection 2.3.4 of the ESP SSAR. The information is thus acceptable. In addition, the staff compared the additional COL information in the application to the relevant NRC regulations and acceptance criteria defined in NUREG-0800, Section 2.3.4. The staff concluded that the applicant is in compliance with the relevant requirements of 10 CFR Part 50. COL Information Items NAPS COL 2.0-10-A, NAPS COL 2A.2-1-A, and NAPS COL 2A.2-2-A, as well as COL Action Item NAPS ESP COL 2.3-2, have been adequately addressed by the applicant and can be considered closed.

2.3.5 Long-Term (Routine) Diffusion Estimates (related to RG 1.206 Section 2.3.5, "Long-Term Atmospheric Dispersion Estimates for Routine Releases")

2.3.5.1 *Introduction*

Subsection 2.3.5, "Long-Term (Routine) Diffusion Estimates," of the North Anna 3 COL FSAR provides site specific information on χ/Q and dry deposition factor (D/Q) estimates to a distance of 80 kilometers (50 miles) from the plant, for releases of radiological effluents to the atmosphere during normal plant operation for annual average release limit calculations and offsite dose estimates.

2.3.5.2 *Summary of Application*

This subsection of the North Anna 3 COL FSAR addresses site specific information on long-term atmospheric dispersion estimates for routine releases. The applicant addressed the information as follows:

COL Items

- NAPS COL 2.0-11-A Long-Term Diffusion Estimates

This COL information item states that the COL applicant should supply site specific information in accordance with SRP Section 2.3.5. That is, the COL applicant should provide χ/Q and D/Q estimates for calculating concentrations in the air and the amount of material deposited on the ground as a result of routine releases of radiological effluents into the atmosphere during normal plant operation. The applicant responded to this COL information item by referencing the EAB (site boundary) long-term χ/Q and D/Q values in the ESP SSAR. The applicant also recalculated site specific, long-term χ/Q and D/Q values at specific receptors of interest (i.e. nearest resident, meat animal, and vegetable garden) using (1) the land-use census results reported in the Dominion NAPS 2006 Annual Radiological Environmental Operating Report (AREOR), and (2) ESBWR-specific vent building height and building cross-sectional area data. These new North Anna 3 long-term χ/Q and D/Q values at specific receptors of interest are in North Anna 3 COL FSAR Table 2.3-16R. The applicant also provided long-term χ/Q and D/Q values in each direction sector, for a set of radial distances out to 50 miles, in North Anna 3 COL FSAR Tables 2.3-208 through 2.3-215.

- NAPS ESP COL 2.3-3 Release Points and Receptor Locations

This COL action item states that the COL applicant should verify specific release point characteristics and specific locations of receptors of interest used to generate the ESP SSAR long-term (routine release) atmospheric dispersion site characteristics. The applicant responded to this COL action item by recalculating site specific, long-term χ/Q and D/Q values at specific receptors of interest using (1) the land-use census results reported in the Dominion NAPS 2006 AREOR, and (2) ESBWR-specific vent building height and building cross-sectional area data. These new North Anna 3 long-term χ/Q and D/Q values at specific receptors of interest are in North Anna 3 COL FSAR Table 2.3-16R. The applicant did not recalculate long-term χ/Q and D/Q values at the site boundary because the applicant had determined that the ESP SSAR values for the site boundary are bounding.

Variance

- NAPS ESP VAR 2.0-1 Long-Term Dispersion Estimates (χ/Q and D/Q)

The applicant proposed variance NAPS ESP VAR 2.0-1 from the ESP SSAR. This variance recalculated North Anna 3 maximum long-term (routine release) χ/Q and D/Q values at specific receptors of interest, to replace corresponding values presented in the ESP SSAR.

This variance resulted from a review of the land-use census results reported in the Dominion NAPS 2006 AREOR, which showed that distances to several of the closest specific receptors of interest had changed from the distances used in the ESP SSAR.

2.3.5.3 *Regulatory Basis*

The regulatory basis for incorporating information by reference to the ESP SSAR is 10 CFR 52.79(b), which states (in part) that if a COL application references an ESP, then the FSAR need not contain information or analyses submitted to the Commission in connection with the ESP, provided that the FSAR must either include or incorporate by reference the ESP SSAR and must contain, in addition to the information and analyses otherwise required, information sufficient to demonstrate that the design of the facility falls within the site characteristics and design parameters specified in the ESP.

The regulatory basis for the information presented in the ESP SSAR is addressed in the SER related to the ESP SSAR (i.e., NUREG-1835).

The acceptance criteria for the additional long-term atmospheric dispersion estimates presented in North Anna 3 COL FSAR Subsection 2.3.5, beyond those presented in the ESP SSAR, are based on meeting the relevant requirements of 10 CFR Parts 20, 50, and 100. NRC staff considered the following regulatory requirements in reviewing the applicant's discussion of long-term atmospheric dispersion and deposition estimates:

- 10 CFR Part 20, Subpart D, with respect to establishing atmospheric dispersion site characteristics for demonstrating compliance with dose limits for individual members of the public.

- 10 CFR 50.34a and Sections II.B, II.C, and II.D of Appendix I of 10 CFR Part 50, with respect to establishing atmospheric dispersion site characteristics for evaluating the numerical guides for design objectives and limiting conditions for operation to meet the requirements that radioactive material in effluents released to unrestricted areas be kept as low as is reasonably achievable.

- 10 CFR 100.21(c)(1), with respect to establishing atmospheric dispersion site characteristics such that radiological effluent release limits associated with normal operation can be met for any individual located offsite.

NUREG-0800, Section 2.3.5 specifies (in part) that an application meets the above requirements if the application provides the following information:

- Points of routine release of radioactive material to the atmosphere, including the characteristics (e.g., location and release mode) of each release point.

- The specific location of potential receptors of interest (e.g., nearest vegetable garden, nearest resident, nearest milk animal, and nearest meat cow in each 22½ degree direction sector within a 5-mile [8-kilometer] radius of the site).

- The χ/Q and D/Q values to be used for assessment of the consequences of routine airborne radiological releases, as described in Section 2.3.5.2 of RG 1.206:

  (1) maximum annual average χ/Q values and D/Q values at or beyond the site boundary and at specific locations of potential receptors of interest, utilizing appropriate meteorological data for each routine venting location

  (2) estimates of annual average χ/Q values and D/Q values for 16 radial sectors to a distance of 50 miles (80 kilometers) from the plant, using appropriate meteorological data

In addition, the long-term atmospheric dispersion estimates for routine releases should be consistent with appropriate sections from the following RGs:

- RG 1.23 provides criteria for an acceptable onsite meteorological measurement program; data from this program are used as inputs for atmospheric dispersion models.

- RG 1.109 presents identification criteria to be used for specific receptors of interest.

- RG 1.111 provides acceptable methods for characterizing atmospheric transport and diffusion conditions for evaluating the consequences of routine effluent releases.

- RG 1.112 provides criteria for identifying release points and release characteristics.

2.3.5.4 *Technical Evaluation*

NRC staff reviewed Subsection 2.3.5 of the North Anna 3 COL FSAR and checked the referenced ESP SSAR. The staff's review confirmed that the information contained in the North Anna 3 COL application and incorporated by reference to Subsection 2.3.5 of the ESP SSAR, Revision 9, addresses the relevant information related to long-term atmospheric dispersion and deposition estimates for routine releases. The staff's technical evaluation of the information incorporated by reference to the ESP SSAR related to long-term atmospheric dispersion estimates for routine releases is documented in the corresponding SER (i.e., NUREG-1835).

The staff's technical evaluation of this subsection is limited to reviewing (1) the resolution of COL Information Item NAPS COL 2.0-11-A, (2) the resolution of COL Action Item NAPS ESP COL 2.3-3, (3) variance NAPS ESP VAR 2.0-1, and (4) whether the North Anna 3 long-term atmospheric dispersion and deposition site characteristics fall within the ESBWR DCD long-term atmospheric dispersion and deposition site parameter values.

<u>*COL Items*</u>

- NAPS COL 2.0-11-A Long-Term Diffusion Estimates

NRC staff reviewed the applicant's resolution to DCD COL Item 2.0-11-A, related to supplying site specific, long-term atmospheric dispersion and deposition estimates for routine releases. The staff's review of COL Information Item NAPS COL 2.0-11-A is discussed below.

- NAPS ESP COL 2.3-3 Release Points and Receptor Locations

NRC staff reviewed the applicant's resolution to North Anna ESP COL 2.3-3, related to verifying specific-release point characteristics and specific locations of receptors of interest used to generate the ESP SSAR long-term (routine release) atmospheric dispersion and deposition site characteristics. The staff's review of COL Action Item NAPS ESP 2.3-3 is discussed below.

<u>*Variance*</u>

- NAPS ESP VAR 2.0-1 Long-Term Dispersion Estimates (χ/Q and D/Q)

The staff reviewed the applicant's recalculated North Anna 3 maximum long-term χ/Q and D/Q values at specific receptors of interest. The staff's review of variance NAPS ESP VAR 2.0-1 is discussed below.

North Anna 3 COL FSAR Revision 0 Table 2.3-17R presented long-term χ/Q values at various downwind distances out to 50 miles for the east-southeast sector, which is the sector that had the highest χ/Q values. Similar information was presented in ESP SSAR Table 2.3-17. The staff asked the applicant in **RAI 2.3.5-1** to explain why the east-southeast sector χ/Q values presented in North Anna 3 COL FSAR Table 2.3-17R differed from the east-southeast sector χ/Q values presented in ESP SSAR Table 2.3-17.

The applicant's response to **RAI 2.3.5-1** dated October 17, 2008, stated that because the reactor technology had not been selected at the time of the North Anna ESP application, the ESP SSAR long-term χ/Q and D/Q values were based on assumptions of "representative" building dimensions, such as a vent building height of 32 meters and a building cross-sectional area of 2,250 square meters (m^2). The applicant recalculated the long-term χ/Q and D/Q values for the North Anna 3 COL FSAR using the ESBWR-specific vent building height of 49 meters and a building cross-sectional area of 2,400 m^2. The applicant's RAI response also stated that the recalculated North Anna 3 COL FSAR long-term χ/Q and D/Q values (1) were generated using the same atmospheric dispersion model used in the ESP SSAR (XOQDOQ), (2) were assumed to be ground-level releases, and (3) were based on the same 1996–1998 onsite meteorological data used in the ESP SSAR. The applicant revised the North Anna 3 COL FSAR Subsection 2.3.5.1 to describe the input data and assumptions used to calculate the new North Anna 3 long-term χ/Q and D/Q values. Therefore, the staff considered **RAI 2.3.5-1** to be resolved.

The staff noted that the higher ESBWR vent building height and larger ESBWR building cross-sectional area values used by the applicant to recalculate the North Anna 3 long-term χ/Q and D/Q values resulted in slightly lower χ/Q values. These slightly lower χ/Q values indicate better dispersion conditions and result in lower airborne concentrations. These results are to be expected because larger building dimensions create additional turbulence that enhances dispersion.

As part of the resolution to NAPS COL 2.0-11-A and NAPS ESP COL 2.3-3, the applicant (1) continued to use the long-term EAB χ/Q and D/Q values from the ESP SSAR, (2) recalculated long-term χ/Q and D/Q values for specific points of interest, and (3) calculated long-term χ/Q and D/Q values for radial distances out to 50 miles. The staff's review of each set of long-term χ/Q and D/Q values is discussed below.

A. Site Boundary (EAB) χ/Q and D/Q Values

The applicant reevaluated the distances to the site boundary using the North Anna 3 facility boundary shown in North Anna 3 COL FSAR Figure 2.0-205. The applicant concluded that the ESP SSAR distances to the site boundary are bounding (i.e., shorter). Therefore, the applicant chose to continue to use the long-term EAB χ/Q and D/Q values from the ESP SSAR because they would be bounding (higher) than χ/Q and D/Q values recalculated using the longer North Anna 3 power block building distances to the site boundary.

The staff found the continued use of the ESP SSAR long-term EAB χ/Q and D/Q values acceptable because of the following reasons:

- The North Anna 3 plant site shown in North Anna 3 COL FSAR Figure 2.1-201 is within the North Anna ESP proposed facility boundary—as shown in North Anna 3 COL FSAR Figure 2.0-205—and the ESP SSAR long-term χ/Q and D/Q site characteristic values were conservatively determined by selecting the shortest distances from any point on the ESP SSAR plant envelope to the EAB for each directional sector. Consequently, the downwind distances used in the ESP SSAR to calculate the EAB χ/Q and D/Q site characteristic values bound the corresponding North Anna 3 plant facility distances to the EAB.

- The ESP SSAR long-term χ/Q and D/Q site characteristic values were conservatively determined by treating all releases as ground-level releases. A ground-level release assumption generally produces more conservative χ/Q and D/Q values for relatively flat terrain sites, such as North Anna 3, compared to the elevated and mix-mode (part-time elevated, part-time ground-level) releases discussed in RG 1.111. The ESBWR standard design employs three ventilation stacks that are routine airborne release points. Two of these stacks, the reactor building and fuel building (RB and FB) stack, and the turbine building stack qualify as mix-mode releases because their release points are above the height of adjacent solid structures, but less than two times the height of adjacent solid structures. Nonetheless, the applicant assumed that all releases were ground-level releases, which is a conservative assumption.

- The ESP SSAR long-term χ/Q and D/Q site characteristic values were conservatively determined using lower vent building heights and smaller building cross-sectional area values compared to the ESBWR actual building dimension values.

The staff concluded that the input assumptions used to model the ESP SSAR long-term (routine release) site boundary χ/Q and D/Q values bound the actual North Anna 3 plant and site characteristics for all three release points, and the use of one set of routine release χ/Q and D/Q values to model all three release points is appropriate. Therefore, the staff finds that the applicant's use of the ESP SSAR site boundary χ/Q and D/Q values for North Anna 3 is appropriate.

B. Specific Receptor χ/Q and D/Q values

The applicant reviewed the land-use census in the Dominion North Anna 2006 AREOR to determine whether the distances of any of the nearest specific receptors of interest modeled in the ESP SSAR had changed. The applicant found that a number of distances had changed. Subsequently, the applicant recalculated the long-term χ/Q and D/Q values for the specific receptors of interest by conservatively assuming that each receptor type was at the location of the closest receptor to the North Anna 3 plant facility boundary, which was conservatively assumed to be a residence in the northwest sector at a distance of 0.74 miles (1.20 kilometers). In other words, except for the milk animal receptors, one of each type of receptor was assumed to be at 0.74 miles (1.20 kilometers) in each compass direction. The applicant stated in North Anna 3 COL FSAR Table 2.0-201 that no χ/Q and D/Q site characteristic values were calculated for the milk animal receptors, because there were no reported cows or goats used for milk production within 5 miles of the site.

North Anna 3 COL FSAR Revision 0 Table 2.3-16R presented the maximum recalculated χ/Q and D/Q values for the specific receptors of interest. North Anna 3 COL ER Revision 0 Table 2.7-4 also presented recalculated χ/Q and D/Q values for the specific receptors of interest in each downwind sector. The staff asked the applicant in **RAI 2.3.5-2** to clarify an inconsistency between North Anna 3 COL FSAR Section 2.3-16R and North Anna 3 COL ER Table 2.7-4. In particular, North Anna 3 COL FSAR Table 2.3-16R showed a maximum D/Q value of 9.0E-09 $1/m^2$ in the east-southeast sector at 0.74 miles for the specific receptors of interest, whereas North Anna 3 COL ER Table 2.7-4 showed a higher D/Q value of 1.1E-08 $1/m^2$ in the north-northeast sector at 0.74 miles for the specific receptors of interest.

In the response to **RAI 2.3.5-2** dated October 17, 2008, the applicant stated that the east-southeast sector D/Q value of 9.0E-09 1/m^2 listed in North Anna 3 COL FSAR Table 2.3-16R was not the maximum D/Q value among all the specific receptors of interest. The maximum D/Q value of 1.1E-08 1/m^2, which is in the north-northeast sector, should have been shown on North Anna 3 COL FSAR Table 2.3-16R. The applicant revised North Anna 3 COL FSAR Subsection 2.3.5.1 and Tables 2.0-201 and 2.3-16R in Revision 1 to identify the maximum D/Q value as 1.1E-08 1/m^2 in the north-northeast sector. The maximum D/Q value of 1.1E-08 1/m^2 was also used by the applicant to recalculate the maximally exposed individual doses presented in Revision 1 to the North Anna 3 COL FSAR Tables 12.2-18bR, 12.2-201, and 12.2-203. Therefore, the staff considers **RAI 2.3.5-2** to be resolved.

The staff finds that the applicant has generated conservative North Anna 3 long-term χ/Q and D/Q values for the specific receptors of interest by (1) treating all releases as ground-level releases, (2) using the shortest distance from any point on the facility boundary to determine the closest receptor, and (3) assuming each receptor type is at the location of the closest receptor. The staff also concludes that the use of one set of routine release χ/Q and D/Q values to model all three release points is appropriate for the reasons identified above.

C. 50-Mile Radius χ/Q and D/Q values

North Anna 3 COL FSAR Revision 0 Table 2.3-17R presented (1) long-term χ/Q values at various downwind distances out to 50 miles for the east-southeast sector, and (2) long-term D/Q values at various downwind distances out to 50 miles for the north-northeast sector. The east-southeast and north-northeast sectors had the highest χ/Q and D/Q values, respectively. NRC staff asked the applicant in **RAI 2.3.5-3** to include χ/Q and D/Q values out to 50 miles in all direction sectors, because these data are needed to perform the population-dose calculation for the radwaste system cost-benefit analyses required by Section II.D of Appendix I to 10 CFR Part 50. The applicant's response to **RAI 2.3.5-3** dated October 17, 2008, provided long-term χ/Q and D/Q values out to 50 miles in all direction sectors. The applicant included these χ/Q and D/Q values as Tables 2.3-208 through 2.3-215 in Revision 1 to the North Anna 3 COL FSAR. Therefore, the staff considers **RAI 2.3.5-3** to be resolved**.**

The staff confirmed the applicant's North Anna 3 long-term χ/Q and D/Q values for specific receptors of interest and the 50-mile radius of the site by running the XOQDOQ computer code (1) using the 1996–1998 onsite meteorological data presented in support of the ESP SSAR, (2) assuming a ground-level release, and (3) using ESBWR vent building heights and building cross-sectional area values that were developed independently by the NRC staff. The staff obtained results similar to those of the applicant. The staff's technical evaluation of the appropriateness of using the XOQDOQ computer code with the 1996–1998 onsite meteorological data to model the atmospheric dispersion of routine airborne releases at the North Anna 3 site is discussed in the North Anna ESP SER (NUREG-1835). In light of the foregoing discussion, the staff accepts the applicant's North Anna 3 long-term χ/Q and D/Q values for specific receptors of interest and a 50-mile radius.

Evaluation of Site Parameters and Site Characteristics

Section 2.0 of the North Anna 3 COL FSAR evaluated whether the North Anna 3 site characteristics fall within the ESBWR DCD site parameter values. A comparison of the ESBWR DCD long-term dispersion estimates with the ESP SSAR and revised North Anna 3 long-term dispersion estimates is in North Anna 3 COL FSAR Table 2.0-201. Smaller χ/Q and D/Q values are associated with greater dilution capability, resulting in lower radiological doses. When comparing the ESBWR DCD site parameter χ/Q and D/Q values with the corresponding North Anna 3 site characteristic χ/Q and D/Q values, the North Anna 3 site is acceptable for the ESBWR design if the North Anna 3 site characteristic χ/Q and D/Q values are smaller than the corresponding ESBWR site parameter χ/Q and D/Q values. Such a comparison shows that the North Anna 3 site has better dispersion characteristics than those required by the ESBWR reactor design.

North Anna 3 COL FSAR Table 2.0-201 shows that most of the North Anna 3 χ/Q and D/Q site characteristic values are greater than the corresponding ESBWR DCD site parameter χ/Q and D/Q values, thereby demonstrating that site meteorological dispersion conditions may result in higher doses than those presented in ESBWR DCD Section 12.2. North Anna 3 COL FSAR Table 2.0-201 also shows that many of the North Anna 3 site characteristic χ/Q and D/Q values are greater than the North Anna ESP site characteristic χ/Q and D/Q values, thereby potentially resulting in estimating higher doses than those presented in the ESP SSAR. The applicant identified this deviation from the North Anna ESP as Variance NAPS ESP VAR 12.2-1, "Gaseous Pathway Doses," in Part 7, "Departures Report," of the North Anna 3 COL application.

Consequently, the applicant recalculated the offsite airborne doses resulting from routine releases in North Anna 3 COL FSAR Subsection 12.2 using the revised North Anna 3 long-term dispersion estimates. The review of these revised dose calculations is discussed in SER Subsection 12.2.

2.3.5.5 *Post Combined License Activities*

There are no post COL activities associated with this subsection.

2.3.5.6 *Conclusion*

NRC staff reviewed the application and checked the referenced ESP SSAR. The staff's review confirmed that the applicant has addressed the relevant information and there is no outstanding information expected to be addressed in the COL FSAR related to this subsection.

The staff concludes that the information pertaining to North Anna 3 COL FSAR Subsection 2.3.5 is within the scope of the ESP and adequately incorporates by reference Subsection 2.3.5 of the ESP SSAR. The information is thus acceptable. In addition, the staff compared the additional COL information in the application to the relevant NRC regulations and acceptance criteria defined in NUREG-0800, Section 2.3.5. The staff concludes that the applicant is in compliance with the relevant requirements of 10 CFR Parts 20, 50, and 100. COL Information Item NAPS COL 2.0-11-A and COL Action Item NAPS ESP COL 2.3-3 have been adequately addressed by the applicant and can be considered closed.

2.4 Hydrologic Engineering

This section of the SER addresses the COL- and hydrology-specific site parameters and site characteristics identified in Chapter 5 of Tier 1 and Chapter 2 of Tier 2 of Revision 5 to the ESBWR DCD.

2.4.1 Hydrologic Description

2.4.1.1 *Introduction*

The hydrologic description of the nuclear power plant site includes the interface of the plant with the hydrosphere, hydrological causal mechanisms, surface and groundwater uses, hydrologic data, and alternate conceptual models. The review covers the following specific areas: (1) interface of the plant with the hydrosphere including descriptions of site location, major hydrological features in the site vicinity, surface- and groundwater related characteristics, and the proposed water supply to the plant; (2) hydrological causal mechanisms that may require special plant design bases or operating limitations with regard to floods and water supply requirements; (3) current and likely future surface and groundwater uses by the plant and water users in the vicinity of the site that may impact safety of the plant; (4) available spatial and temporal data relevant for the site review; (5) alternate conceptual models of the hydrology of the site that reasonably bound hydrological conditions at the site; (6) potential effects of seismic and nonseismic data on the postulated design bases and how they relate to the hydrology in the vicinity of the site and the site region; and (7) any additional information requirements prescribed within the "Contents of Application" sections of the applicable Subparts to 10 CFR Part 52.

2.4.1.2 *Summary of Application*

This subsection of the COL FSAR describes the site from the standpoint of hydrologic considerations. This subsection also provides topographic and regional maps showing proposed changes to the site's natural drainage features and major hydrological features. The applicant has addressed the DCD and ESP information as follows:

<u>*COL Item*</u>

- NAPS COL 2.0-12-A Hydrologic Description

The applicant incorporated by reference SSAR Subsection 2.4.1 to address DCD COL Item 2.0-12-A. The applicant provided updated site specific information to supplement SSAR Subsection 2.4.1.1, "Site and Facilities."

2.4.1.3 *Regulatory Basis*

The regulatory basis of the information incorporated by reference is addressed in the FSER related to the North Anna ESP. In addition, guidance relevant to the Commission's regulations for the hydrologic descriptions, and the associated acceptance criteria, are in Section 2.4.1 of NUREG-0800.

2.4.1.4 *Technical Evaluation*

NRC staff reviewed Subsection 2.4.1 of the North Anna 3 COL FSAR and checked the referenced ESP SSAR. The staff's review confirmed that the information contained in the application and incorporated by reference addresses the relevant information related to this hydrologic description.

The staff's technical review of this application includes the supplemental information pertaining to NAPS COL 2.0-12-A. This review also includes staff evaluation of certain items discussed elsewhere in the ESP and the COL FSAR, as described below. The staff reviewed the resolution to these items as addressed below:

COL Items

- NAPS COL 2.0-12-A Hydrologic Description

The applicant's updated design plant grade elevation for Unit 3 is 290.0 feet mean sea level (msl), which is 20 feet above the flood elevation site characteristic (elevation 270 ft msl) specified in Appendix A of the North Anna ESP. The updated design plant grade for Unit 3 is also 19 feet above the controlling value for minimum site grade (elevation 271 ft msl) specified in Appendix B of the North Anna ESP. The applicant provided a figure showing the layout of the external structures and components of Unit 3. The applicant reported that no other changes to natural drainage features would be required to accommodate Unit 3. The staff finds that the additional information is consistent with the information in the ESP SSAR, which has already been accepted in the ESP SER.

- NAPS ESP COL 2.4-1 Passive Cooling Design

This ESP COL Action item is discussed in FSAR Section 1.12.

Based on the passive-cooling design specified in the ESBWR DCD, the staff determined that neither Lake Anna nor the piping to and from Lake Anna provide safety functions and, therefore, ESP COL Action Item 2.4-1 is no longer required.

- NAPS ESP COL 2.4-2 Shut Down Water Level

Although Appendix C of the North Anna ESP discusses Action Item 2.4-2 in ESP SER Section 2.4.1, the applicant chose to discuss this item in FSAR Section 2.4.14. This report follows the FSAR convention, and staff's review of NAPS ESP COL 2.4-2 can be found in Section 2.4.14.

- ESP Permit Condition 3.E(2) Second New Unit Shall Use A Dry Cooling System

In FSAR Table 1.10-202, the Applicant states that Permit Condition 3 is not applicable to Unit 3.

The North Anna 3 COL FSAR considers the construction of a single new unit. Therefore, ESP Permit 3.E(2), which states that a second new unit shall use a dry cooling tower system to remove waste heat from the working fluid passed through the turbine/generator set during normal operations, does not apply to this licensing action.

- NAPS ESP VAR 2.0-7 Coordinates

This variance is discussed in the Variances Section of the Departures Report (Part 7) of the Combined License Application.

The applicant requested a variance from one of the coordinate systems presented in the ESP, Appendix A, Figure 1. This figure lists the coordinates of the site in State NAD 83 South Zone as well as in the NAPS Grid coordinates. In the variance, the applicant requested to use the values in STATE PLANE NAD 83 VA SOUTH ZONE, shown in FSAR Figure 2.0-205, to replace those in State NAD 83 South Zone. The coordinates provided in NAPS Grid coordinates remain unchanged. This variance corrects an administrative error.

2.4.1.5 *Post Combined License Activities*

There are no post COL activities related to this subsection.

2.4.1.6 *Conclusion*

NRC staff reviewed the application and checked the referenced ESP SSAR. The staff's review confirmed that the applicant has addressed the relevant information and there is no outstanding information expected to be addressed in the COL FSAR related to this subsection.

As set forth above, the applicant has presented and substantiated information relative to the hydrologic description in the vicinity of the site and site regions important to the design and siting of this plant. The staff reviewed the available information provided. For the reasons given above, the staff concluded that the identification and consideration of the hydrology in the vicinity of the site and site regions are acceptable and meet the requirements of 10 CFR Part 50, 10 CFR 52.79, and 10 CFR 100.20(c), with respect to determining the acceptability of the site for the ESBWR design.

The staff finds that the applicant has considered the appropriate site phenomena for establishing the design bases for SSCs important to safety. The staff accepted the methodologies used to determine the hydrologic description in the vicinity of the site and site regions reflected in site characteristics documented in the ESP SER. Accordingly, the staff concluded that the use of these methodologies results in site characteristics containing sufficient margins for the limited accuracy, quantity, and period of time in which the data have been accumulated. The staff concluded that the identified site characteristics meet the requirements of 10 CFR 52.79 and 10 CFR 100.20(c), with respect to establishing the design basis for SSCs important to safety.

2.4.2 Floods

2.4.2.1 *Introduction*

This subsection discusses the historical flooding at the proposed site or in the region of the site. The information summarizes and identifies the individual types of flood-producing phenomena, and combinations of flood-producing phenomena, considered in establishing the flood design bases for safety-related plant features. The discussion also covers the potential effects of local intense precipitation. The flood history and the potential for flooding are reviewed for the sources and events listed below. Factors affecting potential runoff (such as urbanization, forest fire, changes in agricultural use, erosion, and sediment deposition) are considered in the review. In addition to describing flood history, this subsection also determines the local intense precipitation on the site to estimate local flooding. Local intense precipitation is reported as a site characteristic used in site grading design.

2.4.2.2 *Summary of Application*

This subsection of the COL FSAR addresses the need for information on site specific flooding. The applicant addressed the information as follows:

COL Items

- NAPS COL 2.0-13-A Floods

The applicant incorporated by reference ESP SSAR Subsection 2.4.2 to address DCD COL Item 2.0-13-A The applicant also provided updated site specific information to supplement ESP SSAR Subsections 2.4.2.2 ,“Flood Design Consideration,” indicating that the design plant grade elevation for safety-related SSCs is above the maximum flood level at the site, resulting from a probable maximum flood in Lake Anna’s watershed, the simultaneous failure of upstream storage reservoirs, and coincident wave action as discussed in the ESP SER.

- NAPS ESP COL 2.4-3

Appendix C of the North Anna ESP states that NAPS ESP COL 2.4-3 is not used. Therefore, a sequential gap exists between NAPS ESP COL 2.4-2, which is discussed in FSAR Section 2.4.14, and NAPS ESP COL 2.4-4, which is discussed in FSAR Section 2.4.2.

- NAPS ESP COL 2.4-4
- NAPS ESP COL 2.4-5

The applicant provided updated site specific information to supplement ESP SSAR Subsection 2.4.2.3, “Effects of Local Intense Precipitation,” to address ESP COL Action Items 2.4-4 and 2.4-5. The applicant provided two figures showing the site layout and sub-basin drainage areas and the site’s probable maximum precipitation (PMP).

2.4.2.3 *Regulatory Basis*

The regulatory basis of the information incorporated by reference is addressed in the FSER related to the North Anna ESP. In addition, guidance relevant to the Commission’s regulations for the floods, and the associated acceptance criteria, are in Section 2.4.2 of NUREG-0800.

2.4.2.4 *Technical Evaluation*

NRC staff reviewed Subsection 2.4.2 of the North Anna 3 COL FSAR and checked the referenced ESP SSAR. The staff’s review confirmed that the information contained in the application and incorporated by reference addresses the relevant information related to this subsection. Based a on review of the North Anna Unit 3 site grading plan, the design plant grade elevation is 290.0 feet. The design plant grade is approximately 20 feet above the maximum flood level at the site resulting from a probable maximum flood in Lake Anna’s watershed, the simultaneous failure of upstream storage reservoirs, and coincident wave action (elevation 270 feet), as discussed in the ESP SER.

The staff’s technical review of this application includes reviewing the supplemental information pertaining to NAPS COL 2.0-13-A and ESP COL Action Items 2.4-4 and 2.4-5. The staff reviewed the resolution to DCD COL Item 2.0-13-A and the ESP COL action items addressed below:

COL Items

- NAPS COL 2.0-13-A Floods

NRC staff reviewed the resolution to DCD COL 2.0-13-A, related to historical flooding at the proposed site or in the region of the site, and included under Section 2.4.2 of the North Anna 3 COL FSAR.

The staff checked ESP SER Subsection 2.4.1.3 and supplements the ESP safety evaluation with an independent confirmation of the applicant's steady-state HEC-RAS numerical modeling analysis. DCD Tier 1, Chapter 5, Table 5.1-1 requires that the maximum flood level be 1.0 foot below the design plant grade elevation. Based on a review of the North Anna Unit 3 site grading plan, the design plant grade elevation is 290.0 feet. Hence, the DCD maximum flood level corresponds to an elevation of 289.0 feet. The maximum flood level at the site resulting from a probable maximum flood in Lake Anna's watershed, the simultaneous failure of upstream storage reservoirs, and coincident wave action is at an elevation of 270 feet, as discussed in the ESP SER.

- NAPS ESP COL 2.4-4 and 2.4-5

The applicant provided the input files to the numerical model HEC-RAS that were used for analysis of the locally intense PMP and associated site drainage in response to a site audit (ML090260661). The site drainage plan is in Figure 2.4.2.4-101. The site drainage plan satisfies the requirements of ESP COL Action Item 2.4-4 and ESP COL Action Item 2.4-5. NRC staff reviewed the numerical model and conducted sensitivity tests.

Information Submitted by Applicant The site drainage plan consists of two drainage channels (labeled north ditch and south ditch in Figure 2.4.2.4-101), a storm water management (SWM) Basin, and an outfall channel. The plant access roads were treated as broad-crested weirs. The applicant set up the hydraulic model (HEC-RAS) using Manning's n values of 0.030 for the grass-lined section and 0.035 for rip-rap lined sections. These values imply that the ditch is clean and straight with no deep pools but with some stones and weeds (HEC, 2008). The applicant used contraction and expansion coefficients of contraction = 0.1 and expansion = 0.3, which assume a gradual transition between two cross sections. However, for cross sections near the abrupt bend of the south ditch, near cross section 404, the contraction and expansion coefficient values were set to contraction = 0.3 and expansion = 0.5. These higher coefficient values were also applied at other abruptly varied sections, such as at the access road crossings of the north ditch (e.g., cross sections 1312 to 1190 and 550 to 288). The downstream boundary condition of the HEC-RAS model is the water surface elevation of Lake Anna applied at cross section 0. The applicant assigned a constant elevation of 265 feet.

The highest water surface elevation computed by the applicant occurred at the upstream ends of both the north ditch and south ditch. These elevations were 287.2 feet (north ditch) and 286.9 feet (south ditch). These water surface elevations are 1.8 feet or more below the Unit 3 DCD's site parameter value for maximum flood level (elevation 289.0 feet).

The applicant assumed that the roads crossing both the south ditch and the outfall from the SWM Basin would function as broad-crested weirs during the PMP-generated flood. The applicant set the weir coefficient value to 2.6. The applicant inserted a lateral weir structure into the HEC-RAS numerical model along the south ditch from cross sections 820 to 497. A description of the lateral weir was not included in the FSAR. The lateral weir is used in the model to handle overflow from the south ditch. Flow re-enters downstream of the abrupt bend in the south ditch at cross section 278. Specific details regarding hydraulic conditions of the overflow were not explicitly specified in the numerical model or in the FSAR.

Supercritical velocities were computed in both the north ditch and south ditch during the PMP-generated flood. In the south ditch, supercritical velocities occurred from cross section 820 to 440 (see Figure 2.4.2.4-102). Water velocities along this reach of the south ditch ranged from approximately 8 to 12 feet per second. A hydraulic jump is produced in the south ditch near

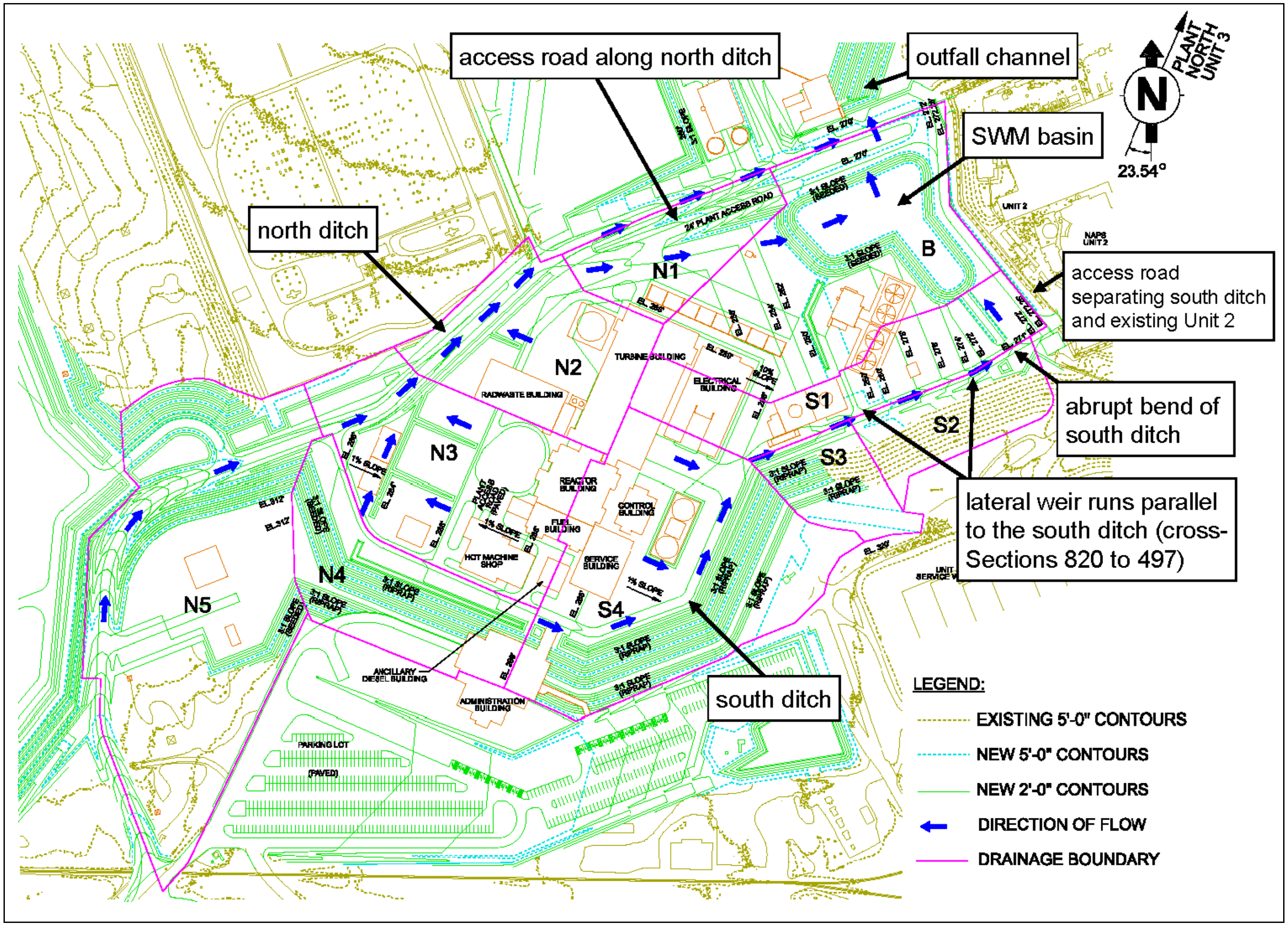

Figure 2.4.2.4-101 Site layout and sub-basin drainage areas

The figure is derived from FSAR Figure 2.4-201. The reaches labeled “S” are the south ditch. The reaches labeled “N” are the north ditch. The area labeled “B” is the outfall pond. The location of the access roads for the outfall channel and south ditch are indicated.

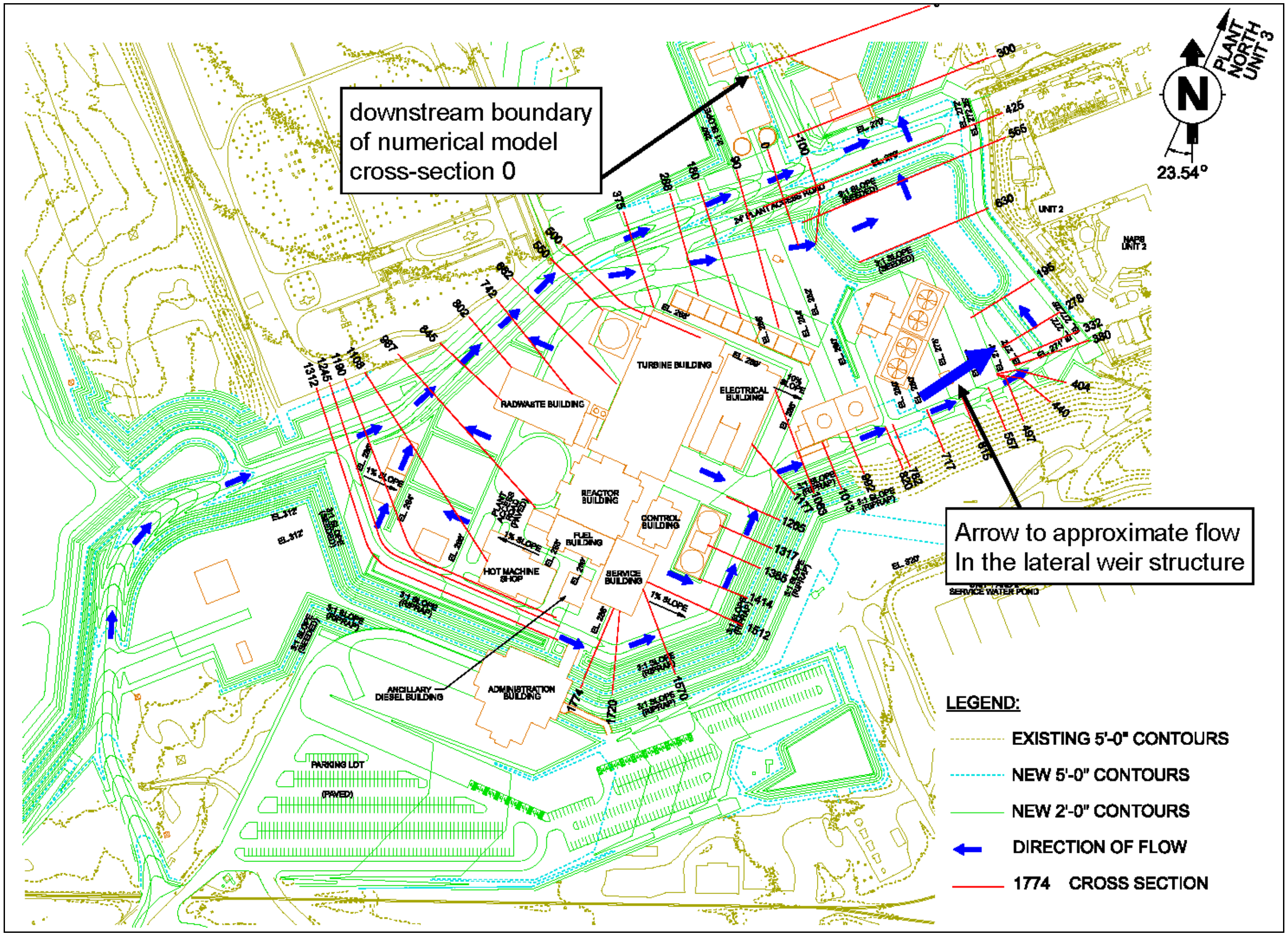

Figure 2.4.2.4-102 Site layout and HEC-RAS cross section locations

The figure is derived from FSAR Figure 2.4-203.

cross section 404 and upstream of the road crossing at cross section 380. Just downstream of this cross section, the ditch makes an abrupt turn to the north. Flows are contained in the ditch by the 24-foot plant access road (see FSAR Figure 2.4-201). On the other side of the plant access road is the existing Unit 1 and 2 yard; Unit 2 is the closest to the south dike. The maximum water surface elevation computed by the applicant at this bend in the south dike is 272.1 feet. The crest elevation of the plant access road is 272.25 feet.

In the north ditch, supercritical velocities occurred from cross section 288 to -100 (i.e., where the north ditch discharges into the SWM Basin). Water velocities along this reach of the north ditch range from approximately 9 to 13 feet per second. Between cross sections 144 and -33.3, the flow is split into two streams (see arrows in Figure 2.4.2.4-102) as the water divides on either side of the access road. Between cross sections -33 and -100, the computed water surface elevation is above the access road. A hydraulic jump is expected to occur in the downstream-most portion of this reach of the north ditch as the flow enters the SWM Basin.

The SWM Basin receives flow from both the south ditch and north ditch. Flow was computed to leave the basin by overtopping the main access road, which was simulated as a broad-crested weir. The water-surface elevation in the SWM basin during the steady-flow simulation was 271.7 feet. The elevation of the plant access road between the SWM basin and existing Unit 2 is 272.25 feet. The existing Unit 1 and 2 yard elevation is 270.0 feet.

NRC Staff's Technical Evaluation NRC staff requested the HEC-RAS model inputs from the applicant (ML090260661). HEC-RAS is a numerical model developed by the U.S. Army Corps of Engineers, Hydrologic Engineering Center (HEC). The model is widely used within the engineering community and is accepted as a standard engineering-practice tool.

Sensitivity results presented below were computed using these model inputs, including cross sections based on Revision 0 of the COL.[4] Sensitivity tests included systematic variations of the runoff coefficient, channel roughness (Manning's n), contraction-expansion coefficients, weir coefficients, and the downstream elevation boundary conditions. Summary results showing the impact of these sensitivity tests on water-surface elevations are in Table 2.4.2.4-101.

The applicant estimated the PMP-generated runoff using the rational method, which relies on estimates of the time of concentration, rainfall PMP intensity, sub-basin area, and an empirical runoff coefficient. The applicant estimated the runoff coefficient based on land cover and assigned values of 0.9 for vegetated areas and 1.0 for all other areas. The composite values were at least 0.94 (see FSAR Table 2.4-203). To test the sensitivity of this coefficient to resultant water-surface elevations in the HEC-RAS model, the staff increased the runoff coefficient to 1.0 for all subbasins. As shown in Table 2.4.2.4-101, the model-computed, water-surface elevations increased only slightly from those generated using the applicant's values. In the region of Unit 3's safety-related SSCs, differences between sensitivity simulations are relatively small in comparison to the margin between the maximum flood elevation (elevation 287.2 ft) and the design plant grade elevation (elevation 290 ft).

The staff examined a range of bed-roughness values for the south ditch, north ditch, and outfall channel. The range of Manning's n tested by staff was between 0.02 and 0.045, which represents a variety of construction materials and potential rip-rap sizes (HEC, 2008). . As shown in Table 2.4.2.4-101, the model-computed, water-surface elevations increased only slightly from those generated using the applicant's values. In the region of Unit 3's safety-

[4] Revised cross sections are expected by staff in response to RAI 2.4.2-2, issued on March 9, 2009.-

related SSCs, differences between sensitivity simulations are relatively small in comparison to the margin between the maximum flood elevation (elevation 287.5 ft) and the design plant grade elevation (elevation 290 ft)..

The contraction and expansion coefficients account for energy losses between cross sections. Typical coefficient values are 0.1 to 0.3 for gradual transitions, 0.3 to 0.5 for typical bridge

Table 2.4.2.4-101 Maximum Water Surface Elevations from the Sensitivity Analyses***

LOCATION	APPLICANT'S WATER SURFACE ELEVATION*	RUNOFF COEFFICIENT	MANNING'S ROUGHNESS		GLOBAL CHANGE OF CONTRACTION-EXPANSION COEFFI CIENTS		CONTRACTION-EXPANSION CHANGE AT CROSS-SECTION 404 ONLY (SOUTH DITCH)		DOWN STREAM BOUNDARY CONDITION	SOUTH DITCH INLINE WEIR COEFFICIENT		LATERAL WEIR	
		1.0	**0.020**	**0.045**	**(0.0, 0.0)**	**(0.6, 0.8)**	**(0.6, 0.8)**	**(1.0, 1.0)**	**270.0 ft**	**2.0**	**3.0**	**REMOVE WEIR**	**FLOW ENTERS AT CROSS-SECTION 380**
North Ditch (Cross-section 1312)	287.2	287.2	286.9	287.4	287.2	287.3	na	na	287.2	na	na	na	na
South Ditch (Cross-section 1774)	286.9	286.9	286.3	287.5	287.1	287.2	286.9	286.9	286.9	286.9	286.9	286.9	286.9
Abrupt Bend of South Ditch (Cross-section 380)**	272.02	272.15	272.14	272.14	272.03	272.14	272.02	272.02	272.02	272.24	272.02	272.24	272.24

na = analysis is not relevant at this location.

* The applicant assigned Manning's n values of 0.030 or 0.035 and a downstream boundary elevation of 265 feet. Other values assigned by the applicant are described in the text.

** The elevation of plant access road crest separating the south ditch from Unit 2 is 272.25 feet. Values shown in this table row carry an extra significant digit following the convention in the Applicant's FSAR. This precesion is necessary to show a margin between the model's computed values and the crest of the plant access road

*** Results based on site cross-sections proved via ML090260661. Staff expect revised cross sections will be provided by the applicant in response to **RAI 2.4.2-2**.

sections, and 0.6 to 1.0 (maximum) for abrupt transitions (HEC, 2008). The staff examined the impact of these coefficients on the maximum water-surface elevation in the north ditch and south ditch by globally changing these values for two simulation. The values were globally changed to contraction = 0.0, expansion = 0.0 and contraction = 0.6,expansion = 0.8. The staff also examined changing the contraction and expansion coefficients at only the abrupt bend in the south ditch (cross section 404) by performing two additional simulations. The values in the south bend (only) were changed to contraction = 0.6,expansion = 0.8 and contraction = 1.0,expansion = 1.0. As shown in Table 2.4.2.4-101, the model-computed, water-surface elevations increased only slightly from those generated using the applicant's values. In the region of Unit 3's safety-related SSCs, differences between sensitivity simulations are relatively small in comparison to the margin between the maximum flood elevation (elevation 287.3 ft) and the design plant grade elevation (elevation 290 ft).

Locations where water flowed over the access roads were assumed to act as broad-crested weirs. The user-specified weir coefficient accounts for the energy losses. For a fixed upstream water surface elevation, a smaller weir coefficient will result in the model computing less flow to pass over the weir. Typical broad-crested weir coefficients range from 2.6 to 3.1 (HEC, 2008). Staff varied model coefficients for the broad-crested weir at cross section 379 to determine how nearby hydraulic conditions would change. The staff used a weir coefficient value of 3.0 to represent an efficiently flowing weir with minimal energy losses and a value of 2.0, which is smaller than typical, but was used to represent a weir partially clogged with debris. As shown in Table 2.4.2.4-101, simulation results with a weir coefficient of 3.0 produced negligible changes in water-surface elevation. However, with a weir coefficient of 2.0, the water-surface elevation increased near the abrupt bend in the south ditch (cross section 380) from 272.02 feet to 272.24 feet. The elevation of the crown of the plant access road that separates the south ditch from Unit 2 is 272.25 feet.

A lateral weir structure along the south ditch provides overflow relief for cross sections 820 through 497 (see Figure 2.4.2.4-101). The applicant's simulation results indicate this structure conveyed approximately 139 cubic feet per second (cfs), with approximately 300 cfs remaining in the south ditch at the abrupt bend near cross-section 380. To evaluate the sensitivity of water surface elevations near this abrupt bend, the staff removed the lateral weir from the HEC-RAS input so that the south ditch conveyed the entire 439.1 cfs. The resulting water surface elevation at cross-section 380 increased to 272.24 feet, or 0.01 foot below the access road crest between the south ditch and the Unit 1 and 2 yard (see Table 2.4.2.4-101).

Staff performed a second sensitivity test of the lateral weir structure by altering the location where the weir flow reentered the south ditch (see Figure 2.4.2.4-102). The applicant's simulation specified that this flow would reenter the south ditch at cross section 278. The staff's simulation assumed that the flow ran parallel to the south ditch and reentered between cross sections 404 and 380. The resulting water-surface elevation at cross-section 380 was 272.24 feet, or 0.01 foot below the access road crest between the south ditch and the Unit 1 and 2 yard. These results are nearly identical to the first sensitivity test where the lateral weir was completely removed and all flow was confined to the south ditch (see Table 2.4.2.4-101).

In **RAI 2.4.2-1**, the staff requested additional information from the applicant regarding the locally intense precipitation analysis:

Based on the requirements associated with GDC 2, of 10 CFR Part 50, 10 CFR 52.79, and 10 CFR 100.20(c), the applicant computed the effects of locally intense precipitation falling on and near the site. Results from these computations are described in FSAR Section 2.4.2. On

June 10, 2008, Dominion submitted the HEC-RAS input files that were used to compute the reported water-surface elevation values. Based on the staff's review of the FSAR and the HEC-RAS files, the staff asked Dominion to explain why a 3-inch safety margin is sufficient to provide reasonable assurance that runoff from the Unit 3 site will not impact the Units 1 and 2 site (FSAR page 2-127). Specifically, the staff requested Dominion to provide the following:

a. Assurance that the "as-built" site topography will match values provided in the HEC-RAS cross-sections (locations shown in FSAR Figure 2.4-203) and that this topography will remain static (or is a conservative assumption), considering the length of the Unit 3 licensing period;

b. A description of provisions to prevent placement of obstructions or other channel blockages in key drainage canals throughout the Unit 3 licensing period and hence, to justify the selected HEC-RAS model parameters (e.g., contraction/expansion coefficients, channel roughness, and channel geometry values);

c. A description of how runoff from each building and parking lot in FSAR Figure 2.4-201 has been captured in the HEC-RAS model and hence, is correctly represented in the sub-basin drainage boundaries in FSAR Figure 2.4-201.

On September 16, 2008, the applicant responded to **RAI 2.4.2-1** in Letter No. 028 (ML082680033). The applicant stated that the analysis incorporated conservative assumptions, so that the resulting water levels are conservatively high. The conservative assumptions include a high runoff coefficient, a 25 percent reduction in time of concentration values, conservative estimates of flow into the north ditch because some flow will likely overflow the access road and bypass the SWM Basin, the assumption that all culverts were blocked, and the estimated discharge for each sub-basin that was applied to the upstream end of the sub-basin.

Specifically concerning **RAI 2.4.2-1(a)**, the applicant stated that it will reevaluate any changes to final site grade and the effect on the local PMP analyses based on 10 CFR 50.59 requirements.

Specifically concerning **RAI 2.4.2-1(b)**, the applicant stated that a storm water pollution prevention plan (SWPPP) and an erosion and sediment control plan will be prepared that include provisions to prevent placement of obstructions and blockages in the drainage channels.

Specifically concerning **RAI 2.4.2-1(c)**, the applicant provided a description of runoff from impervious areas. The applicant also stated that there are no parking areas within the power block area for Unit 3. Runoff from the administration building parking lot discharges to the storm water basin located at the southeast corner of the lot. This basin then discharges to the WHTF.

However, the staff has several unresolved issues with the locally intense precipitation analysis performed by the applicant.

Accordingly, additional information was requested in **RAI 2.4.2-2** and **RAI 2.4.2-3**, which incorporated changes related to Revision 1 to the application. These requests are associated with the locally intense precipitation flood event described in FSAR Section 2.4.2 and assurances that this event will not adversely impact Unit 3's safety-related SSCs, or those that satisfy the regulatory treatment of non-safety systems (RTNSS) criteria. **RAI 2.4.2-2** requests:

a. Provide the updated HEC-RAS input files used to conduct the FSAR Revision 1 analyses.

b. The FSAR should be revised to include a description of the lateral-flow structure, the expected flow path, the depth and velocity of flow, erosion control measures, and a list of buildings and structures (including their RTNSS categorization, if appropriate) that are intercepted.

c. Provide a map showing the locations where supercritical flows and hydraulic jumps are likely to occur in the south ditch, north ditch, outfall channel, and associated overland-flow areas. The map should indicate locations where flood events produce velocities larger than the design velocity for the channel bed material or are capable of eroding overland flow areas (i.e., where damage exceeding normal maintenance would result). At these locations, the applicant was asked to describe how a potential failure of these drainage features could degrade any safety-related SSCs or structures that satisfy RTNSS criteria.

d. Provide additional detail regarding administrative controls or surveillance requirements, including the frequencies at which surveys will be conducted.

The applicant responded to this RAI on April 3, 2009, in RAI Letter Number 33. The staff is currently reviewing the RAI response. This RAI is being tracked as **Open Item 2.4.2-2**.

The staff also asked for the following information in **RAI 2.4.2-3**:

> The COL must contain information to assure that the construction of Unit 3 will not impact the existing units (see 10 CFR 52.79(a)(31]). Revision 1 of the application states "at the eastern edge of the Unit 3 site where the plant access road crosses the south drainage ditch, the grade elevation at the high point between the Unit 3 site and the Units 1 and 2 site is at Elevation 82.98 m (272.25 ft) msl. The maximum water level at the inline weir is Elevation 82.94 m (272.1 ft) msl, which is 0.05 m (0.15 ft) below the high point elevation and thus all Unit 3 PMP flows will be confined to the Unit 3 site and runoff generated from Unit 3 will not impact the Units 1 and 2 site." Because the predicted water velocities in the south ditch immediately upstream of the abrupt bend near the plant access road exceed 10 feet per second, and because the margin is relatively small, the staff requested the applicant to describe the design measures to ensure that all discharge in the south ditch will complete the 90-degree abrupt bend during the PMP-generated flood event. This description should include how two-dimensional effects, the superelevation of flow, and the potential hydraulic jump were factored into the design. In addition, describe fortification measures to prevent failure of the plant access road when the SWM basin is at the PMP-generated maximum elevation.

This RAI, 2.4.2-3, was sent to the applicant on March 9, 2009. The applicant responded on April 3, 2009, in RAI Letter Number 33. The staff is currently reviewing the RAI response. This RAI is being tracked as **Open Item 2.4.2-3**.

2.4.2.5 *Post Combined License Activities*

There are no post COL activities related to this subsection.

2.4.2.6 *Conclusion*

NRC staff reviewed the application and checked the referenced ESP SSAR and staff's ESP SER. The staff's review confirmed that the applicant has addressed the relevant information but there is outstanding information expected to be addressed in the COL FSAR related to this subsection. Because the design plant grade has an elevation of 290.0 feet, the staff concluded that the site is above the maximum flood level that could result from a probable maximum flood in Lake Anna's watershed, the simultaneous failure of upstream storage reservoirs, and coincident wave action (elevation 270 feet), as discussed in the ESP SER.

As described above, the staff specified **Open Item 2.4.2-2 and Open Item 2.4.2-3**. These open items pertain to providing reasonable assurance that the locally intense precipitation flood event will not adversely impact Unit 3's safety-related SSCs, or those that satisfy the RTNSS criteria, and that construction of Unit 3 will demonstrate compliance with 10 CFR 52.79(a)(31). The staff outlined additional information that needs to be reflected in sections of the FSAR, as appropriate. The staff's review of FSAR Section 2.4.2 will be complete after these two open items have been resolved.

2.4.3 Probable Maximum Flood on Streams and Rivers

2.4.3.1 *Introduction*

The probable maximum flood on streams and rivers is used to determine the extent of any flood protection required for those safety-related SSCs necessary to ensure the capability to shut down the reactor and maintain it in a safe shutdown condition. The specific areas of review are as follows: (1) design basis for flooding in streams and rivers, (2) design basis for site drainage, (3) consideration of other site-related evaluation criteria, and (4) any additional information requirements prescribed in the "Contents of Application" sections of the applicable subparts to 10 CFR Part 52.

2.4.3.2 *Summary of Application*

This subsection of the COL FSAR addresses the need for information on site specific probable maximum flood on streams and rivers. The applicant addressed the information as follows:

<u>*COL Item*</u>

- NAPS COL 2.0-14-A Probable Maximum Flood

The applicant incorporated by reference ESP SSAR Subsection 2.4.3 to address DCD COL Item 2.0-14-A. The applicant also provided updated site specific information to supplement ESP SSAR Subsections 2.4.3, "Probable Maximum Flood on Streams and Rivers," indicating that the plant grade for safety-related components and structures is above the design-basis flood level.

2.4.3.3 *Regulatory Basis*

The regulatory basis of the information incorporated by reference is addressed in the FSER related to the North Anna ESP. In addition, the guidance relevant to the Commission's regulations for the probable maximum flood on streams and rivers, and the associated acceptance criteria, are in Section 2.4.3 of NUREG-0800.

2.4.3.4 *Technical Evaluation*

NRC staff reviewed Subsection 2.4.3 of the North Anna 3 COL FSAR and checked the referenced ESP SSAR. The staff's review confirmed that the information contained in the application and incorporated by reference addresses the relevant information related to this subsection.

The staff's technical review of this application is limited to reviewing the supplemental information pertaining to NAPS COL 2.0-14-A. The staff reviewed the resolution to DCD COL Item 2.0-14-A as addressed below:

<u>*COL Item*</u>

- NAPS COL 2.0-14-A Probable Maximum Flood

NRC staff reviewed the resolution to the DCD COL Item 2.0-14-A, which is related to the probable maximum flood on streams and rivers used to determine the extent of any flood protection required for those safety-related SSCs necessary to ensure the capability to shut down the reactor and maintain it in a safe shutdown condition, included under Subsection 2.4.3 of the North Anna 3 COL FSAR. The staff finds the additional information consistent with the information provided in the ESP SSAR, which has already been accepted in the ESP SER. The elevation of the design plant grade is 290.0 feet, which is 20 feet above the maximum flood level at the site resulting from a probable maximum flood in Lake Anna's watershed, the simultaneous failure of upstream storage reservoirs, and coincident wave action as in the ESP SER.

2.4.3.5 *Post Combined License Activities*

There are no post COL activities related to this subsection.

2.4.3.6 *Conclusion*

NRC staff reviewed the application and checked the referenced ESP SSAR and staff's SER. The staff's review confirmed that the applicant has addressed the relevant information and there is no outstanding information expected to be addressed in the COL FSAR related to this subsection.

As set forth above, the applicant has presented and substantiated information relative to the probable maximum flooding on streams and rivers important to the design and siting of this plant. The staff reviewed the available information provided. For the reasons given above, the staff conclude that the identification and consideration of the probable maximum flooding on streams and rivers at the site and in the surrounding area are acceptable and meet the requirements of 10 CFR 52.79 and 10 CFR 100.20(c), with respect to determining the acceptability of the site for the ESBWR design.

The staff find that the applicant has considered the appropriate site phenomena in establishing the design bases for SSCs important to safety. The staff accepted the methodologies used to determine the probable maximum flooding on streams and rivers reflected in the site characteristics documented in the ESP SER. Accordingly, the staff concluded that the use of these methodologies results in design bases containing a sufficient margin for the limited accuracy, quantity, and period of time in which the data have been accumulated. The staff concluded that the identified design bases meet the requirements of 10 CFR 100.20(c) with respect to establishing the design basis for SSCs important to safety.

2.4.4 Potential Dam Failures

2.4.4.1 *Introduction*

The potential dam failures are addressed to ensure that any potential hazard to the safety-related facilities due to the failure of onsite, upstream, and downstream water control structures is considered in the plant design. The specific areas of review are as follows: (1) flood waves resulting from a dam breach or failure, including those due to hydrologic failure as a result of overtopping for any reason, routed to the site and the resulting highest water surface elevation that may result in the flooding of SSCs important to safety; (2) successive failures of several dams in the path to the plant site caused by the failure of an upstream dam due to plausible reasons, such as a probable maximum flood, landslide-induced severe flood, earthquakes, or volcanic activity and the effect of the highest water surface elevation at the site under the cascading failure conditions; (3) dynamic effects of dam failure-induced flood waves on SSCs important to safety; (4) failure of a dam downstream of the plant site that may affect the availability of a safety-related water supply to the plant; (5) effects of sediment deposition or erosion during dam failure-induced flood waves that may result in blockage or loss of function of SSCs important to safety; (6) failure of onsite water control or storage structures such as levees, dikes, and any engineered water storage facilities that are located above site grade and may induce flooding at the site; (7) the potential effects of seismic and nonseismic data on the postulated design bases and how they relate to dam failures in the vicinity of the site and the site region; and (8) any additional information requirements prescribed in the "Contents of Application" sections of the applicable subparts to 10 CFR Part 52.

2.4.4.2 *Summary of Application*

This subsection of the COL FSAR addresses the needs for site specific information on potential dam failures. The applicant addressed the information as follows:

<u>*COL Items*</u>

- NAPS COL 2.0-15-A Potential Dam Failures

The applicant incorporated by reference ESP SSAR Subsection 2.4.4 to address DCD COL Item 2.0-15-A.

- NAPS ESP COL 2.4-6
- NAPS ESP COL 2.4-7

The applicant provided updated site specific information to supplement ESP SSAR Subsection 2.4.4, "Potential Dam Failures," to address ESP COL Action Items 2.4-6 and 2.4-7, indicating that the UHS described in the ESBWR DCD addresses NRC's requirements to provide sufficient emergency cooling capability.

2.4.4.3 *Regulatory Basis*

The regulatory basis of the information incorporated by reference is addressed in the FSER related to the North Anna ESP. In addition, the guidance relevant to the Commission's regulations for the potential dam failures, and the associated acceptance criteria, are in Section 2.4.4 of NUREG-0800.

2.4.4.4 *Technical Evaluation*

NRC staff reviewed Subsection 2.4.4 of the North Anna 3 COL FSAR and checked the referenced ESP SSAR and staff's ESP SER. The staff's review confirmed that the information contained in the application and incorporated by reference addresses the relevant information related to this subsection. The elevation of the design plant grade is 290.0 feet, which is 20 feet above the maximum flood level at the site resulting from a probable maximum flood in Lake Anna's watershed, the simultaneous failure of upstream storage reservoirs, and coincident wave action as in the ESP SER.

The staff's technical review of this application is limited to the supplemental information pertaining to NAPS COL 2.0-15-A and ESP COL Action items 2.4-6 and 2.4-7. The staff reviewed the resolution to DCD COL Item 2.0-15-A and the ESP COL Action items, as addressed below:

<u>*COL Items*</u>

- NAPS COL 2.0-15-A Potential Dam Failures

NRC staff reviewed the resolution to DCD COL Item 2.0-15-A, related to any potential hazard to the safety-related facilities due to the failure of onsite, upstream, and downstream water control structures. These potential hazards are considered in the plant design included under Subsection 2.4.4 of the North Anna 3 COL FSAR. The staff finds that the additional information is consistent with the information in the ESP SSAR, which has already been accepted in the ESP SER.

- NAPS ESP COL 2.4-6
- NAPS ESP COL 2.4-7

Based on the passive cooling design specified in the ESBWR DCD, NRC staff determined that no underground surface water reservoir is required and, therefore, ESP COL Action Items 2.4-6 and 2.4-7 are no longer required.

2.4.4.5 *Post Combined License Activities*

There are no post COL activities related to this subsection.

2.4.4.6 *Conclusion*

NRC staff reviewed the application and checked the referenced ESP SSAR and staff's SER. The staff's review confirmed that the applicant has addressed the relevant information and there is no outstanding information expected to be addressed in the COL FSAR related to this subsection.

As set forth above, the applicant has presented and substantiated information relative to the effects of dam failures important to the design and siting of this plant. The staff reviewed the available information provided. For the reasons given above, the staff concluded that the identification and consideration of the effects of dam failures at the site and in the surrounding area are acceptable and meet the requirements of 10 CFR 52.79, 10 CFR 100.23(d), and 10 CFR 100.20(c).

The staff finds that the applicant has considered the appropriate site phenomena in establishing the design bases for SSCs important to safety. The staff accepted the methodologies used to determine the effects of dam failures reflected in the site characteristcs documented in the ESP SER. Accordingly, the staff concludes that the use of these methodologies results in design bases containing a sufficient margin for the limited accuracy, quantity, and period of time in which the data have been accumulated. The staff concludes that the identified design bases meet the requirements of 10 CFR 100.23(d) and 10 CFR 100.20(c), with respect to establishing the design basis for SSCs important to safety.

2.4.5 Probable Maximum Surge and Seiche Flooding

The probable maximum surge and seiche flooding are addressed to ensure that any potential hazard to the safety-related facilities due to the effects of probable maximum surge and seiche is considered in plant design. The specific areas of review are as follows: (1) probable maximum hurricane (PMH) that causes the probable maximum surge as it approaches the site along a critical path at an optimum rate of movement; (2) probable maximum wind storm (PMWS) from a hypothetical extratropical cyclone or a moving squall line that approaches the site along a critical path at an optimum rate of movement; (3) a seiche near the site, and the potential for seiche wave oscillations at the natural periodicity of a water body that may affect flood water surface elevations near the site or cause a low water surface elevation affecting safety-related water supplies; (4) wind-induced wave run-up under a PMH or PMWS winds; (5) effects of sediment erosion and deposition during a storm surge and seiche-induced waves that may result in blockage or loss of function of SSCs important to safety; (6) the potential effects of seismic and nonseismic information on the postulated design bases and how they relate to a surge and seiche in the vicinity of the site and the site region; (7) any additional information requirements prescribed in the “Contents of Application” sections of the applicable subparts to 10 CFR Part 52.

In North Anna 3 COL FSAR Section 2.4.5, the applicant addresses a probable maximum surge and seiche flooding. The applicant incorporates by reference ESP SSAR Subsection 2.4.5 with no supplement to address DCD COL Item 2.0-16-A, related to a probable maximum surge and seiche flooding. NRC staff reviewed the application and checked the referenced ESP SSAR and the staff’s ESP SER. The staff confirmed that there is no outstanding information related to this subsection.

2.4.6 Probable Maximum Tsunami Hazards

The probable maximum tsunami hazards are addressed to ensure that any potential tsunami hazards to the SSCs important to safety are considered in plant design. The specific areas of review are as follows: (1) historical tsunami data, including paleotsunami mappings and interpretations, regional records and eyewitness reports, and more recently available tide gauge and real-time bottom pressure gauge data; (2) probable maximum tsunami (PMT) that may pose hazards to the site; (3) tsunami wave propagation models and model parameters used to simulate the tsunami wave propagation from the source toward the site; (4) extent and duration of wave run-up during the inundation phase of the PMT event; (5) static and dynamic force metrics including the inundation and drawdown depths, current speed, acceleration, inertial component, and momentum flux that quantify the forces on any safety-related SSCs that may be exposed to the tsunami waves; (6) debris and water-borne projectiles that accompany tsunami currents and may impact safety-related SSCs; (7) effects of sediment erosion and deposition caused by tsunami waves that may result in blockage or loss of function of safety-related SSCs; (8) potential effects of seismic and nonseismic information on the postulated design bases and how they relate to tsunami in the vicinity of the site and the site region; (9) any additional information requirements prescribed in the "Contents of Application" sections of the applicable subparts to 10 CFR Part 52.

In the North Anna 3 COL FSAR Section 2.4, the applicant addresses probable maximum tsunami hazards. The applicant incorporates by reference ESP SSAR Subsection 2.4.6 with no supplement to address DCD COL Item 2.0-17-A related to probable maximum tsunami flooding. NRC staff reviewed the application and checked the referenced ESP SSAR and the staff's ESP SER. The staff confirmed that there is no outstanding information related to this subsection.

2.4.7 Ice Effects

2.4.7.1 *Introduction*

The ice effects are addressed to ensure that safety-related facilities and water supply are not affected by ice-induced hazards. The specific areas of review are as follows: (1) regional history and types of historical ice accumulations (i.e., ice jams, wind-driven ice ridges, floes, frazil ice formation, etc.); (2) potential effects of ice-induced, high- or low-flow levels on safety-related facilities and water supplies; (3) potential effects of a surface ice-sheet to reduce the volume of available liquid water in safety-related water reservoirs; (4) potential effects of ice to produce forces on, or cause blockage of, safety-related facilities; (5) potential effects of seismic and nonseismic data on the postulated worst-case icing scenario for the proposed plant site; (6) any additional information requirements prescribed in the "Contents of Application" sections of the applicable subparts to 10 CFR Part 52.

2.4.7.2 *Summary of Application*

In North Anna 3 COL FSAR Section 2.4, the applicant addresses ice effects. The applicant incorporates by reference ESP SSAR Subsection 2.4.7 with the following supplement to address DCD COL Item 2.0-18-A, related to ice effects on the safety-related SSCs:

<u>COL Item</u>

- NAPS COL 2.0-18-A Ice Effects

The applicant clarified that the emergency cooling water for Unit 3 is provided from the UHS, which is not affected by the ice conditions, and that the normal cooling systems for Unit 3 are non-safety-related systems. The applicant further clarified that there is no safety-related system interconnection or inter-system reliance between normal and emergency cooling.

The applicant stated that the plant service water system (PSWS), which uses pumps in the intake for water makeup, is not safety-related. The applicant also stated that the most likely location for anchor ice to form is at the intake trash racks or intake screens, but continuous rotation or traveling screens and the use of the trash removal rake will effectively prevent any anchor ice formation in the event of a shutdown of Units 1 and 2 during cold weather.

The applicant mentioned that the skimmer wall at the front of the Unit 3 intake structure extends below the design low water level to further preclude the entry of ice sheets. The applicant clarified that the intake and associated pump system that could be affected by ice layer formation on the lake are not safety-related SSCs.

2.4.7.3 *Regulatory Basis*

The regulatory basis of the information incorporated by reference is addressed in the FSER related to the North Anna ESP. In addition, the guidance relevant to the Commission's regulations related to ice effects, and the associated acceptance criteria, are in Section 2.4.7 of NUREG-0800.

2.4.7.4 *Technical Evaluation*

NRC staff reviewed Subsection 2.4.7 of the North Anna 3 COL FSAR and checked the referenced ESP SSAR and staff's SER. The staff's review confirmed that the information contained in the application and incorporated by reference addresses the relevant information related to this subsection.

The staff's technical review of this application is limited to reviewing the supplemental information pertaining to DCD COL 2.0-18-A, as addressed below:

<u>*COL Item*</u>

- NAPS COL 2.0-18-A Ice Effects

The applicant incorporated by reference ESP SSAR Subsection 2.4.7 to address DCD COL Item 2.0-18-A and provided updated site specific information to supplement ESP SSAR Subsections 2.4.7, related to ice effects. The UHS, described in DCD Section 9.2.5 provides the emergency cooling for Unit 3 and is not impacted by ice conditions.

To deal with potential icing at the intake trash racks, the applicant committed to continuously rotate the traveling water screens should Units 1 and 2 be shutdown during cold weather. In addition, the applicant committed to use the trash removal rake on the intake trash rack to prevent anchor ice formation. PSWS pumps withdraw water from the Unit 3 intake. However, this system is not safety-related.

The staff also reviewed the additional information concerning surface ice and roof loads provided in the North Anna 3 FSAR. The staff finds that the additional information is consistent with the information in the ESP SSAR, which has already been accepted in the ESP SER.

2.4.7.5 *Post Combined License Activities*

There are no post COL activities related to this subsection.

2.4.7.6 *Conclusion*

NRC staff reviewed the application and checked the referenced ESP SSAR and staff's SER. The staff's review confirmed that the applicant has addressed the relevant information and there is no outstanding information expected to be addressed in the COL FSAR related to this subsection.

As set forth above, the applicant has presented and has substantiated information relative to the ice effects important to the design and siting of this plant. The staff reviewed the available information provided. For the reasons given above, the staff concluded that the identification and consideration of the potential for ice flooding, ice blockage of water intakes, ice forces on structures, and the minimum low water levels (from an upstream ice blockage) are acceptable and meet the requirements of 10 CFR 52.79 and 10 CFR 100.20(c), with respect to determining the acceptability of the site for the ESBWR design.

The staff finds that the applicant has considered the appropriate site phenomena for establishing the design basis for SSCs important to safety. The staff accepted the methodologies used to determine the potential for ice formation and blockage reflected in the site characteristics documented in the ESP SER. Accordingly, the staff concluded that the use of these methodologies results in site characteristics containing a sufficient margin for the limited accuracy, quantity, and period of time in which the data have been accumulated. The staff concluded that the identified site characteristics meet the requirements of 10 CFR 52.79 and 10 CFR 100.20(c), with respect to establishing the design basis for SSCs important to safety.

2.4.8 Cooling Water Canals and Reservoirs

2.4.8.1 *Introduction*

The cooling water canals and reservoirs used to transport and impound water supplied to the SSCs important to safety are reviewed to verify their hydraulic design basis. The specific areas of review are as follows: (1) design bases postulated and used by the applicant to protect structures such as riprap, inasmuch as they apply to safety-related water supply; (2) design bases of canals pertaining to capacity, protection against wind waves, erosion, sedimentation, and freeboard and the ability to withstand a probable maximum flood (PMF) (surges, etc.), inasmuch as they apply to a safety-related water supply; (3) design bases of reservoirs pertaining to capacity, PMF design basis, wind wave and run-up protection, discharge facilities (e.g., low-level outlet, spillways, etc.), outlet protection, freeboard, and erosion and sedimentation processes inasmuch as they apply to a safety-related water supply; (4) potential effects of seismic and nonseismic information on the postulated hydraulic design bases of canals and reservoirs for the proposed plant site; and (5) any additional information requirements prescribed in the “Contents of Application” sections of the applicable subparts to 10 CFR Part 52.

2.4.8.2 *Summary of Application*

In North Anna 3 COL FSAR Section 2.4, the applicant addresses the hydraulic design basis of cooling water canals and reservoirs. The applicant incorporates by reference ESP SSAR Subsection 2.4.7, with the following supplement, to address DCD COL Item 2.0-19-A related to cooling water canal and reservoirs.

<u>*COL Items*</u>

- NAPS COL 2.0-19-A Cooling Water Canals and Reservoirs

The applicant incorporated by reference ESP SSAR Subsection 2.4.8 to address DCD COL Item 2.0-19-A. The applicant also provided updated site specific information to supplement ESP SSAR Subsection 2.4.8, related to the hydraulic design basis of cooling water canals and reservoirs.

- ESP COL 2.4-8

The applicant provided updated site specific information to supplement ESP SSAR Subsection 2.4.8 to address whether or not Lake Anna is used for safety-related water withdrawals. The applicant added that the North Anna Reservoir and WHTF, which comprise Lake Anna, are not used for safety-related water withdrawal for Unit 3. The emergency cooling water for Unit 3 comes from the UHS, as described in DCD Section 9.2.5.

2.4.8.3 *Regulatory Basis*

The regulatory basis of the information incorporated by reference is addressed in the FSER related to the North Anna ESP. In addition, the guidance relevant to the Commission's regulations related to cooling water canal and reservoirs, and the associated acceptance criteria, are in Section 2.4.8 of NUREG-0800.

2.4.8.4 *Technical Evaluation*

NRC staff reviewed Subsection 2.4.8 of the North Anna 3 COL FSAR and checked the referenced ESP SSAR and staff's SER. The staff confirmed that the information in the application and incorporated by reference addresses the relevant information related to this subsection is sufficient and appropriate.

The staff's technical review of this application is limited to reviewing the supplemental information pertaining to NAPS COL 2.0-19-A and the ESP COL Action Item 2.4-9, as addressed below:

<u>*COL Items*</u>

- NAPS COL 2.0-19-A Cooling Water Canals and Reservoirs

The applicant incorporated by reference ESP SSAR Subsection 2.4.8 to address DCD COL Item 2.0-19-A, related to cooling water canals and reservoirs. The staff finds that the additional information is consistent with the information provided in the ESP SSAR, which has already been accepted in the ESP SER.

- NAPS ESP COL 2.4-8

Based on the review of the descriptions of the UHS system and IC/PCCS pools in DCD Section 9.2.5, NRC staff concurred that the North Anna Reservoir and WHTF are not used for safety-related water withdrawal for Unit 3.

2.4.8.5 *Post Combined License Activities*

There are no post COL activities related to this subsection.

2.4.8.6 *Conclusion*

NRC staff reviewed the application and checked the referenced ESP SSAR and the staff's ESP SER. The staff's review confirmed that the applicant has addressed the relevant information and there is no outstanding information expected to be addressed in the COL FSAR related to this subsection.

2.4.9 Channel Diversions

Plant and essential water supplies used to transport and impound water supplies were evaluated to ensure that they will not be adversely affected by stream or channel diversions. The review includes stream channel diversions away from the site (which may lead to a loss of safety-related water) and stream channel diversions toward the site (which may lead to flooding). In addition, in such an event, the applicant needs to show that alternate water supplies are available to safety-related equipment. The specific areas of review are as follows: (1) historical channel migration phenomena including cutoffs, subsidence, and uplift; (2) regional topographic evidence that suggests a future channel diversion may or may not occur (used in conjunction with evidence of historical diversions); (3) thermal causes of channel diversion, such as ice jams, which may result from downstream ice blockages that may lead to flooding from backwater or upstream ice blockages that can divert the flow of water away from the intake; (4) potential for forces on safety-related facilities or the blockage of water supplies resulting from channel migration-induced flooding (flooding not addressed by hydrometeorological-induced flooding scenarios in other sections); (5) potential of channel diversion from human-induced causes (i.e., land-use changes, diking, channelization, armoring, or failure of structures); (6) alternate water sources and operating procedures; (7) potential effects of seismic and nonseismic information on the postulated worst-case channel diversion scenario for the proposed plant site; (8) any additional information requirement prescribed in the "Contents of Application" sections of the applicable subparts to 10 CFR Part 52.

The applicant incorporated by reference ESP SSAR Subsection 2.4.9 with no supplement or departure to address DCD COL Item 2.0-20-A, related to channel diversions. NRC staff reviewed the application and checked the referenced ESP SSAR and the staff's ESP SER. The staff confirmed that there is no outstanding information related to this subsection.

2.4.10 Flooding Protection Requirements

2.4.10.1 *Introduction*

The flooding protection requirements address the locations and elevations of safety-related facilities and those of structures and components required for protection of safety-related facilities. These requirements are then compared with design-basis flood conditions to determine whether flood effects need to be considered in the plant's design or in emergency procedures. The specific areas of review are as follows: (1) safety-related facilities exposed to flooding; (2) type of flood protection (e.g., "hardened facilities," sandbags, flood doors, bulkheads, etc.) provided to the SSCs exposed to floods; (3) emergency procedures needed to implement flood protection activities and warning times available for their implementation reviewed by the organization responsible for reviewing issues related to plant emergency procedures; (4) potential effects of seismic and nonseismic information on the postulated flooding protection for the proposed plant site; and (5) any additional information requirements prescribed in the "Contents of Application" sections of the applicable subparts to 10 CFR Part 52.

2.4.10.2 *Summary of Application*

This subsection of the COL FSAR addresses the needs for site specific information on flooding protection requirements. The applicant addressed the information as follows:

COL Items

- NAPS COL 2.0-21-A Flooding Protection Requirements

The applicant incorporated by reference ESP SSAR Subsection 2.4.10 to address DCD COL Item 2.0-21-A and provided updated site specific information to supplement ESP SSAR Subsection 2.4.10.

- NAPS ESP COL 2.4-9 Slope Embankment Protection

The applicant provided updated site specific information to supplement ESP SSAR Subsection 2.4.10 to address ESP COL Action Item 2.4-9. The applicant indicated that the Unit 3 water intake structure pump house is separated from Lake Anna by an elevated berm that protects it from flood events up to a 100-year flood on Lake Anna. Rip-rap protection of the slope embankment is provided to protect against local erosion near the intake structure. The applicant added that the Unit 3 water intake structure pump house is not a safety-related structure.

2.4.10.3 *Regulatory Basis*

The regulatory basis of the information incorporated by reference is addressed within the FSER related to the North Anna ESP. In addition, the guidance relevant to the Commission's regulations related to flood protection requirements, and the associated acceptance criteria, are given in Section 2.4.10 of NUREG-0800.

2.4.10.4 *Technical Evaluation*

NRC staff reviewed Subsection 2.4.10 of the North Anna 3 COL FSAR and checked the referenced ESP SSAR and staff's SER. The elevation of the design plant grade for Unit 3 is 290.0 feet. This elevation is approximately 20 ft above the maximum flood level at the site resulting from a probable maximum flood in Lake Anna's watershed, the simultaneous failure of upstream storage reservoirs, and coincident wave action (elevation 270 feet) as discussed in the ESP SER.

The staff specified **Open Item 2.4.2-2 and Open Item 2.4.2-3**. That open item pertains to providing reasonable assurance that the locally intense precipitation flood event will not adversely impact Unit 3's safety-related SSCs or those that satisfy the RTNSS criteria, and that construction of Unit 3 will demonstrate compliance with 10 CFR 52.79(a)(31). The staff outlined additional information that needs to be reflected in sections of the FSAR, as appropriate.

The staff's technical review in this subsection is limited to the supplemental information pertaining to DCD COL Item 2.0-21-A and ESP COL Action Item 2.4-9, as addressed below:

COL Items

- NAPS COL 2.0-21-A Flood Protection Requirements

NRC staff reviewed the resolution to the DCD COL Item 2.0-21-A, related to flooding protection requirements, and the comparison with design-basis flood conditions to determine whether flood effects need to be considered in the plant's design or in emergency procedures included under Section 2.4.10 of the North Anna 3 COL FSAR. The staff finds that the additional information is consistent with the information provided in the ESP SSAR, which has already been accepted in the ESP-FSER.

- NAPS ESP COL 2.4-9

Based on the passive cooling design specified in the ESBWR DCD, staff determined that a safety-related intake structure is not required and therefore, ESP COL Action Item 2.4-9 is no longer required.

2.4.10.5 *Post Combined License Activities*

There are no post COL activities related to this subsection.

2.4.10.6 *Conclusion*

NRC staff reviewed the application and checked the referenced ESP SSAR and staff's ESP SER. The staff's review confirmed that the applicant has addressed the relevant information and there is no outstanding information expected to be addressed in the COL FSAR in this subsection.

As described in Subsection 2.4.2, however the staff specified **Open Items 2.4.2-2 and 2.4.2-3**. Those open items pertain to providing reasonable assurance that the locally intense precipitation flood event will not adversely impact Unit 3's safety-related SSCs, or those that satisfy the RTNSS criteria, and that construction of Unit 3 will demonstrate compliance with 10 CFR 52.79(a)(31). The staff outlined additional information that needs to be reflected in sections of the FSAR, as appropriate. The staff's review of FSAR Section 2.4.10 will be complete after the resolution of those open items.

2.4.11 Low Water Considerations

2.4.11.1 *Introduction*

The low water considerations address natural events that may reduce or limit the available safety-related cooling water supply. The applicant ensures that an adequate water supply will exist to shut down the plant under conditions requiring safety-related cooling. The specific areas of review are as follows: (1) worst drought considered reasonably possible in the region; (2) effects of low water surface elevations caused by various hydrometeorological events and a potential blockage of intakes by sediment, debris, littoral drift, and ice because they can affect the safety-related water supply; (3) effects on the intake structure and pump design bases in relation to the events described in SAR Sections 2.4.7, 2.4.8, 2.4.9, and 2.4.11, which consider the range of water supply required by the plant (including minimum operating and shutdown flows during anticipated operational occurrences and emergency conditions) compared with availability (considering the capability of the UHS to provide adequate cooling water under conditions requiring safety-related cooling); (4) use limitations imposed or under discussion by Federal, State, or local agencies authorizing the use of the water; (5) potential effects of seismic and nonseismic information on the postulated worst-case low water scenario for the proposed plant site; and (6) any additional information requirements prescribed in the "Contents of Application" sections of the applicable subparts to 10 CFR Part 52.

2.4.11.2 *Summary of Application*

This subsection of the COL FSAR addresses the impacts of low water on water supply. The applicant addressed the information as follows:

<u>COL Items</u>

- NAPS COL 2.0-22-A Low Water Considerations

The applicant incorporated by reference ESP SSAR Subsection 2.4.11 to address DCD COL Item 2.0-22-A.

- NAPS ESP COL 2.4-10

The applicant provided updated site specific information to supplement ESP SSAR Subsections 2.4.11.5, “Plant Requirements,” and 2.4.11.6, “Heat Sink Dependability Requirements,” to address ESP COL Action Item 2.4-10. The applicant indicated that the Unit 3 CWS has two modes of operation: energy conservation (when Lake Anna water level is at or above an elevation of 250 feet at the North Anna Dam), and maximum water conservation (when the water level is below an elevation of 250 feet and is not restored within a reasonable period of time). The UHS, described in DCD Section 9.2.5, provides the emergency cooling for Unit 3 and the operation would not be impacted by low water conditions in Lake Anna.

2.4.11.3 *Regulatory Basis*

The regulatory basis of the information incorporated by reference is addressed in the FSER related to the North Anna ESP. In addition, the guidance relevant to the Commission’s regulations related to low water considerations, and the associated acceptance criteria, are in Section 2.4.10 of NUREG-0800.

2.4.11.4 *Technical Evaluation*

NRC staff reviewed Subsection 2.4.11 of the North Anna 3 COL FSAR and checked the referenced ESP SSAR and staff’s SER. The staff’s review confirmed that the information in the application and incorporated by reference addresses the relevant information related to this subsection.

The staff’s technical review of this application is limited to the supplemental information pertaining to DCD COL 2.0-22-A and ESP COL Action Item 2.4-10, as addressed below:

<u>COL Items</u>

- NAPS COL 2.0-22-A Low Water Considerations

NRC staff reviewed the resolution to the DCD COL Item 2.0-22-A, related to low water considerations to ensure that an adequate water supply will exist to shut down the plant under conditions requiring safety-related cooling, included under Section 2.4.11 of the North Anna 3 COL FSAR. The staff finds that the additional information is consistent with the information in the ESP SSAR, which has already been accepted in the ESP SER

- NAPS ESP COL 2.4-10

Based on the passive cooling design specified in the ESBWR DCD, the staff determined that ESP COL Action Item 2.4-10 is no longer required.

2.4.11.5 *Post Combined License Activities*

There are no post COL activities related to this subsection.

2.4.11.6 *Conclusion*

NRC staff reviewed the application and checked the referenced ESP SSAR and staff's SER. The staff's review confirmed that the applicant has addressed the relevant information and there is no outstanding information expected to be addressed in the COL FSAR related to this subsection.

As set forth above, the applicant has presented and substantiated information relative to the low water effects important to the design and siting of this plant. The staff reviewed the available information provided. For the reasons given above, the staff concluded that the identification and consideration of the potential for low water conditions are acceptable and meet the requirements of 10 CFR 52.79 and 10 CFR 100.20(c), with respect to determining the acceptability of the site for the ESBWR design.

The staff finds that the applicant has considered the appropriate site phenomena in establishing the design bases for SSCs important to safety. The staff accepted the methodologies used to determine the potential for low water conditions reflected in the site characterists documented in the ESP SER. Accordingly, the staff concluded that the use of these methodologies results in design bases containing a sufficient margin for the limited accuracy, quantity, and period of time in which the data have been accumulated. The staff concluded that the identified design bases meet the requirements of 10 CFR 100.20(c) with respect to establishing the design basis for SSCs important to safety.

2.4.12 Groundwater

2.4.12.1 *Introduction*

This section describes the hydrogeological characteristics of the site.

The most significant objective of groundwater investigations and monitoring at this site is to evaluate the effects of groundwater on plant foundations. The evaluation is performed to assure that the maximum groundwater elevation remains less than the DCD site parameter value of 0.61 meters (2 feet) below plant grade. Most of the discussion of groundwater issues presented below is related to this objective. Other significant objectives are to examine whether groundwater provides any safety-related water supply and to determine whether dewatering systems are required to maintain groundwater elevation below the required level.

The specific areas of review are as follows:

(1) identification of the aquifers, types of onsite groundwater use, sources of recharge, present withdrawals and known and likely future withdrawals, flow rates, travel time, gradients (and other properties that affect the movement of accidental contaminants in groundwater),

groundwater levels beneath the site, seasonal and climatic fluctuations, monitoring and protection requirements, and manmade changes that have the potential to cause long-term changes in local groundwater regime; (2) effects of groundwater levels and other hydrodynamic effects of groundwater on design bases of plant foundations and other SSCs important to safety; (3) reliability of groundwater resources and related systems used to supply safety-related water to the plant; (4) reliability of dewatering systems to maintain groundwater conditions within the plant's design bases; (5) potential effects of seismic and nonseismic information on the postulated worst-case groundwater conditions for the proposed plant site; and (6) any additional information requirements prescribed in the "Contents of Application" sections of the applicable subparts to 10 CFR Part 52.

2.4.12.2 *Summary of Application*

This subsection of the COL FSAR addresses the groundwater in terms of impacts on structures and water supply. The applicant addressed these issues as follows:

<u>*COL Item*</u>

- NAPS COL 2.0-23-A Groundwater

The applicant incorporated by reference ESP SSAR Subsection 2.4.12 to address DCD COL Item 2.0-23-A. The applicant provided updated site specific information to supplement or replace ESP SSAR Subsections 2.4.12.1.3.1, "Plant Operating Requirements;" 2.4.12.1.3.2, "Construction Requirements;" 2.4.12.3, "Groundwater Levels and Movement;" 2.4.12.2.4, "Hydrogeologic Properties of Subsurface Materials;" 2.4.12.3, "Monitoring or Safeguard Requirements;" 2.4.12.4, "Design Basis for Subsurface Hydrostatic Loadings;" and 2.4.12.5, "References."

<u>*Variances*</u>

The following variances from the ESP SSAR are listed in FSAR Table 1.8-202:

- NAPS ESP VAR 2.0-2 Hydraulic Conductivity

The applicant requested VAR 2.0-2 to the ESP SSAR hydraulic conductivity value and used larger maximum and geometric mean values in FSAR Subsection 2.4.12.1.2.

- NAPS ESP VAR 2.0-3 Hydraulic Gradient

The applicant requested VAR 2.0-3 to the ESP SSAR hydraulic gradient value and used a larger value in FSAR Subsection 2.4.12.1.2.

- NAPS ESP VAR 2.4-1 Void Ratio, Porosity, and Seepage Velocity

The applicant requested VAR 2.4-1 to the ESP SSAR values for void ratio, porosity (total and effective), and seepage velocity and estimated smaller values for void ratio and porosity, and a larger value for seepage velocity, in FSAR Subsection 2.4.12.1.2.

- NAPS ESP VAR 2.4-2 NAPS Water Supply Well Information

The applicant requested VAR 2.4-2 to use revised information for the water supply well information and provided FSAR Table 2.4-17R to correct certain information in the ESP SSAR Table 2.4-17.

2.4.12.3 *Regulatory Basis*

The regulatory basis of the information incorporated by reference is addressed in the FSER related to the North Anna ESP.

2.4.12.4 *Technical Evaluation*

NRC staff reviewed Subsection 2.4.12 of the North Anna 3 COL FSAR and checked the referenced ESP SSAR and staff's SER. The staff's review confirmed that the information contained in the application and incorporated by reference addresses the relevant information related to this subsection.

The staff's technical review of this application is limited to reviewing the supplemental information pertaining to COL Item DCD COL 2.0-23-A and to variances NAPS ESP VAR 2.0-2, NAPS ESP VAR 2.0-3, NAPS ESP VAR 2.4-1, and NAPS ESP VAR 2.4-2, as addressed below.

In order to improve readability, the staff's discussion of groundwater characteristics is organized into the following technical areas. Variances and open items are described where appropriate within these areas.

2.4.12.4.1 General Hydrogeological Characteristics of Site

One COL item related to this topic was addressed by the FSAR:

<u>COL Item</u>

- NAPS COL 2.0-23-A Groundwater

NRC staff reviewed the resolution to the DCD COL Item 2.0-23-A related to the hydrogeological characteristics of the site, the effects of groundwater on plant foundations, and the reliability of safety-related water supply and dewatering systems included under Section 2.4.12 of the North Anna 3 COL FSAR.

The purpose of this COL item is to assure that the specific hydrogeological characteristics of the site are considered. Hydrogeological characteristics were addressed initially in the ESP SSAR, and the information presented there was supplemented in the FSAR.

<u>*Information Submitted by Applicant*</u> The application's description of the regional hydrogeology and groundwater conditions is in ESP SSAR Section 2.4.12 and is incorporated by reference into the FSAR with no supplements or variances.

The application's description of the site hydrogeology and groundwater conditions was supplemented based on the results of a Unit 3 subsurface field investigation conducted from August to November of 2006, as described in FSAR Section 2.5.4.2.3. This investigation included 55 exploratory borings and the installation of seven observation wells.

The FSAR used the same classification of subsurface materials as in the ESP SSAR. Subsurface materials are classified as crystalline parent bedrock, weathered rock, saprolite of 10 to 50 percent core stone, saprolite of less than 10 percent core stone, residual soil, and fill. Groundwater at the site occurs in the saprolite and in the fractures of the bedrock. Four of the seven wells installed as part of the Unit 3 subsurface field investigation were described as completed in rock, and three were described as completed in soil/weathered rock. Based on groundwater heads observed in well pairs completed at different elevations, the applicant concluded that the bedrock and saprolite are hydraulically connected.

NRC Staff's Technical Evaluation The staff reviewed the supplemental information provided in the FSAR regarding site hydrogeology and groundwater conditions. The staff determined that the methods used were appropriate, and that the supplemental information was consistent with the overall picture of site conditions presented in the ESP SSAR.

2.4.12.4.2 Use of Groundwater at Site

The applicant stated that groundwater will not be used for safety-related functions at Unit 3 (FSAR Section 2.4.12.1.3, "Site Groundwater Use"), but groundwater will be used for purposes such as drinking and sanitation.

The staff determined that the groundwater supply's lack of safety function is consistent with the uses stated for groundwater and with provisions for safety-related water supply from other sources, as described in the FSAR.

2.4.12.4.3 Hydraulic Conductivity (NAPS ESP Var 2.0-2)

Information Submitted by Applicant Slug tests were conducted in four of the new wells to supplement the existing data used to estimate hydraulic conductivities in the saprolite and the shallow bedrock. Packer test results from a borehole adjacent to one of the wells were included in the shallow bedrock estimate of hydraulic conductivity. These additional data resulted in estimates of hydraulic conductivity for the saprolite of 0.076 to 3.017 meters per day with a geometric mean of 0.53 meters per day (compared to a range of 0.06 to 1.04 meters per day and a geometric mean of 0.40 meters per day from the ESP SSAR), and for the shallow bedrock of 0.152 to 1.920 meters per day with a geometric mean of 0.625 meters per day (compared to a range of 0.61 to 0.91 meters per day from the ESP SSAR).

The maximum groundwater hydraulic conductivity of 3.0 m/d in FSAR Section 2.4.12.1.2 is higher than the hydraulic conductivity site characteristic in Appendix A of the North Anna ESP. The ESP hydraulic conductivity of 1.0 meter per day was based on the data obtained during the ESP subsurface field investigation. The additional hydraulic conductivity data obtained during the Unit 3 field investigation resulted in a larger estimate of the maximum hydraulic conductivity. There is no DCD site parameter value for this site characteristic.

In the COL Application Departures Report, the applicant identified the hydraulic conductivity variance (NAPS ESP Var 2.0-2) and requested to use the FSAR value of 3.0 meters per day instead of the 1.04 meters per day value in the ESP SSAR and ESP. The applicant provided two justifications for the request.

1. The ESP hydraulic conductivity value of 1.04 meters per day was used in the groundwater transport analysis of FSAR Section 2.4.13. The applicant stated that this analysis is conservative, in part because the value of 1.04 m/d is greater than 87.5

percent of the hydraulic conductivities reported in FSAR Table 2.4-16R. The Unit 3 subsurface field investigation resulted in measurements of hydraulic conductivity that were greater than 1.04 meters per day at two locations. The applicant stated that these measurements are not relevant to the groundwater transport analysis because they were made at locations that are not in the transport pathway.

2. The groundwater flow model used in FSAR Section 2.4.12 to evaluate the maximum post-construction groundwater elevation incorporated the data from the Unit 3 subsurface field investigation and satisfied the DCD limit on maximum groundwater level.

NRC Staff's Technical Evaluation The staff reviewed the supplemental slug test and packer test data in FSAR Appendix 2.5.4AA and the resulting saturated hydraulic conductivities in FSAR Table 2.4-16R. The staff determined that the methods used were appropriate and that the estimated conductivities were consistent with the previous estimates in the ESP SSAR. The supplemental data expanded the range of observed saturated hydraulic conductivity for both the saprolite and shallow bedrock, resulting in larger maximum hydraulic conductivity estimates than were provided in the ESP SSAR: 3.0 meters per day for the saprolite and 1.92 meters per day for the shallow bedrock. Because a saturated hydraulic conductivity value of 3.0 meters per day is based on site specific observations and is conservative, the staff concludes that this value is an appropriate site characteristic and accepts NAPS ESP VAR 2.0-2.

2.4.12.4.4 Hydraulic Gradient (NAPS ESP Var 2.0-3)

Information Submitted by Applicant The maximum hydraulic gradient of 0.04 provided in FSAR Section 2.4.12.1.2 is higher than the hydraulic gradient site characteristic provided in Appendix A of the North Anna ESP. The ESP hydraulic gradient of 0.03 was based on the groundwater head measurements obtained during the ESP subsurface field investigation. The additional groundwater head measurements obtained during the Unit 3 field investigation resulted in a larger estimate of the maximum groundwater hydraulic gradient. There is no DCD site parameter value for this site characteristic.

In the COL Application Departures Report, the applicant identified the hydraulic gradient variance (NAPS ESP Var 2.0-3) and requested to use the FSAR value of 0.04 instead of the value of 0.03 in the ESP SSAR and ESP. The applicant justified the use of the larger hydraulic gradient by demonstrating compliance with the 10 CFR Part 20, Appendix B, Table 2 concentration limits using the FSAR hydraulic gradient value of 0.04 in the FSAR Section 2.4.13 analysis of groundwater release.

NRC Staff's Technical Evaluation The staff evaluated the site groundwater head measurements provided in FSAR Table 2.4-15R and illustrated in Figure 2.4-205 and Figures 2.4-207 through 2.4-214. The staff determined that the data obtained in 2006 and 2007 are consistent with earlier measurements. Groundwater flow direction from the Unit 3 reactor area is generally to the northeast toward Lake Anna. Three of the wells installed as part of the Unit 3 subsurface field investigation were located adjacent to and deeper than existing wells, providing a total of four well pairs that were used to evaluate vertical groundwater head gradients at the site. Based on the small observed vertical gradients in the well pairs, the staff concluded that the shallow bedrock and saprolite units are hydraulically connected. The applicant used heads at observation wells (OW) 901 and OW-848 to estimate the horizontal groundwater gradient between the reactor building and Lake Anna. Based on the observed heads, the staff concluded that although the local gradient at the reactor building is likely to be larger, 0.04 is a conservative estimate of the average gradient between the reactor building and Lake Anna. This value is conservative because the actual groundwater flow path would be longer than the straight-line distance between wells OW-901 and OW-848 used to compute the gradient. Because a groundwater hydraulic gradient of 0.04 is based on site specific observations and is conservative, the staff concluded that this value is an appropriate site characteristic and accepts NAPS ESP VAR 2.0-3.

2.4.12.4.5 Void Ratio, Porosity, and Seepage Velocity (NAPS ESP Var 2.4-1)

Information Submitted by Applicant Samples from the Unit 3 field investigation boreholes were used to supplement the moisture content and specific gravity data used to estimate the void ratio and porosity. Based on laboratory tests of saprolite samples, the applicant determined that the median moisture content is 17 percent and the median specific gravity is 2.65. Using these values, the void ratio was estimated to be 0.45 with a resulting total porosity of 0.31. (The ESP SSAR estimates were 26 percent for the average moisture content and 2.68 for the specific gravity, resulting in estimates of 0.7 for the void ratio and 0.41 for the porosity.) The FSAR effective porosity was assumed to be 80 percent of the total porosity, or 0.25. (This assumption was also made in the ESP SSAR resulting in an effective porosity of 0.33.)

The applicant used the Unit 3 field investigation supplemental data described above to compute an estimate of groundwater velocity of 0.085 m/d (compared to the ESP SSAR groundwater velocity of 0.037 m/d). Based on this velocity and a travel distance of 304.8 m, the groundwater travel time between the Unit 3 radwaste building and the shoreline of Lake Anna was estimated to be 10 years (compared to the travel time of 40 years in the ESP SSAR for a distance of 549 m).

In the COL Application Departures Report, the applicant identified the void ratio, porosity, and seepage velocity variance (NAPS ESP Var 2.4-1) and requested to use the FSAR values instead of the values in the ESP SSAR. The applicant justified the use of the FSAR values because they result in a larger seepage velocity than the corresponding values used in the ESP SSAR, demonstrating compliance with the 10 CFR Part 20, Appendix B, Table 2 concentration limits using the FSAR seepage velocity value in the FSAR Section 2.4.13 analysis of groundwater release.

NRC Staff's Technical Evaluation The staff reviewed the data on gravimetric water content in FSAR Table 2.5-212, FSAR Appendix 2.5.4AA, and the applicant's computation of porosity. While using conservative values (i.e., maximum observed) for the site characteristic hydraulic gradient and saturated hydraulic conductivity, the applicant used an average value for the site characteristic porosity. The staff reviewed the gravimetric water content data in Table 3.1 of FSAR Appendix 2.5.4AA. Using a specific gravity of 2.65 as in FSAR Section 2.4.12, the staff calculated average and minimum porosities for samples with less than 10 percent gravel and for samples with more than 10 percent gravel. Results are in Table 2.4.12-1 (compared to the applicant's total porosity estimate of 0.31, as presented in FSAR Section 2.4.12.1.2). Although smaller values of porosity were observed, the staff concluded that a total porosity estimate of 0.31 is appropriate because the large number of samples provides confidence in the average value and the samples with gravel greater than 10 percent were few in number, not contiguous, and therefore unlikely to be evidence of a low porosity and high velocity pathway.

Table 2.4.12-1 Average and minimum porosity for soil samples with percentage of gravel greater than and less than 10 percent

	Gravel < 10%	Gravel > 10%
Number of Samples	102	7
Average Porosity	0.328	0.244
Minimum Porosity	0.129	0.053

The supplemental data obtained in the Unit 3 subsurface field investigation, as reported in the FSAR, resulted in a lower estimate of effective porosity (0.25, i.e., 80 percent of 0.31) than provided in the ESP SSAR. The staff reviewed the computation of groundwater velocity using the applicant's site characteristic values of hydraulic gradient, saturated hydraulic conductivity, and effective porosity. Staff concludes that the resulting groundwater velocity of 0.085 m/d is an appropriate site characteristic and accepts NAPS ESP VAR 2.4-1.

2.4.12.4.6 NAPS Water Supply Well Information (NAPS ESP Var 2.4-2)

Information Submitted by Applicant. Corrected and supplemental information is provided on the location and pumping rates for existing groundwater supply wells onsite in FSAR Tables 2.4-17R and 2.4-205. The applicant states that any groundwater used for Unit 3 will not be safety-related.

In the COL Application Departures Report, the applicant identifies a variance in the plant water supply well information (NAPS ESP Var 2.4-2). The variance arises from the use of incorrect information in the ESP SSAR and new information obtained on plant water supply wells. The applicant justifies the FSAR water supply well information (see FSAR Table 2.4-17R) because it better reflects current plant water supply well conditions, and because it continues to support the ESP SSAR conclusions that future groundwater withdrawals will likely be from the existing wells or from new wells drilled onsite, and any future additional groundwater use is not expected to impact offsite wells.

NRC Staff's Technical Evaluation. The staff reviewed the supplemental information provided in the FSAR describing onsite groundwater use. The well located at the North Anna Nuclear Information Center (NANIC) supplies potable water. The staff reviewed the maps of groundwater head and the information provided on the NANIC well construction and operation. The NANIC well is located approximately 0.9 kilometers (0.4 miles) upgradient of the radionuclide source used in the FSAR Section 2.4.13 Accidental Release Analysis, the head in the NANIC well is approximately 12.2 meters (40 feet) higher than at the source location, the NANIC well is finished in bedrock at a depth of 79.2 m (260 feet) (much deeper than the source), and the current groundwater hydraulic heads reflect pumping from the well so future changes in hydraulic gradients are not expected. The staff concluded that an accidental release pathway to the NANIC water supply well is implausible.

2.4.12.4.7 Groundwater Monitoring Programs

Information Submitted by Applicant. Supplemental information is provided in the FSAR on the groundwater monitoring programs required during and following plant construction. The applicant states that seven new observation wells were installed during subsurface investigations for Unit 3, and that these have been monitored in addition to continuing monitoring of wells installed previously. In the future, some observation wells may need to be closed prior to site earthwork activities; an evaluation will be conducted to determine whether new wells will be required to provide adequate evaluation of construction impacts on site groundwater levels. Regarding the frequency of monitoring, the applicant states that groundwater levels will be measured monthly during any construction-related dewatering, quarterly for two years following the completion of construction, and semi-annually or annually during plant operations.

NRC Staff's Technical Evaluation. The staff reviewed the supplemental information provided in the FSAR regarding groundwater monitoring programs. The staff recognizes that groundwater monitoring is an ongoing activity, and that monitoring wells may need to be closed and new wells installed because of changing site access conditions during construction. The staff agrees that further evaluation and the possible installation of new wells will be necessary to assure that groundwater levels will be adequately monitored as site conditions change. The frequency of monitoring proposed by the applicant is reasonable for monitoring the effects of construction and natural variations on groundwater levels.

2.4.12.4.8 Groundwater Levels and Modeling

Information Submitted by Applicant The design plant grade elevation is specified in the FSAR as 88.4 meters (290 feet) mean sea level (msl). Construction of Unit 3 will require cut and fill on the site, which is anticipated to modify the existing groundwater elevations. An analysis of post-construction groundwater heads was conducted using a groundwater flow model developed in Visual MODFLOW Pro 4.2. No technical details of model development or application were provided in the FSAR. At the site audit, the applicant discussed additional details about the development and calibration of the numerical groundwater flow model. The applicant provided groundwater model input files to the staff following the safety audit. A narrative description of the groundwater model was provided to the staff in the applicant's Letter No. 024 dated September 19, 2008 (in response to **RAI 2.4.12-1**). Based on the results of the modeling, the applicant concluded that the maximum post-construction groundwater elevation in the power block area will be 86.26 meters (283 feet) North American Vertical Datum of 1988 (NAVD88), 2.134 meters (7 feet) below the design plant grade elevation. Because the maximum groundwater elevation is less than the DCD site parameter value of 0.61 m (2 feet) below plant grade (87.79 meters or 288 feet msl, the applicant concluded that a permanent dewatering system is not needed for safe operation of Unit 3.

The maximum post-construction groundwater elevation of 86.26 m (283 feet) NAVD88 provided in FSAR Section 2.4.12.4 is higher than the Maximum Elevation of Groundwater site characteristic provided in Appendix A of the North Anna ESP. The ESP maximum groundwater elevation of 82.3 meters (270 feet) msl was based on a proposed site grade of 82.6 meters (271 feet) msl and a prior estimate of maximum groundwater elevation for the existing units. The Unit 3 design plant grade of 88.4 meters (290 feet) msl was used to estimate a higher maximum groundwater elevation of 86.26 meters (283 feet). As stated above, however, the maximum groundwater elevation DCD site parameter limit was met.

NRC Staff's Technical Evaluation In requesting additional information about the groundwater modeling conducted to evaluate subsurface hydraulic loading, the staff was concerned about three issues: the technical basis for model development, an explanation for the high head observed at well OW-901, and the basis for confidence in model predictions. These issues were the subject of **RAI 2.4.12-1**.

The groundwater modeling report provides the technical basis for the assumptions, parameter values, and boundary conditions of the groundwater flow model. A steady-state, two-layer model was developed (the upper layer representing the saprolite, the lower layer the shallow bedrock). The lower, no-flow boundary (at a depth of 100 feet) is consistent with the conceptual model in which the occurrence of water-bearing fractures decreases with depth. Lateral and internal boundaries reflect the locations of drainages, ponds, and Lake Anna. The north and south boundaries are based on extrapolating observed heads. A general head boundary was used along the topographically high southwest boundary to represent recharge under a fixed-head gradient. Two saturated hydraulic conductivity zones were used (in plan view) with the demarcation between zones defined by differences in the observed values of conductivity from slug tests and from the location of a fault identified in ESP SSAR Figure 2.5-18. Conductivities were the same in the two model layers and were assumed to be isotropic (this latter assumption was tested by the applicant via simulation). Recharge was assumed to be zero at the location of buildings and paved surfaces, higher than surrounding areas at the Units 1 and 2 service water reservoir, and uniform over the remainder of the model domain (this latter assumption was tested by the applicant via simulation). The staff reviewed the model assumptions and boundary conditions and concluded that they are appropriate and consistent with the site data and conceptual model.

Recharge and saturated hydraulic conductivity were adjusted by the applicant to fit observed groundwater heads in May 2007. Calibration criteria were based on the root mean squared residual (RMSR); the normalized RMSR; the absolute value of the maximum residual; mass balance; and a preference for simpler models when the other criteria were met. Calibrated recharge values were 22.9 centimeters per year (9 inches per year) over the majority of the domain and 63.5 centimeters per year (25 inches per year) over the service water reservoir. Calibrated hydraulic conductivity values were 0.52 meters per day in the northern zone and 0.17 meters per day in the southern zone.

The calibration criteria were met except for the maximum absolute residual criterion, which was violated at well OW-901, located at the position of the Unit 3 reactor building. As stated in the safety audit trip report (ML082040903), the applicant suggested that the relatively high head in OW-901 was the result of the location of the well at a topographical high point. From information provided in the FSAR, the staff noted that well OW-901 was screened at a depth significantly deeper than the nearby wells OW-845 and OW-846, where the heads were consistently more than 10 feet lower than at OW-901. The staff concluded that the topographical differences among the wells did not rule out the possibility of upward groundwater flow in the area of well OW-901. In the groundwater modeling report, the relatively large head difference between wells OW-901 and OW-845 was attributed to (page 22) "local heterogeneities in the distribution and characteristics of fractures in the bedrock, which cannot be accounted for in the model." To address the importance of well OW-901, an alternative calibration was completed in which the general recharge rate was increased to 31.7 cm/yr (12.5 in./yr) in order to fit the observed head at OW-901. The increased recharge resulted, however, in generally overestimating heads at other wells.

Predictive simulations of post-construction heads were conducted using the results of the two calibrations described above. In these simulations, the topography of the model was modified to reflect the final site grading, model cells were made inactive where deep building foundations will occur, a backfill zone with a hydraulic conductivity of 0.86 m/d was used in the area around the power block, a recharge rate of zero was applied where buildings and paved areas will be located, and model drain cells were included to represent the surface drainage ditches planned for controlling surface runoff around the power block and the cooling tower. Drain elevations were set at 85.95 m (282 ft.) NAVD88 around the power block. The applicant also conducted a sensitivity simulation in which the backfill hydraulic conductivity was increased and decreased by a factor of ten. The post-construction, simulated maximum groundwater elevation in the power block area was 85.65 m (281 ft.) for the base calibration, 85.95 m (282 ft.) when the backfill conductivity was decreased by a factor of ten, and 86.26 m (283 ft) for the calibration with an increased recharge (all elevations NAVD88). All simulations predicted that the maximum groundwater elevation would be more than 0.61 m (2.0 ft.) below the Unit 3 power block design elevation of 88.39 m (290 ft.) msl, which met the DCD requirement.

The applicant transmitted MODFLOW input files used in the evaluation of post-construction hydraulic loading. Input files for all the simulations described in the groundwater modeling report were received and used in the staff's review. Based on the staff's review of the information in the FSAR and in the groundwater modeling report, the staff concluded that the groundwater model developed by the applicant appropriately represents, with one exception, the site characterization data and the conceptual understanding of site groundwater flow.

The one significant exception is the representation of the groundwater head observed in well OW-901, located at the Unit 3 reactor building. The applicant has not attempted to modify the conceptual basis of the model to better represent the observed head at OW-901. Instead, the applicant has attempted to bound the expected behavior of the system to demonstrate that the maximum groundwater level will meet the DCD requirement even when groundwater heads are unrealistically elevated across the site to match the head at OW-901. The staff determined that this is an appropriate approach for establishing a conservative result and thereby providing confidence in the conclusions based on the model results. The staff concluded, however, that the groundwater elevations predicted by the model are strongly dependent on the characteristics of the model drain cells that represent the site surface water drainage system surrounding the power block. Because the observed groundwater heads at well OW-901 have been less than 0.61 m (2.0 ft.) below the design grade elevation, the staff concluded that meeting the DCD requirement on maximum groundwater level depends on the ability of the surface water drainage system to act as a groundwater drain.

The staff requested additional information to resolve this issue in **RAI 2.4.12-2** to support the applicant's conclusion that the groundwater elevations in the power block area will meet the maximum groundwater level requirement of the DCD over the life of the facility. Specific information requested by the staff include (1) model sensitivity studies that demonstrate the impact on groundwater elevations of the drain cell characteristics such as drain elevations, drain conductance, and local recharge rates; (2) additional evidence that the surface water drainage system will behave as a groundwater drain (as predicted by the groundwater model) over the life of the facility, such as additional details of the surface water drainage system design and maintenance; and (3) operational groundwater monitoring data to evaluate groundwater elevations in the power block area.

This **RAI (2.4.12-2)** was sent to the applicant on March 26, 2009, as part of RAI Letter Number 34. The applicant responded to this RAI on June 17, 2009, in RAI Letter Number 34. The staff is currently reviewing the RAI response. This RAI is being tracked as **Open Item 2.4.12-2**.

Regarding seismic effects, SRP Section 2.4.12 states that seismic criteria should be evaluated to determine whether they should be used in postulating worst-case groundwater effects at a site. In FSAR Section 2.5, the applicant submitted information on seismic risks and the potential effects of earthquakes on structures and foundations. Also in Section 2.5, the applicant discussed groundwater conditions in relation to construction and foundation stability (see Section 2.5.4.6).

The applicant did not submit specific information on potential effects of seismic and nonseismic causes on worst-case groundwater conditions. The staff considered the probability that seismic events could significantly raise groundwater levels. The staff does not believe that any plausible scenarios present conditions in which seismic events could have significant effects on groundwater levels or supplies at this site.

2.4.12.5 *Post Combined License Activities*

There are no post COL activities related to this subsection.

2.4.12.6 *Conclusion*

NRC staff reviewed the application and checked the referenced ESP SSAR and staff's SER. The staff's review confirmed that the applicant has addressed the relevant information. As stated above, **Open Item 2.4.12-2** requires additional evidence supporting the applicant's conclusion that the groundwater elevations in the power block area will meet the maximum groundwater level requirement of the DCD over the life of the facility. The staff's review of FSAR Section 2.4.12 will be complete after this Open Item has been resolved.

2.4.13 GoundwaterAccidental Release of Radioactive Liquid Effluent in Ground and Surface Waters

2.4.13.1 *Introduction*

This section considers the potential effects of relatively large accidental releases from systems that handle liquid effluents generated during normal plant operations. Such releases would have relatively low levels of radioactivity, but could be large in volume. Normal and accidental releases are also considered in the applicant's environmental report.

The accidental release of radioactive liquid effluents in ground and surface waters is evaluated based on the hydrogeological characteristics of the site that govern existing uses of groundwater and surface water and their known and likely future uses. The source term from a postulated accidental release is reviewed under SRP 11.2 following the guidance in Branch Technical Position (BTP) 11-6, "Postulated Radioactive Releases Due to Liquid-containing Tank Failures." The source term is determined from a postulated release from a single tank outside of the containment.

The specific areas of review are (1) alternate conceptual models of the hydrology at the site that reasonably bound hydrogeological conditions at the site inasmuch as these conditions affect the transport of radioactive liquid effluent in the ground and surface water environment; (2) bounding set of plausible surface and subsurface pathways from potential points of an accidental release to determine the critical pathways that may result in the most severe impact on existing uses and known and likely future uses of ground and surface water resources in the vicinity of the site; (3) ability of the groundwater and surface water environments to delay, disperse, dilute, or concentrate accidentally released radioactive liquid effluent during its transport; (4) assessment of scenarios wherein an accidental release of radioactive effluents is combined with potential effects of seismic and nonseismic events (e.g., assessing effects of hydraulic structures located upstream and downstream of the plant in the event of structural or operational failures and the ensuing sudden changes in the regime of flow); and (5) any additional information requirements prescribed in the "Contents of Application" sections of the applicable subparts to 10 CFR Part 52.

2.4.13.2 *Summary of Application*

This section of the COL FSAR addresses the accidental release of radioactive liquid effluents in ground and surface waters. The section focuses on the analysis of new COL-specific application materials in the following sources:

<u>*COL Item*</u>

- NAPS COL 2.0-24-A — Accidental Releases of Liquid Effluents in Ground and Surface waters

The applicant incorporated by reference ESP SSAR Subsection 2.4.13 to address DCD COL Item 2.0-24-A. The applicant provided updated site specific information to supplement ESP SSAR Subsections 2.4.13.1, "Groundwater," and 2.4.13.2, "Surface Water."

- ESP Permit Condition 3.E(3) — Features to Preclude Radioactive Releases into any Potential Liquid Pathway

The applicant provided updated site specific information to supplement ESP SSAR Subsections 2.4.13 in order to address ESP permit condition 3.E(3). The applicant indicated that below-grade compartments containing tanks with high level liquid radwaste are steel lined and are capable of containing a release of liquid from the tank within the compartment. The basin surrounding the above-grade condensate storage tank is designed to prevent uncontrolled runoff in the event of a tank failure.

<u>*Variance*</u>

- NAPS ESP VAR 2.0-5 — Distribution Coefficient (K_d)

The applicant requested VAR 2.0-5 to use the distribution coefficients provided in FSAR Table 2.4-208 rather than the corresponding values in ESP SSAR Tables 1.9-1 and 2.4-20. The values in the COL FSAR are smaller than those used in the ESP SSAR.

2.4.13.3 *Regulatory Basis*

The regulatory basis of the information incorporated by reference is addressed in the SER of the North Anna ESP (NUREG-1835).

2.4.13.4 *Technical Evaluation*

NRC staff reviewed the resolution to the COL specific items related to the accidental release of radioactive liquid effluents in ground and surface waters included under Section 2.4.13 of the North Anna 3 COL application and in the ESP SSAR. The staff's review confirmed that the information in the application and incorporated by reference addresses the relevant information related to this subsection.

The staff's technical review of this application is limited to the supplemental information pertaining to NAPS COL 2.0-24-A, and ESP Permit Condition 3.E(3), as addressed in the following sections. Also discussed within this context are three requests for additional information: RAIs 2.4.13-1, 2.4.13-2, and 2.4.13-3; one variance, NAPS VAR 2.0-5; and **Open Item 2.4.13-1**.

For release to groundwater, one of the equipment drain collection tanks was selected as the source. Source term inventory was taken from DCD Revision 4, Table 12.2-13a. Radionuclide source concentrations and modeled concentrations in groundwater are in FSAR Table 2.4-206.

For the release to surface water, the condensate storage tank was selected as the source because it is the only above-grade tank containing radioactivity outside of containment. Source term inventory was taken from DCD Table 12.2-13a, "Liquid Waste Management System Equipment Drain Collection Tank Activity," with radionuclide source concentrations and modeled surface water concentrations in FSAR Table 2.4-212.

Applicable to both release scenarios, the applicant lists design features of the facility intended to preclude liquid releases, stating that the release scenarios are extremely conservative as a result.

In order to improve readability, the staff's discussion of groundwater characteristics is organized into the following technical areas. Variances and open items are described where appropriate within these areas.

2.4.13.4.1 Groundwater Releases

Information Submitted by Applicant The equipment drain collection tank selected as the source is located at a floor elevation of 74.37 meters (244 feet) msl and has a volume of 140 cubic meters (m^3). The tank is postulated to instantaneously release 80 percent of its volume (112 m^3) to the unconfined aquifer. The applicant noted that the floor elevation of the source tank is below the ambient groundwater heads at the location of the source tank, providing an additional level of conservatism in the release scenario.

Based on observed groundwater head contour maps, the flow pathway is determined to be north-northeast toward the cove used for the Unit 3 intake in Lake Anna. A straight-line path between the radwaste building and the cove is assumed, i.e., a distance of 305 meters (1,000 feet). The applicant stated that the existing groundwater supply well in the power block area will be closed before Unit 3 construction, and as a result, groundwater from the postulated release will discharge to the Lake Anna cove that constitutes the Unit 3 water supply intake. Some of this discharge may be temporarily recirculated to the plant before reaching the release point.

The applicant described a scenario in which the groundwater discharged to Lake Anna is diluted with lake water before being pumped back into the Unit 3 facility as makeup water, entering the circulating water and service water cooling systems, or the potable, demineralized, and fire protection systems. Radionuclides are either volatilized or concentrated in the circulating system and are discharged with cooling tower blowdown to the discharge canal, mixing there with the circulating water from Units 1 and 2. The end of the discharge canal is taken as the release point to unrestricted areas for compliance with the 10 CFR Part 20, Appendix B, Table 2 radionuclide concentration limits.

The applicant's groundwater radionuclide transport analysis is based on a method of characteristics solution to the one-dimensional advection-dispersion equation with first-order decay and linear equilibrium adsorption. Dispersion was neglected in deriving the analytical solutions for parent and progeny radionuclides. The analysis was conducted using three stages of progressive refinement. At the first two stages, only radionuclides whose concentrations were greater than 0.01 times the applicable concentration limit were considered in the following stage.

The first stage of analysis considered radioactive decay only, and computed radionuclide concentrations at the groundwater discharge location. A groundwater travel time of 5.03 years was computed using a hydraulic conductivity of 1.04 meters per day, a hydraulic gradient of 0.04, and an effective porosity of 0.25. The 14 radionuclides for which the resulting concentration was greater than 0.01 times the 10 CFR Part 20, Appendix B, Table 2 value were included in the next stage of the analysis.

The second stage of the applicant's analysis included the effect of radionuclide decay and adsorption in computing radionuclide concentrations at the groundwater discharge location. Distribution coefficients for this analysis were based on NUREG/CR-6697, Attachment C, Table 3.9-1 (Yu et al., 2000), assuming lognormal distributions and selecting the 10th percentile as a conservative value. Site specific distribution coefficient values were obtained in the laboratory using soil samples from 12 borings and water from the unconfined aquifer. Although the minimum observed value was less than the literature-derived value for five out of the eleven radionuclides analyzed, the applicant concluded that the literature-derived values were conservative. Retardation factors were computed using an effective porosity of 0.25 and a bulk density of 1.83 gram per cubic centimeters (g/cm^3), (based on an assumed particle specific gravity of 2.65 g/cm^3 and a total porosity of 0.31). Again, radionuclides for which the resulting concentration was greater than 0.01 times the 10 CFR Part 20, Appendix B, Table 2 value were included in the next stage of the analysis.

The approach to selecting distribution coefficients described in the previous paragraph represents a variance from the distribution coefficients described in the ESP SSAR. The applicant formally states this variance in the COL Application Departures Report as NAPS ESP Var 2.0-5. The values reported in ESP SSAR Table 2.4.20 were based on Sheppard and Thibault (1990) and the U.S. Environmental Protection Agency (1999). The values used in the FSAR (Table 2.4-208) were based on NUREG/CR-6697 (Yu et al., 2000). The applicant justifies the use of the FSAR Table 2.4-208 distribution coefficient values because they are all smaller, and thus more conservative, than the corresponding values used in the ESP SSAR, and compliance with the 10 CFR Part 20, Appendix B, Table 2 concentration limits is demonstrated using the FSAR distribution coefficient values in the FSAR Section 2.4.13 analysis of groundwater release. An evaluation of the distribution coefficients from the ESP SSAR and the FSAR is also in FSAR Table 2.0-201, "Evaluation of Site/Design Parameters and Characteristics."

The third stage of the applicant's analysis included the effect of decay, adsorption, and dilution of groundwater discharged to Lake Anna by the water supply requirements of Unit 3 when running in the maximum water conservation mode (0.96 m^3/s). Radionuclide flux to Lake Anna was computed using a discharge area equal to the product of the width of the radwaste building normal to groundwater flow (65 meters) and an assumed aquifer saturated thickness of 7.92 meters. A concentration factor of four was applied to determine the radionuclide concentrations at the point of entry to the discharge canal. All radionuclide concentrations were less than the concentration limits in 10 CFR Part 20, Appendix B, Table 2. In addition, the "sum of fractions approach" described in 10 CFR Part 20 was evaluated using the minimum concentration resulting from the application of the three stages. The applicant concluded that the 10 CFR Part 20 requirements were satisfied. The discharge of tritium as water vapor from the evaporation of Unit 3 cooling water was determined to be less than an air pathway tritium concentration evaluated in the ESP FEIS Appendix H.3 and found to be insignificant.

Technical Evaluation by Staff The staff reviewed the accidental release scenario verifying that the source tank selected was the most conservative source with respect to volume and activity.

The release scenario is conservative because it assumes that 80 percent of the tank volume is instantaneously transmitted into the aquifer. The applicant did not specify whether the source tank would contain chelating agents that might affect transport. In response to **RAI 2.4.13-1**, the applicant stated that there is no plan to use chelating agents based on (1) the ESBWR standard design does not require the use of chelating agents, and (2) chelating agents are not currently used at two other operating plants (Surry and North Anna) (Applicant's Letter No. 026, dated October 2, 2008).

The applicant assumed that there were no differences in the flow and transport characteristics between the saprolite and the shallow bedrock. This assumption is consistent with the hydrogeological conceptual model in FSAR Section 2.4.12.

The applicant used literature-based values for the adsorption (distribution) coefficients (K_d) for the transport analysis. The applicant also made laboratory measurements of K_d values on 20 soil and weathered rock samples. Laboratory K_d values were highly variable with ranges between one and four orders of magnitude for individual radionuclides. For some radionuclides, the minimum laboratory value was less than the literature-based value used in the transport analysis. In **RAI 2.4.13-2**, the staff requested that the applicant provide the technical basis for concluding that using literature-derived K_d values in the transport analysis that were larger than site specific observed minimum values is a conservative approach. The applicant responded with a qualitative argument that using minimum observed K_d would not cause the 10 CFR Part 20, Appendix B, Table 2 effluent concentration limits to be exceeded (Letter No. 026, dated October 2, 2008). The staff concluded that the analysis using literature-derived K_d values is not demonstrably conservative without an analysis of results using minimum, site specific measured values. Additional information was requested of the applicant on this issue as part of **RAI 2.4.13-4**, discussed later in this section.

At the site audit, the staff reviewed a report documenting the laboratory measurements of K_d for the transport analysis. Measurements were conducted on the less than 2 millimeter-size fraction of the samples, with the fraction greater than 2 millimeters reported as zero for most of the samples. Given the reported presence of rock fragments in the saprolite and their potential effect on radionuclide adsorption, the staff requested information on the technical basis for neglecting this effect in a conservative analysis (**RAI 2.4.13-2**). The staff also noted that a wide range of pH values was measured in the soil samples used in the K_d measurements and that there was an apparent relationship between the measured K_d values and the measured pH values. The staff also requested information on the technical basis for neglecting this effect in a conservative analysis (**RAI 2.4.13-2**). In response to both of these issues (Letter No. 026, dated October 2, 2008), the applicant argued that the use of the relatively small 10^{th} percentile K_d values (from the literature-based distributions) implicitly considers the effects of rock fragments and pH, both of which could act to reduce K_d values. Given the wide range of measured K_d values and the lack of a plausible low-pH pathway, the staff concludes that the use of minimum K_d values is demonstrably conservative with respect to the effect of the pH on adsorption. Although a pathway containing significant gravel is plausible (e.g., the Zone IIb/III pathway in FSAR Figure 2.4-217), the impact of gravel on K_d would be small compared to the wide range of K_d values observed. The staff therefore concluded that a transport analysis using minimum, site specific measured K_d values would be demonstrably conservative.

The groundwater transport analysis in FSAR Section 2.4.13 uses a hydraulic conductivity value (1.04 meters per day) that is less than the maximum observed value (3.017 meters per day) from the site slug tests. This analysis also describes a single transport pathway. In **RAI 2.4.13-3,** the staff requested technical justification for the hydraulic conductivity value used, a discussion of the alternative groundwater transport pathways considered, and a technical justification for the selected pathway considered to be conservative. In addition, the staff requested a discussion of the consistency between the MODFLOW model results for post-construction groundwater heads in FSAR Section 2.4.12 and the groundwater transport analysis of FSAR Section 2.4.13, especially with respect to the conservativeness of the transport analysis and consistency of the transport pathway.

The applicant responded (Letter No. 026, dated October 2, 2008) to the request for technical justification of the hydraulic conductivity value used in the transport analysis by noting that the only slug test results that were greater than 1.04 m/d were obtained upgradient of the reactor building (wells OW-945 and OW-946), and that the calibrated hydraulic conductivity values of the MODFLOW model used in FSAR Section 2.4.12 were less than 1.04 m/d. The staff noted, however, that there is no suggestion in FSAR Section 2.4.12 that the region around OW-945 and OW-946 should be considered to have a high hydraulic conductivity. While two hydraulic conductivity zones were used in the MODFLOW model, the accidental release transport pathway is located within the higher conductivity zone. The staff also noted that the calibrated conductivities are not intended to represent conservative values. The staff concluded that the use of a hydraulic conductivity in the transport analysis of FSAR Section 2.4.13, other than the maximum observed value, is not demonstrably conservative. Additional information was requested from the applicant on this issue as part of **RAI 2.4.13-4**.

As currently presented in FSAR Section 2.4.13, the groundwater transport analysis has not been shown to be conservative with respect to two factors. The transport analysis uses K_d values based on literature data that, in some cases, are greater than the minimum observed site specific values. This issue was raised in **RAI 2.4.13-2** but has not been resolved. In addition, the transport analysis uses a groundwater hydraulic conductivity (to compute groundwater velocity) that is less than the maximum value observed at the site. This issue was raised in **RAI 2.4.13-3** but has also not been resolved. As a follow-on to these two issues, in **RAI 2.4.13-4** the staff requested the results of a transport analysis that uses the maximum observed hydraulic conductivity and the minimum site specific K_d values for comparison with the 10 CFR Part 20, Appendix B, Table 2 effluent concentration limits. This information should be reflected in the FSAR to demonstrate a bounding analysis.

This **RAI 2.4.13-4** was sent to the applicant on March 26, 2009, as part of RAI Letter Number 34. The staff has not yet received a response to this RAI. This is being tracked as **Open Item 2.4.13-4**.

The staff reviewed the applicant’s approach to computing the limiting value of the radionuclide mixture as described in 10 CFR Part 20, Appendix B, Table 2 (Note 4). The staff determined that the applicant’s approach computes the required sum without regard to the time of arrival of each radionuclide at the accessible environment, thereby maximizing the value of the sum. The staff therefore concluded that the applicant’s approach is conservative.

The applicant responded to **RAI 2.4.13-3** on alternative transport pathways by identifying five alternatives that could be considered. As described by the applicant, these pathways are:

a. Flow north-northeast in the saprolite to the Unit 3 intake forebay (the selected pathway)
b. Flow northeast in the saprolite to the Units 1 and 2 intake bay
c. Flow southeast in the saprolite to the discharge canal
d. Flow north in the saprolite to Lake Anna
e. Flow in fractured bedrock to the Unit 3 intake forebay.

The applicant concluded that, compared to the selected pathway, the other saprolite pathways are longer and less plausible when evaluated against the observed groundwater heads and the post-construction MODFLOW model results. The applicant stated that the selected pathway is more conservative than the bedrock pathway, because the hydraulic conductivity in the bedrock generally decreases with depth due to a decrease in the number and extent of fractures. The staff noted that effective porosity is also expected to decrease with depth, which would tend to increase groundwater velocity. The limited slug and pressure test data for the shallow bedrock suggests that the hydraulic conductivity is comparable to the saprolite. There is no site specific information on which to base an effective porosity estimate for the shallow bedrock. The staff concluded that it is appropriate to base a conservative transport analysis on the site specific properties of the saprolite.

The staff requested additional information in **RAI 2.4.13-3** about the consistency between the MODFLOW model used to model groundwater levels in FSAR Section 2.4.12 and the contaminant transport model. The issue was that these two models used different values of hydraulic conductivity. The applicant provided a comparison between the values of hydraulic conductivity used in the two models (Letter No. 026, dated October 2, 2008). The applicant also provided a comparison between the groundwater travel times calculated using the different values of hydraulic conductivity. The staff reviewed these calculations and concluded that the applicant's contaminant transport model is not consistent with the MODFLOW model because it uses larger, more conservative values of hydraulic conductivity. The staff concluded that using conservative values in transport modeling is appropriate because it is desirable to calculate groundwater travel times in a conservative manner. It is not necessary for the transport model and the MODFLOW groundwater level model to use the same values of hydraulic conductivity, because their purposes are different.

2.4.13.4.2 Surface Releases

The condensate storage tank is postulated by the applicant to instantaneously release 80 percent of its volume (3,908 m^3) to an empty Stormwater Retention Pond 1, which discharges to Lake Anna near the Unit 3 intake at a flowrate of 0.017 cubic meters per second (m^3/s). When Unit 3 is operating, the pond discharge is assumed to be entrained in and diluted by the makeup water flow required by Unit 3 in the maximum water conservation mode and by the discharge from Units 1 and 2. When Unit 3 is shut down and Units 1 and 2 are operating, the pond discharge is assumed to be entrained in and diluted by the Units 1 and 2 circulating water. When all three units are shut down, dilution occurs in a minimal amount of water (15 m^3/s) circulated in Units 1 and 2 to dilute normal plant releases. The resulting radionuclide concentrations were determined to be less than the 10 CFR Part 20, Appendix B, Table 2 effluent concentration limits to satisfy the "sum of fractions" requirement.

2.4.13.4.3 Preclusion of Accidental Releases of Liquid Effluents

ESP Permit Condition 3.E(3) required the applicant to include features "to preclude accidental releases of radionuclides into potential liquid pathways." The purpose of this condition is to help assure that the risk of liquid radionuclide releases is minimized by providing an additional layer of protection against releases into the environment.

The staff determined that the features described below are adequate to satisfy ESP Permit Condition 3.E(3). Therefore, no further action is required for this permit condition. As with other plant design features, other forms of inspection and monitoring will be conducted during construction to assure that the design features described in the applicant's response to this permit condition are installed as described.

The design features corresponding to the permit condition include:

1. Below-grade tanks containing radioactivity are located in the radwaste building, which is designed to seismic requirements as specified in DCD Table 3.2-1. Compartments containing high-level liquid radwaste are steel lined to a height capable of containing the release of all liquid radwaste. Releases as a result of major cracks in the tanks result in the release of the liquid radwaste to the compartment and then to the building sump system for containment in other tanks or emergency tanks.

2. The only above-grade tank containing radioactivity outside of the containment is the condensate storage tank. The basin surrounding this tank is sized to contain the total tank capacity, a design intended to prevent uncontrolled runoff in the event of a tank failure and to collect tank overflow. A sump located inside the retention basin has provisions for sampling collected liquids before routing them to the liquid waste management system or the storm sewer per sampling and release requirements.

2.4.13.5 *Post Combined License Activities*

There are no post COL activities related to this subsection.

2.4.13.6 *Conclusion*

NRC staff reviewed the application and checked the referenced ESP SSAR and staff's SER. The staff's review confirmed that the applicant has addressed the relevant information.

The staff specified **Open Item 2.4.13-4,** regarding the results of a transport analysis that uses the maximum observed hydraulic conductivity and the minimum site specific K_d values for comparison with the 10 CFR Part 20, Appendix B, Table 2 effluent concentration limits. The staff outlined additional information that needs to be reflected in sections of the FSAR, as appropriate. The staff's review of FSAR Section 2.4.13 will be complete after this open item has been resolved.

2.4.14 Technical Specification and Emergency Operation Requirements

2.4.14.1 *Introduction*

The technical specifications and emergency operation requirements described here implement protection against floods for safety-related facilities to ensure that an adequate supply of water for shutdown and cool-down purposes is available. The specific areas of review are (1) controlling hydrological events, as determined in previous hydrology sections of the SAR, to identify bases for emergency actions required during these events; (2) the amount of time available to initiate and complete emergency procedures before the onset of conditions while controlling hydrological events that may prevent such action; (3) reviewing technical specifications related to all emergency procedures required to ensure adequate plant safety from controlling hydrological events by the organization responsible for the review of issues related to technical specifications; (4) potential effects of seismic and nonseismic information on the postulated technical specifications and emergency operations for the proposed plant site;

and (5) any additional information requirements prescribed in the "Contents of Application" sections of the applicable subparts to 10 CFR Part 52.

2.4.14.2 *Summary of Application*

This section of the COL FSAR addresses technical specifications and emergency operation requirements. The applicant addressed the information as follows:

<u>*COL Items*</u>

- NAPS COL 2.0-25-A — Technical Specifications and Emergency Operation Requirements

The applicant provided Subsection 2.4.14 in the COL FSAR to address DCD COL Item 2.0-25-A and referenced Subsections 2.4.2 and 2.4.12 of the COL FSAR regarding design basis floods and maximum groundwater elevation and their impacts on safety-related SSCs. The applicant concluded that the combination of the DCD design and the plant grade elevation do not necessitate emergency procedures or technical specifications to prevent hydrological phenomena from degrading the UHS.

- NAPS ESP COL 2.4-2 — Shut Down Water Level

The applicant provided site specific information in Subsection 2.4.14 to address ESP Action Item 2.4-2. The applicant stated that Unit 3 will be shut down when the water level in Lake Anna drops below the elevation of 242.0 ft msl. The applicant added that this operational restriction is not related to the protection of safety-related SSCs or degradation of the UHS. This operational restriction is therefore not a technical specification limiting condition for operation (LCO).

2.4.14.3 *Regulatory Basis*

Guidance relevant to the Commission's regulations for the technical specifications and emergency operation requirements, and the associated acceptance criteria, are in Section 2.4.14 of NUREG-0800. The applicable regulatory requirements for reviewing the applicant's discussion of technical specifications and emergency operation requirements are 10 CFR Part 100, 10 CFR 100.23 (d), 10 CFR 52.79(a)(1)(iii), and 10 CFR 50.36; and RGs 1.29, 1.59, and 1.102.

2.4.14.4 *Technical Evaluation*

The NRC staff reviewed Subsection 2.4.14 of the North Anna 3 COL FSAR and checked the referenced DCD to ensure that the combination of DCD site parameters, ESP site characteristics, and the information in the applicant's COL represent the complete scope of information relating to this review topic.

The staff reviewed the following information contained in COL FSAR Section 2.4.14:

COL Items

- NAPS COL 2.0-25-A Technical Specifications and Emergency Operation Requirements

The NRC staff reviewed the resolution to DCD COL Item 2.0-25-A, related to the technical specifications and emergency operation requirements that implement protection against floods for safety-related facilities to ensure that an adequate supply of water for shutdown and cool-down purposes is available. Based on the DCD design and the applicant's selection of design basis plant grade, no emergency procedures or technical specifications are necessary to prevent hydrological phenomena from degrading the UHS

- NAPS ESP COL 2.4-2 Shut Down Water Level

Appendix A of the North Anna ESP specifies that the minimum lake water level for operation of the NAPS Units 1, 2, and 3 is elevation 242 ft msl. The applicant commited to shut down the Unit 3 when the water level in Lake Anna drops below elevation 242 ft msl in FSAR Section 2.4.14. Because of the UHS design, this operational restriction is not related to protection of safety-related SSCs or degradation of the UHS.

2.4.14.5 *Post Combined License Activities*

There are no post COL activities related to this subsection.

2.4.14.6 *Conclusion*

The NRC staff reviewed the application and checked the referenced DCD. The review confirmed that no emergency procedures or technical specifications are necessary to prevent hydrological phenomena from degrading the UHS. No outstanding information is expected to be addressed in the FSAR related to this section. Therefore, staff conclude that the requirments of 10 CFR 50.36 and 10 CFR 100.20(c) have been met with respect to determining the acceptability of the site for the ESBWR design.

2.5 Geology, Seismology, and Geotechnical Engineering

In Section 2.5, "Geology, Seismology, and Geotechnical Engineering," of the North Anna Unit 3 FSAR, the applicant described the geologic, seismic, and geotechnical engineering properties of the North Anna 3 COL application site. FSAR Section 2.5.1, "Basic Geologic and Seismic Information," presents information on geologic and seismic characteristics of the COL site and region surrounding the site. FSAR Section 2.5.2, "Vibratory Ground Motion," describes the vibratory ground motion assessment for the COL site through a Probabilistic Seismic Hazard Analysis (PSHA) and develops the Safe Shutdown Earthquake (SSE) ground motion. FSAR Section 2.5.3, "Surface Faulting," evaluates the potential for surface tectonic and non-tectonic deformation at the COL site. FSAR Sections 2.5.4, "Stability of Subsurface Materials and Foundations," and 2.5.5, "Stability of Slopes," describe foundation and subsurface material stability at the COL site. FSAR Section 2.5.6, "Embankments and Dams," describes the embankments and dams in the site area.

The FSAR incorporates by reference the information contained in Revision 9 of the ESP SSAR of the ESP and ESBWR DCD Revision 5; and adds new information to address DCD and ESP COL items, to satisfy ESP permit conditions, and to resolve variances from the ESP. The applicant defined three zones around the site: the region within 320 km (200 miles), a vicinity within 40 km (25 miles), and an area within 8 km (5 miles). The COL site is in the area within 1 km (0.6 mile) of the site location adjacent to NAPS Units 1 and 2, abandoned foundation mats for Units 3 and 4, and the independent spent fuel storage installation (ISFSI).

This SER was compiled by NRC staff and is divided into six main sections (2.5.1 to 2.5.6), which parallel the six main sections included in the applicant's FSAR. Each of the six SER sections is then divided into six subsections: (1) "Introduction/Overview/General" provides a brief description of the contents of each main FSAR section; (2) "Technical Information in the Application" describes the technical content of the FSAR, the investigations performed by the applicant, and the results; (3) "Regulatory Basis" summarizes the regulations and NRC RGs used by the applicant to formulate the FSAR; (4) "Technical Evaluation" describes the staff's evaluation of what the applicant did, including any RAIs, open items, and confirmatory analyses performed by the NRC staff; (5) "Post Combined License Activities"; and (6) "Conclusions." This last section provides the staff's conclusions and documents whether the applicant provided a thorough characterization for the site, and whether the results described in the FSAR provide an adequate basis for the applicant's conclusions.

2.5.1 Basic Geologic and Seismic Information

2.5.1.1 *Introduction*

Section 2.5.1 of this SER provides the basic geologic and seismic information related to the North Anna Unit 3 site. Section 2.5.1.2 of this SER summarizes the relevant geologic and seismic information in FSAR Section 2.5.1 of the North Anna COL application. SER Section 2.5.1.3 summarizes the regulations and guidance used by the applicant to perform the investigation. SER Section 2.5.1.4 reviews the staff's evaluation of FSAR Section 2.5.1, including any requests for additional information, open items, and confirmatory analyses performed by the staff. SER Section 2.5.1.5 discusses any post combined license activities. Finally, SER Section 2.5.1.6 provides an overall summary of the applicant's conclusions, as well as the staff's conclusions; restates any bases covered in the application; and confirms that regulations were met or fulfilled by the applicant.

2.5.1.2 *Summary of Application*

Section 2.5.1 of the North Anna 3 COL FSAR incorporates by reference Section 2.5.1 of the ESP SSAR, Revision 9. In addition, in FSAR Section 2.5.1, the applicant provided supplemental information to address the geologic and geotechnical data collected as part of the additional Unit 3 site borings. This information included additional descriptions of the Ta River Metamorphic Suite and the saprolite and artificial material encountered in the site subsurface. The applicant also supplied additional details on the engineering geology of the soil and rock at the site. Finally, the applicant provided information to satisfy permit conditions 5 through 7 from the North Anna ESP.

This COL FSAR section also addresses COL Item 2.0-26-A from Revision 5 to the ESBWR DCD; ESP COL Action Item 2.5-1; and permit conditions identified in the North Anna ESP SER (NUREG-1835) and summarized in Part 3, Section E of the North Anna ESP (ML073330302).

COL Items

- NAPS COL 2.0-26-A

NAPS COL 2.0-26-A addresses the provisions of Table 2.0-1 of the ESBWR DCD, relating to the site specific geologic and seismic information to be provided.

- NAPS ESP COL 2.5-1

NAPS ESP COL 2.5-1 states that additional borings are needed to identify any weathered or fractured rock beneath the new foundations.

- ESP Permit Conditions 3.E(4) through 3.E(6)

The applicant provided supplemental information to address Permit Conditions 3.E(4) through 3.E(6). Permit Condition 3.E(4) requires the replacement of weathered and fractured rock at the foundation level with lean concrete before the initiation of foundation construction. Permit Condition 3.E(5) prohibits the applicant from using engineered fill with high compressibility and low maximum density, such as saprolite, in the construction of Unit 3. Permit Condition 3.E(6) requires the applicant to provide geologic mapping information for future excavations of safety-related structures and to evaluate unforeseen geologic features that are encountered.

- ESP VAR 2.5-2 and 2.0-7

ESP VAR 2.5-2 requests that saprolite be considered suitable fill material so long as the engineered backfill required by Permit Condition 3.E(5) and described in FSAR Section 2.5.4 is met.

ESP VAR 2.0-7 revises the site coordinates from those presented in the ESP to those in FSAR Figure 2.0.205. This variance states that due to the selection of the ESBWR reactor design and the resulting footprint of the safety-related and seismic Category I and II structures at the site, the basemats of abandoned Units 3 and 4 do not need to be removed because they are outside the footprint of the safety-related structures for Unit 3. Therefore, leaving the basemats in place will not adversely affect the safe operation of Unit 3.

2.5.1.3 *Regulatory Basis*

The regulatory basis for incorporating information by reference to the ESP SSAR is 10 CFR 52.79(b), which states (in part) that if a COL application references an ESP, then the FSAR need not contain information or analyses submitted to the Commission in connection with the ESP, provided that the FSAR must either include or incorporate by reference the ESP SSAR and must contain, in addition to the information and analyses otherwise required, information sufficient to demonstrate that the design of the facility falls within the site characteristics and design parameters specified in the ESP. Full descriptions of the applicable regulatory and acceptance criteria, and related NRC guidance, are provided in SRP Section 2.5.1 (NUREG-0800).

The regulatory basis of the information incorporated by reference is addressed in the SER related to the North Anna ESP (NUREG-1835).

2.5.1.4 *Technical Evaluation*

The applicant incorporated by reference Section 2.5.1 of the ESP SSAR, Revision 9. The staff's technical evaluation of Section 2.5.1 of the ESP SSAR is documented in NUREG-1835.

The staff reviewed Subsection 2.5.1 of the North Anna 3 COL FSAR and checked the referenced ESP SSAR. The staff's review confirmed that the information contained in the application and incorporated by reference addresses the relevant information related to this section.

The staff's technical evaluation of this application is limited to reviewing (1) the resolution of DCD COL Item 2.0-26-A and ESP Action Item 2.5-1, (2) adherence to Permit Conditions 5 through 7and (3) ESP variances, as addressed below:

<u>*COL Items*</u>

- NAPS COL 2.0-26-A

In accordance with DCD COL Item 2.0-26-A, the applicant provided additional information on the site area stratigraphy, engineering geology evaluation, and groundwater conditions as determined from additional subsurface investigations conducted at the Unit 3 site. This new information presented by the applicant supplements the information in the ESP SSAR and includes additional information and data obtained through the COL site investigations. The staff concluded that the applicant has included sufficient information from subsurface investigations to supplement ESP SSAR Section 2.5.1 and to resolve DCD COL Item 2.0-26-A.

- NAPS ESP COL 2.5-1

ESP COL Action Item 2.5-1 requires the applicant referencing the North Anna 3 ESP to provide additional boring data to identify any weathered or fractured rock that may be beneath the new foundations. In FSAR Section 2.5.1.2.3, the applicant stated that the borings completed for Unit 3, the logs of which are included in Appendix 2.5.4AA of the FSAR, encountered weathered rock from the elevation of 62.7 to 86.8 meters (206 to 285 feet) and again from 56.9 to 89.0 meters (187 to 292 feet) and from 53.0 to 84.7 meters (174 to 278 feet). The elevations corresponded to moderately to highly weathered Zone III rock, slightly to moderately weathered Zone III-IV rock, and slightly weathered to fresh Zone IV rock, respectively. Because the applicant has identified the subsurface elevations where weathered rock occurs beneath the foundations, the staff concluded that this information is sufficient to satisfy the requirements of ESP COL Action Item 2.5-1. Therefore, the staff considers ESP Action Item 2.5-1 to be resolved.

- ESP Permit Conditions 3.E(4) through 3.E(6) and VAR 2.5-2

Three permit conditions were identified in the ESP SER and summarized in Section E to Part 3 of the ESP. Permit Condition 3.E(4) requires the replacement of weathered and fractured rock at the foundation level with lean concrete before the initiation of foundation construction. The applicant stated in FSAR Section 2.5.1.2.6 that weathered or fractured rock encountered at the site will be excavated and replaced with lean concrete. The staff concluded that this commitment, in addition to the excavation plans summarized in SER Section 2.5.4.2.10, is acceptable and meets the criteria in Permit Condition 3.E(4).

Permit Condition 3.E(5) prohibits the applicant from using engineered fill with high compressibility and low maximum density, such as saprolite, in the construction of Unit 3. FSAR Section 2.5.1.2.3 states that "engineered fill…such as saprolite, will not be used as engineered fill to support or backfill seismic Category I or II structures." The staff reviewed additional excavation and backfill plans in FSAR Section 2.5.4 and determined that the plans do not include the use of high compressibility and low maximum density materials such as engineered fill to support any seismic Category I or II structures. However, the applicant has requested a variance from this permit condition to use some saprolite material that does not have high compressibility and low maximum density.

In VAR 2.5-2, the applicant requested that some of the Zone IIB saprolite be considered appropriate for use as fill material because it meets the criteria for engineered fill laid out in FSAR Section 2.54. This variance clarifies the language of Permit Condition 3.E(5) to allow the use of saprolite that does not have high compressibility and a low maximum density. The applicant stated that the saprolite material proposed for use would be a minor constituent of the engineered fill, which will primarily be composed of crushed rock. The staff reviewed this request, including the applicant's assessment of the suitability of the saprolite material for engineered fill, and concluded that the variance is acceptable because the proposed materials do not have either high compressibility or low maximum density. Furthermore, the acceptance of this variance, as well as the applicant's engineered fill plans described in FSAR Section 2.5.4, adequately addresses the requirements in Permit Condition 3.E(5).

Permit Condition 3.E(6) requires the applicant to provide geologic mapping information for future excavations of safety-related structures and to evaluate unforeseen geologic features that are encountered. The resolution of Permit Condition 3.E(6) is discussed in Subsection 2.5.4.4.5 of this SER.

- ESP VAR 2.0-7

ESP VAR 2.0-7 requests that the coordinates of the site as listed in the ESP be updated to reflect those in FSAR Figure 2.0-205. The variance also requests that the stipulation in the ESP requiring the complete removal of the basemats for abandoned Units 3 and 4 be waived, because the ESBWR design footprint results in no safety-related or seismic Category I or II structures being founded on or near the abandoned basemats. The staff considered the first part of this variance to be an administrative change of the coordinates and is therefore acceptable. The staff's evaluation of VAR 2.0-7 also considered the reactor footprint for the ESBWR design at the North Anna 3 site. Because the ESBWR footprint for safety-related or seismic Category I or II structures does not overlap with the abandoned basemats from Units 3 and 4, the staff concluded that leaving the abandoned basemats in place will not adversely affect the safety of any seismic Category I and 2 structures for NAPS Unit 3.

2.5.1.5 *Post Combined License Activities*

There are no post COL activities associated with this section.

2.5.1.6 *Conclusion*

NRC staff reviewed the application and checked the referenced ESP SSAR. The staff's review confirmed that the applicant has addressed the relevant information and there is no outstanding information expected to be addressed in the COL FSAR related to this subsection.

The staff concludes that the information pertaining to North Anna 3 COL FSAR Section 2.5.1 is within the scope of the ESP and adequately incorporates by reference Section 2.5.1 of the ESP SSAR and is thus acceptable. In addition, the staff compared the additional COL information in the application to the relevant NRC regulations and acceptance criteria defined in NUREG-0800, Section 2.5.1, and concludes that the applicant is in compliance with the relevant requirements of 10 CFR Parts 52 and 100. The staff also concludes that COL Action Item 2.0-26-A has been adequately addressed by the applicant and can be considered closed. The staff further concludes that the criteria in Permit Conditions 3.E(4) through (6) of the ESP have been met and that Variances 2.5-2 and 2.0-7 are acceptable.

On the basis of the foregoing, the staff concludes that the applicant has provided a thorough and accurate characterization of the geologic and seismic characteristics of the site as required by 10 CFR 52.17(a)(1)(vi), 10 CFR 100.23(c), and 10 CFR 100.23(d). Therefore, the staff concludes that the site is suitable with respect to the geologic and seismic siting criteria for new nuclear power plants.

2.5.2 Vibratory Ground Motion

2.5.2.1 *Introduction*

Section 2.5.2 of this SER provides information on the vibratory ground motion at the North Anna Unit 3 site. Section 2.5.2.2 of this SER provides a summary of relevant geologic and seismic information in FSAR Section 2.5.2 of the North Anna Unit 3 COL application. SER Section 2.5.2.3 summarizes the regulations and guidance used by the applicant to perform the investigation. SER Section 2.5.2.4 reviews the staff's evaluation of FSAR Section 2.5.2, including any RAIs, open items, and confirmatory analyses performed by the staff. SER Section 2.5.2.5 discusses post COL activities. Finally, SER Section 2.5.2.6 provides an overall summary of the applicant's conclusions, as well as the staff's conclusions, restates any bases covered in the application, and confirms that regulations have been met or fulfilled by the applicant.

2.5.2.2 *Summary of Application*

Section 2.5.2 of the North Anna 3 COL FSAR incorporates by reference Section 2.5.2 of the ESP SSAR, Revision 9. In addition, in FSAR Section 2.5.2, the applicant provided supplemental information on additional subsurface details discovered during the COL site investigations.

This COL FSAR section also addresses COL Item 2.0-27-A from Revision 5 of the ESBWR DCD as follows:

<u>*COL Item*</u>

- NAPS COL 2.0-27-A

NAPS COL 2.0-27-A addresses the information provided in accordance with SRP Section 2.5.2 and requires confirmatory information to ensure that the (RB and FB), control building, and fire water service complex foundation input response spectra (FIRS) are enveloped by the ESBWR certified seismic design response spectra (CSDRS) referenced at the foundation level.

ESP Variance

- NAPS ESP VAR 2.0-4

In NAPS ESP VAR 2.0-4, the applicant requested that the Unit 3 horizontal and vertical spectral acceleration (g) values for the site specific SSE at the top of competent rock (Zone III-IV), which the applicant re-evaluated for the COL, be used rather than the corresponding ESP values. After the staff issued the North Anna ESP, the staff updated its guidance and the site specific SSE is now referred to as the Ground Motion Response Spectra (GMRS), as defined in RG 1.208, “A Performance-Based Approach to Define the Site Specific Earthquake Ground Motion.”

In FSAR Section 2.5.2.5, the applicant described the additional data obtained through subsurface investigations at the site and the resulting change to the control point elevation at the Unit 3 site. The control point elevation is the elevation at which the GMRS is determined. The applicant changed the control point elevation from 76.2 meters (250 feet) to 83.2 m (273 feet) based on additional subsurface exploration data. This elevation is the top of competent rock (Zone III-IV). As a result of this change in the site subsurface profile, the applicant reanalyzed the site response analysis and developed a revised GMRS. In addition, the applicant developed FIRS at elevations of 73.5 meters (241 feet), 68.3 meters (224 feet), and 86.0 meters (282 feet) for the control building, RB and FB, and FWSC foundations, respectively.

FSAR Section 2.5.2.6.7 describes the method the applicant used to perform the site-response analyses to determine the GMRS and FIRS for the Unit 3 site. The applicant used the site shear wave velocities and related material properties, which are described in Section 2.5.4 of this SER. Using this profile, the applicant calculated the amplification of the ground motion by the subsurface material underlying the site up to the control point elevation. To incorporate the uncertainties in the subsurface material properties, the applicant developed a set of 60 randomized rock profiles and low- and high-frequency time histories that match the base hard rock spectrum in composite but, individually, are based on high and low reference probability response spectral shapes. The applicant then used these time histories as inputs for the site response analysis for each of the 60 subsurface profiles. Finally, the applicant fit the log average spectrum of the runs with a smooth-fitting function that the applicant then used to obtain the response spectrum for the 21 spectral frequencies in the ESP SSAR. To determine the final GMRS, the applicant used the reference probability approach described in RG 1.165. Similarly, the applicant also developed smooth horizontal free-field outcrop motions for the bases of the control building and RB and FB foundations and incorporated the material properties up to the base of the foundation of the FWSC into the site response analyses.

In FSAR Section 2.5.2.7, the applicant compared the DCD and ESP SSAR operating-basis earthquake (OBE) bounds. The applicant stated that the DCD OBE was chosen to be one-third of the CSDRS, while the ESP SSAR OBE was characterized as one-third of the FIRS. The applicant concluded that the DCD OBE bounds the site since one-third of the CSDRS exceeds one-third of the FIRS. The applicant referred to Section 3.7.1.1 of FSAR and ESBWR DCD for additional information.

2.5.2.3 *Regulatory Basis*

The regulatory basis for incorporating information by reference to the ESP SSAR is 10 CFR 52.79(b), which states (in part) that if a COL application references an ESP, then the FSAR need not contain information or analyses submitted to the Commission in connection with the

ESP provided that the FSAR must either include or incorporate by reference the ESP SSAR and must contain, in addition to the information and analyses otherwise required, information sufficient to demonstrate that the design of the facility falls within the site characteristics and design parameters specified in the ESP. Full descriptions of the applicable regulatory and acceptance criteria, and related NRC guidance, are provided in SRP Section 2.5.2 (NUREG-0800).

The regulatory basis for the information incorporated by reference is addressed in the SER related to the North Anna 3 ESP (NUREG-1835).

2.5.2.4 *Technical Evaluation*

The applicant incorporated by reference Section 2.5.2 of the ESP SSAR, Revision 9. The staff's technical evaluation of Section 2.5.2 of the ESP SSAR is in NUREG-1835.

NRC staff reviewed Subsection 2.5.1 of the North Anna 3 COL FSAR and checked the referenced ESP SSAR. The staff's review confirmed that the information contained in the application and incorporated by reference addresses the relevant information related to this section.

The staff's technical evaluation of this application is limited to the resolution of DCD COL Item 2.0-27-A and discussion of ESP VAR 2.0-4, as addressed below:

COL Item

- NAPS COL 2.0-27-A

In accordance with COL Action Item 2.0-27-A, the applicant updated the site subsurface material properties as a result of COL field investigations. The applicant performed several additional borings to sample the subsurface and also did additional field geophysical measurements. As a result of these additional investigations, the applicant revised the site subsurface profile by moving the top of competent rock from an elevation of 76.2 meters (250 feet) to 83.2 meters (273 feet) and also developed new shear wave velocities for each of the rock units. Based on these updates, the applicant reanalyzed the site response analysis and subsequently the GMRS for the site. The staff reviewed the applicant's revised site response analysis to verify that the applicant had adequately incorporated the site subsurface properties into the analysis. In addition, the staff verified that the applicant had adequately incorporated the variability of the subsurface material properties by developing 60 randomized rock profiles. The final GMRS is very similar to the GMRS developed as part of the ESP application, differing by only 1 to 2 percent over the entire frequency range. The two spectra are plotted in Figure 2.5.2-1 and show that the COL GMRS is slightly lower than the ESP GMRS from frequencies above 10 Hz. This result can be attributed to the higher shear wave velocity values, which the applicant had obtained from COL geophysical measurements that were directly beneath the proposed location of Unit 3. In contrast, the ESP geophysical measurements were made across the entire site and averaged to obtain the final shear-wave velocity profile. The staff's evaluation of the applicant's COL geophysical measurements is in SER Section 2.5.4.4.4.

To evaluate the applicant's site response analysis described above, the staff performed an analysis using a similar method to that used by the applicant. The staff used the same input subsurface profile in terms of the shear-wave velocities and densities, but then developed its own 60 randomized profiles to capture the variability in those values as well as the other subsurface material properties. The staff then compared its site amplification function with that developed by the applicant and found very similar results. Based on this confirmatory analysis and review of the applicant's site response method, the staff concluded that the applicant had adequately incorporated the site subsurface material properties into the determination of the GMRS for the site. In addition, the staff reviewed the FIRS developed by the applicant for the CB, RB and FB, and FWSC structures. For the FIRS, the applicant used the same subsurface profiles used for the GMRS with the addition of the material properties specific to those foundations. The staff's review of these specific foundation material properties is in Section 2.5.4.4.7 of this SER. The staff concluded that the applicant had conducted sufficient analyses, which incorporated the most recent subsurface investigations, and had adequately determined the GMRS based on these updated site investigations to resolve COL Action Item= 2.0-27-A.

ESP Variance

- NAPS ESP VAR 2.0-4

The applicant requested VAR 2.0-4 in order to use the spectral acceleration values at the top of component rock as opposed to those determined in the ESP. The staff considered this variance request and determined that because the top of component rock was redefined as a result of the applicant's COL subsurface investigations, the use of the top of component rock for spectral acceleration in place of that determined as part of the ESP is acceptable.

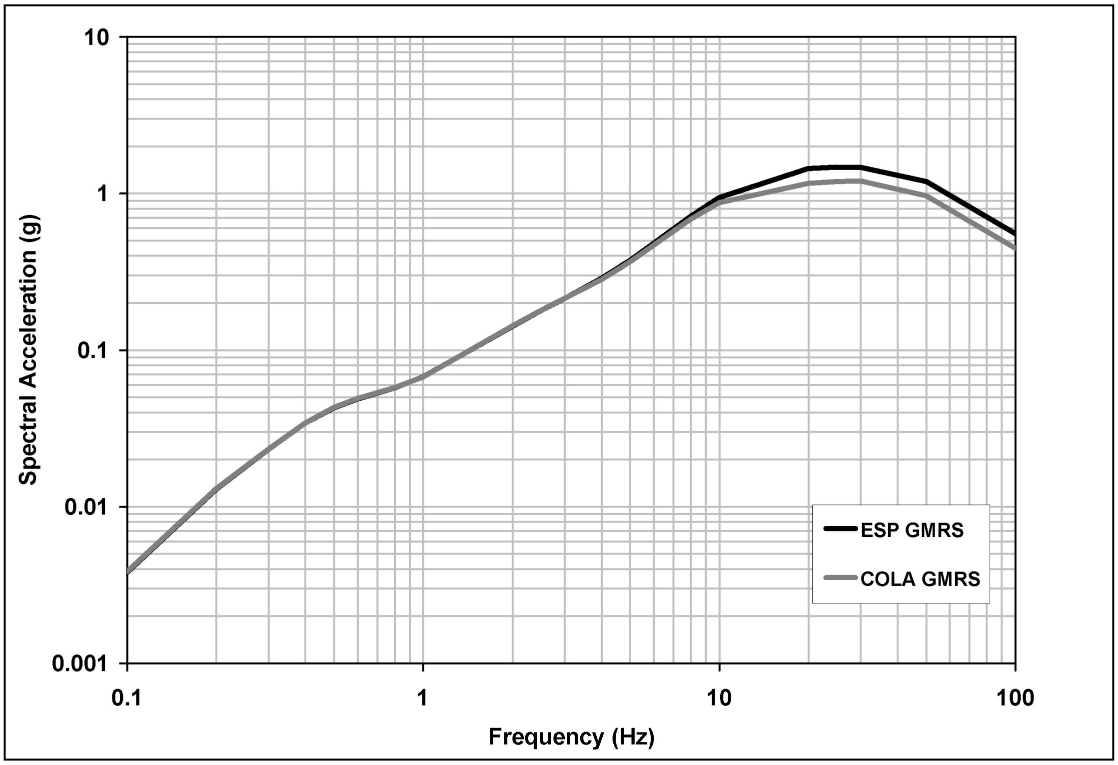

Figure 2.5.2-1 Comparison of the ESP and COL Horizontal Ground Mmotion Response sSectra (GMRS) for the North Anna Site

2.5.2.5 *Post Combined License Activities*

There are no post COL activities associated with this section.

2.5.2.6 *Conclusions*

NRC staff reviewed the application and checked the referenced ESP SSAR. The staff's review confirmed that the applicant has addressed the relevant information and there is no outstanding information expected to be addressed in the COL FSAR related to this subsection.

The staff concludes that the information pertaining to North Anna 3 COL FSAR Section 2.5.2 is within the scope of the ESP and adequately incorporates by reference Section 2.5.2 of the ESP SSAR and is thus acceptable. In addition, the staff compared the additional COL information in the application to the relevant NRC regulations and acceptance criteria defined in NUREG-0800, Section 2.5.2. The staff concluded that the applicant is in compliance with the relevant requirements of 10 CFR Parts 52 and 100. COL Action Item 2.0-27-A has been adequately addressed by the applicant and can be considered closed. Therefore, the staff concluded that the site is suitable with respect to the vibratory ground motion criteria for new nuclear power plants.

2.5.3 Surface Faulting

2.5.3.1 *Introduction*

Section 2.5.3 of this SER provides information on surface faulting related to the North Anna site. Section 2.5.3.2 of this SER provides a summary of relevant geologic and seismic information contained in FSAR Section 2.5.3 of the North Anna COL application. SER Section 2.5.3.3 provides a summary of the regulations and guidance used by the applicant to perform the investigation. SER Section 2.5.3.4 reviews the staff's evaluation of FSAR Section 2.5.3, including any requests for additional information, open items, and confirmatory analyses performed by the staff. SER Section 2.5.3.5 discusses post COL activities. Finally, SER Section 2.5.3.6 provides an overall summary of the applicant's conclusions, as well as the staff's conclusions; restates any bases covered in the application; and confirms that regulations were met or fulfilled by the applicant.

2.5.3.2 *Summary of Application*

Section 2.5.3 of the North Anna 3 COL FSAR, incorporates by reference Section 2.5.3 of ESP SSAR, Revision 9. In addition, in FSAR Section 2.5.3, the applicant provided supplemental information on additional borehole data from Unit 3 borings.

COL Item

- NAPS COL 2.0-28-A

This COL FSAR section also addresses DCD COL Item 2.0-28-A of Revision 5 to the ESBWR DCD. NAPS COL 2.0-28-A addresses the permanent ground deformation from tectonic or non-tectonic faulting. The ESBWR design requires the applicant to demonstrate that there is no potential for permanent ground deformation at the site area.

2.5.3.3 *Regulatory Basis*

The regulatory basis for incorporating information by reference to the ESP SSAR is 10 CFR 52.79(b), which states (in part) that if a COL application references an ESP, then the FSAR need not contain information or analyses submitted to the Commission in connection with the ESP provided that the FSAR must either include or incorporate by reference the ESP SSAR and must contain, in addition to the information and analyses otherwise required, information sufficient to demonstrate that the design of the facility falls within the site characteristics and design parameters specified in the ESP. Full descriptions of the applicable regulatory and acceptance criteria, and related NRC guidance, are provided in SRP Section 2.5.3 (NUREG-0800).

The regulatory basis for the information incorporated by reference is addressed in the SER related to the North Anna ESP (NUREG-1835).

2.5.3.4 *Technical Evaluation*

The applicant incorporated by reference Section 2.5.3 of the ESP SSAR, Revision 9. The staff's technical evaluation of Section 2.5.3 of the ESP SSAR is in NUREG-1835.

NRC staff reviewed Subsection 2.5.1 of the North Anna 3 COL FSAR and checked the referenced ESP SSAR. The staff's review confirmed that the information contained in the application and incorporated by reference addresses the relevant information related to this section.

The staff's technical evaluation of this application is limited to reviewing the resolution of DCD COL Item 2.0-28-A, as addressed below:

<u>*COL Item*</u>

- NAPS COL 2.0-28-A

In accordance with DCD COL Item 2.0-28-A, the applicant provided additional information on the site area determined from additional borings. This additional information yielded no evidence of Quaternary (1.8 millions years ago to the present) fault movement. The staff concluded that the applicant has conducted sufficient subsurface investigations to resolve DCD COL Item 2.0-28-A.

2.5.3.5 *Post Combined License Activities*

There are no post COL activities associated with this subsection.

2.5.3.6 *Conclusion*

NRC staff reviewed the application and checked the referenced ESP SSAR. The staff's review confirmed that the applicant has addressed the relevant information and there is no outstanding information expected to be addressed in the COL FSAR related to this subsection.

The staff concluded that the information pertaining to North Anna 3 COL FSAR Section 2.5.3 is within the scope of the ESP and adequately incorporates by reference Section 2.5.3 of the ESP SSAR and is thus acceptable. In addition, the staff compared the additional COL information in the application to the relevant NRC regulations and acceptance criteria defined in NUREG-0800, Section 2.5.3, and concluded that the applicant is in compliance with the relevant requirements of 10 CFR Parts 52 and 100. COL Action item 2.0-28-A has been adequately addressed by the applicant and can be considered closed. Therefore, the staff concluded that the site is suitable with respect to the surface faulting criteria for new nuclear power plants.

2.5.4 Stability of Subsurface Materials and Foundations

2.5.4.1 *Introduction*

Section 2.5.4 of this SER provides information on the stability of subsurface materials and foundations for the North Anna Unit 3 site. Section 2.5.4.2 of this SER provides a summary of relevant geologic and seismic information in FSAR Section 2.5.4 of the North Anna Unit 3 COL application. SER Section 2.5.4.3 provides a summary of the regulations and guidance used by the applicant to perform the investigation. SER Section 2.5.4.4 provides a review of the staff's evaluation of FSAR Section 2.5.4, including any requests for additional information, open items, and confirmatory analyses performed by the staff. SER Section 2.5.4.5 discusses post COL activities. Finally, SER Section 2.5.4.6 provides an overall summary of the applicant's conclusions, as well as the staff's conclusions, restates any bases covered in the application, and confirms that regulations are met or fulfilled by the applicant.

Based on the information collected during ESP and COL site investigations, the applicant evaluated the stability of the site subsurface materials and foundations as well as the stability of slopes at the COL site.

2.5.4.2 *Summary of Application*

Section 2.5.4 of the North Anna 3 COL FSAR, incorporates by reference Section 2.5.4 of the ESP SSAR, Revision 9. In addition, in FSAR Section 2.5.4, the applicant provided the following supplements, including additional borehole data from Unit 3 borings.

COL Items

- NAPS COL 2.0-29-A

NAPS COL 2.0-29-A provides supplemental information and additional borehole data from Unit 3 borings to address the provisions listed in ESBWR DCD Table 2.0-1, regarding stability of subsurface material and foundation requirements, (DCD COL Item 2.0-29-A).

- NAPS ESP COL 2.5-1

The applicant provided additional information to address ESP COL Action Item 2.5-1, which states that additional borings are needed to identify any weathered or fractured rock beneath the new foundations, and to confirm the applicant's conclusions regarding the engineering properties and stability of the soil and rock underlying the future plant site.

- NAPS ESP COL 2.5-2

The applicant provided additional information to address ESP COL Action Item 2.5-2, which states that plot plans and profiles of all seismic Category I facilities need to be submitted for comparison with the subsurface profile and material properties.

- NAPS ESP COL 2.5-3

The applicant provided additional information to address ESP COL Action Item 2.5-3, which states that detailed excavation and backfill plans will be provided as part of the COL application.

- NAPS ESP COL 2.5-4

The applicant provided additional information to address ESP COL Action Item 2.5-4, which states that the COL application will include an evaluation of groundwater conditions as they affect foundation stability and/or detailed dewatering plans.

- NAPS ESP COL 2.5-5

The applicant provided additional information to address ESP COL Action Item 2.5-5, which states that additional site response analyses will be included at the COL stage once specific locations are selected for the nuclear power plant structures.

- NAPS ESP COL 2.5-6

The applicant provided additional information to address ESP COL Action Item 2.5-6, which states that an analysis of the stability of all planned safety-related facilities, including bearing capacity, rebound, settlement, and differential settlements under deadloads of fills and plant facilities, as well as lateral loading, will be addressed in the COL application.

- NAPS ESP COL 2.5-7

The applicant provided additional information to address ESP COL Action Item 2.5-7, which states that design-related criteria that pertain to structural design, such as wall rotation, sliding, and overturning, will be addressed in the COL application.

- NAPS ESP COL 2.5-8

The applicant provided additional information to address ESP COL Action Item 2.5-8, which states that the COL applicant will provide specific plans for each proposed ground improvement technique the applicant plans to use so that the staff will be able to determine whether the chosen technique will ensure that Zone II saprolitic soils will be able to support safety-related foundations.

- NAPS ESP COL 2.5-9

The applicant provided additional information to address ESP COL Action Item 2.5-9, which states that the COL applicant is responsible for ensuring that the average shear wave velocity of the material underlying the foundation for the reactor containment equals or exceeds that of the chosen design.

- ESP Permit Conditions 3.E(6) and 3.E(7)

The applicant provided additional information to address ESP Permit Condition 3.E(6), which states that the COL applicant should include information on geologic mapping of future excavations for safety-related structures and should evaluate any unforeseen geologic features encountered at the site area. This permit condition is in FSAR Section 2.5.4.5.

The applicant provided additional information to address ESP Permit Condition 3.E(7), which states that the COL applicant should improve Zone II saprolitic soils to reduce any liquefaction potential if safety-related structures are to be founded on them. This permit condition is in FSAR Section 2.5.4.8.

The applicant conducted additional field and laboratory tests to determine the static and dynamic properties of subsurface materials and confirmed that the parameters meet the soil property requirements defined in the ESBWR DCD, such as the minimum shear wave velocity and angle of internal friction parameters. The applicant also performed a site subsurface material liquefaction potential analysis; a static and dynamic bearing capacity analysis; and a settlement analysis to demonstrate that the subsurface materials meet the minimum static and dynamic bearing capacity, no liquefaction, and maximum total and differential settlement requirements. In the analyses, the applicant assumed properties of backfill material based on design. The liquefaction potential analyses results indicated that there might be localized liquefactions at a certain depth on the site, but those potential liquefiable zones were too small and limited to have any impact on the safety of structures.

The applicant performed additional site investigations to further constrain the properties of the subsurface materials, which included redefining the elevation range at which the rock units were encountered at the site during the COL investigations. These investigations were generally of smaller ranges than those determined in the ESP investigations. The applicant also provided contour maps of the subsurface rock units as a supplement to the subsurface profiles presented as part of the ESP. The applicant also performed field investigations to supplement the ESP investigations, including additional exploratory borings, observation wells, and cone penetrometer tests (CPTs) as well as packer tests, geophysical logging, and electrical resistivity tests. The applicant also completed additional laboratory testing, such as chemical and resonant column torsional shear (RCTS) tests, which further constrained the material properties determined from similar tests completed as part of the ESP. The applicant then used the results of the field investigations and the laboratory testing to further constrain the engineering properties of the subsurface materials, as determined during the ESP investigation.

The applicant also used the selection of a reactor design to better describe the foundation interfaces that were generically considered as part of the general exploration program for the NAPS Unit 3 site. The applicant used this information to develop more detailed subsurface profiles. The applicant also performed geophysical surveys to supplement those completed in support of the ESP, including field electrical resistivity, shear and compression wave velocity, and geophysical down hole testing.

The applicant provided significantly more detailed description of the excavation and backfill program compared to what was provided as part of the ESP. The applicant included in this description the excavation plans and the total depths to which excavation and backfilling would be required for the ESBWR design proposed for the NAPS Unit 3 site. The applicant also included additional information regarding the groundwater conditions at the site, supplementing the earlier ESP information with design and site specific interactions between the foundations and the groundwater level, such as construction dewatering plans and the effects of groundwater on foundation stability.

The response of soil and rock to dynamic loading at the site presented in the ESP was also reassessed as part of the COL application, with the applicant considering the placement of the basemat on the native rock or backfill as part of its development of the shear wave velocity profile for the site and the variation of shear modulus and damping with cyclic shear strain.

Regarding liquefaction potential, the applicant concluded in the ESP that the Zone IIA saprolitic soils were prone to liquefaction and would therefore be removed from the site and replaced with structural backfill. In the COL application, the applicant determined that the factor of safety against liquefaction of 1.1, which was determined during the ESP application, is still applicable.

The applicant also revised the static stability of the site to incorporate the design-specific dimensions in the COL application, as opposed to the assumed values of the ESP. The applicant also included the bearing capacity, settlement, and earth pressures in the structural fill or other load-bearing layers in the COL application, whereas the ESP had assumed that Unit 3 would be constructed on Zone IIA saprolitic soils. Due to the change in load-bearing materials and the selection of a reactor design, the applicant reassessed the settlement, bearing capacity, and earth pressures to ensure that they were within the design parameters stated in the ESBWR DCD.

The applicant also restated the design criteria, including factors of safety against liquefaction and slope stability failure, as identified in the ESP, and provided additional factors of safety-related to bearing capacity, calculations, and lateral earth pressures. Finally, the applicant revised the techniques for improving subsurface conditions, which in the ESP involved the use of vibro-stone columns to reinforce the Zone IIA saprolitic soils, while in the COL the applicant committed to removing the potentially liquefiable Zone IIA saprolitic soils and replacing the excavated material with structural backfill.

2.5.4.2.1 Description of Site Geologic Features

FSAR Section 2.5.4.1 refers to the description of regional and site geologic features in FSAR Sections 2.5.1.1 and 2.5.1.2. Since additional Unit 3 borings were conducted, the applicant described the integrated site geologic features in the aforementioned sections based on information from the ESP and new data. Section 2.5.1.4 of this SER contains the technical evaluation of this information.

2.5.4.2.2 Properties of Subsurface Materials

FSAR Section 2.5.4.2 describes the static and dynamic engineering properties of the COL site subsurface materials. This section gives an overview of the subsurface profile materials, field investigation results, and the results of laboratory tests on the subsurface samples from the Unit 3 investigations.

Description of Subsurface Materials

The applicant divided the subsurface materials into four zones, consistent with the site investigation findings of the ESP. FSAR Subsection 2.5.4.2.2 describes each zone and is summarized in the subsections that follow. The applicant also developed profiles to illustrate the subsurface across the Unit 3 power block area. Figure 2.5.4-1 of this SER illustrates one of the subsurface profiles that the applicant developed, showing the subsurface profile across the line A-A in FSAR Figure 2.5-214 across the power block area of the Unit 3 site.

<u>Zone IV Bedrock</u>. The applicant described the bedrock underlying the power block area as gneiss. The applicant identified the top of Zone IV rock as ranging in elevation from 53.0 m (174 ft) to 84.7 m (278 ft), while the Zone III-IV transitional rock ranged in elevation from 56.9 m (187 ft) to 89.0 m (292 ft).

<u>Zone III Weathered Rock</u>. Above Zone IV, the applicant identified Zone III as weathered rock. The top of Zone III ranged in elevation from about 62.7 m (206 ft) to 86.8 m (285 ft).

<u>Zone IIA and Zone IIB Saprolites</u>. The applicant identified the weathered rock lying above the Zone III rock as saprolite, a highly weathered rock, divided into two zones—Zone IIA and IIB. Zone IIA saprolite was identified by the applicant as the upper layer, composed of 80 percent coarse, silty sands and 20 percent finer grained, clayey sands and silts. In contrast, the applicant described the Zone IIB saprolite as dense, silty sands with 10 to 50 percent core

stone. The elevation at the top of Zone IIA ranged from 70.7 m (232 ft) to 102.1 m (335 ft) and IIB ranged from 65.5 m (215 ft) to 91.7 m (301 ft).

Zone I and Fill. The applicant stated that all Zone I soils and existing fills will be excavated and are therefore not considered further for the Unit 3 site.

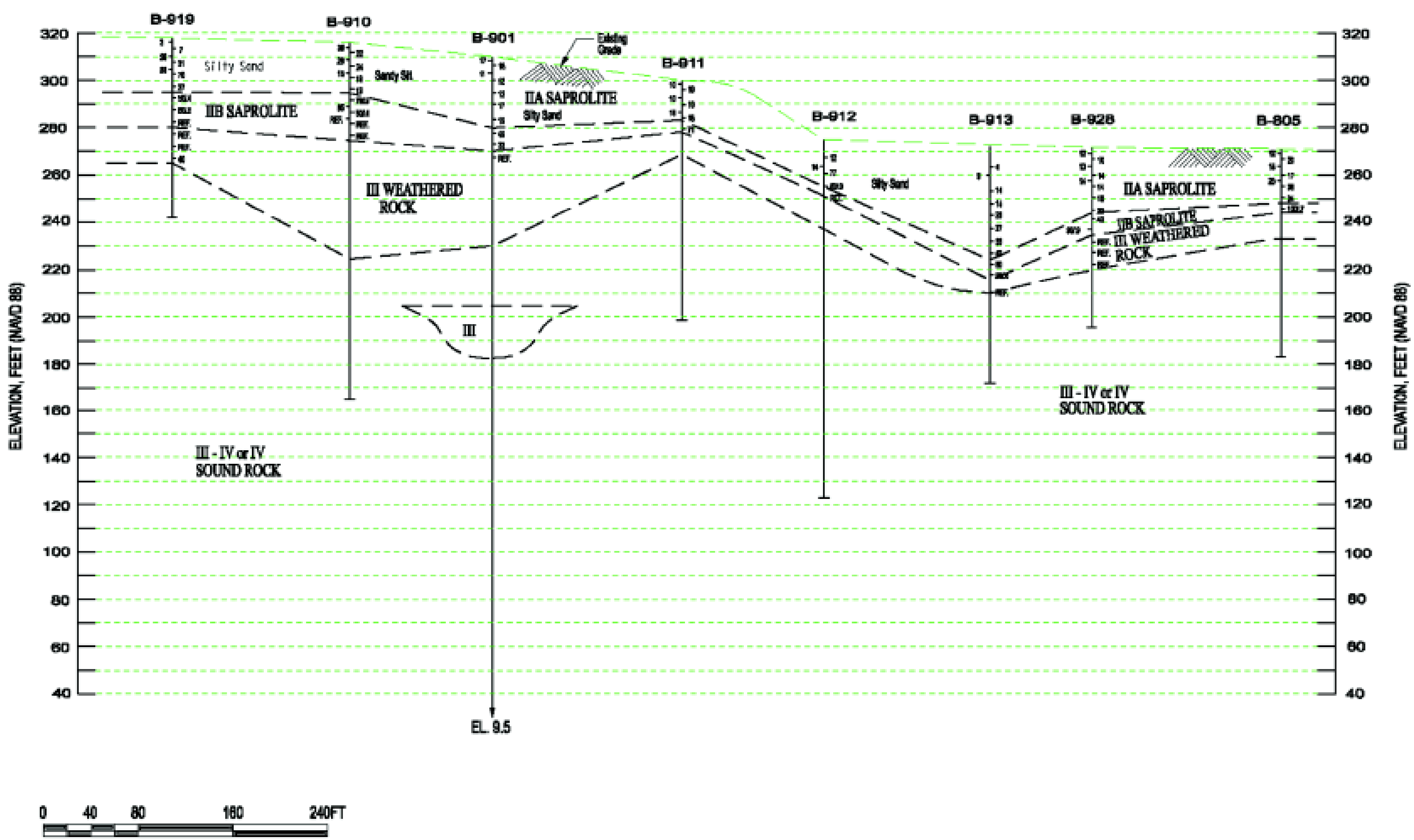

Figure 2.5.4-1 Typical Subsurface Profile across Unit 3 Power Block Area (FSAR Figure 2.5-215)

Field Investigations

As was previously stated, the applicant performed a number of additional borings and tests in support of the COL application. The applicant stated that these investigations conformed to the guidance in RG 1.132 and Subpart 2.20 of American Society of Mechanical Engineers (ASME) NQA-1. FSAR Section 2.5.4.2.3 describes the additional work completed to characterize the geological, seismological, and geotechnical engineering properties of the Unit 3 site and included 55 borings, 23 CPTs, six test pits, three sets of borehole geophysical logging, three sets of shear wave suspension logging, and two sets of electrical resistivity tests as part of the subsurface investigation program. A summary of the tests performed and their results are presented in the following sections.

Borings and Samples/Cores. The applicant drilled 55 borings for the COL site investigation of depths between 6.7 to 91.4 m (22 to 300 ft) around the power block area. The applicant collected soil and rock samples in accordance with relevant ASTM standards, including, but not limited to, ASTM D 1586, 1587, and 2113. The soil samples were collected by the applicant using the standard penetration test (SPT) sampler at 0.76 m (2.5 ft) intervals to about 4.6 m (15 ft) in depth and at 1.5 m (5 ft) intervals below 4.6 m (15 ft). The applicant obtained undisturbed samples by removing disturbed portions at both ends of the sample tube and trimming the ends square. Pocket penetrometer (PP) tests were performed on the trimmed lower end of the samples. The applicant recovered rock core samples by first removing the cores from the split inner barrel before describing the core in detail and recording the information, such as joints and fractures, on the boring log. The applicant also computed the percentage of recovery and the rock quality designation (RQD). The applicant labeled and transported all tubes to the sample storage area.

Observation Wells. The applicant installed seven observation wells adjacent to sample borings, three in the soil/weathered rock zone and four in rock. The applicant developed each well by pumping until the pH and conductivity stabilized and the pumped water was reasonably free of suspended sediment. Using the slug test method, the applicant performed permeability tests in each of the three wells screened in soil/weathered rock and in one of the wells screened in rock. Finally, the applicant used the packer method to conduct permeability tests in the borings adjacent to the four wells screened in rock.

Cone Penetrometer Tests. The applicant conducted 23 CPT tests measuring tip resistance, sleeve friction, and porewater pressure. The applicant also performed down hole seismic and pore pressure dissipation tests in four CPTs.

Test Pits. The applicant excavated six test pits with depths ranging from 0.7 to 1.4 m (2.3 to 4.6 ft) at the site to collect soil samples for laboratory tests to determine soil properties and backfill suitability.

Laboratory Testing

FSAR Section 2.5.4.2.4 describes the results of numerous laboratory tests of soil and rock samples performed for the Unit 3 site investigation. The applicant performed laboratory testing for the Unit 3 investigation to verify the large number of test results from previous investigations, including tests performed for existing units and ESP site investigations. The applicant focused Unit 3 tests on three areas and stated that the guidance of RG 1.138 was followed. The applicant sought to verify the properties of the soil and rock beneath the Unit 3 power block area similar to those beneath Units 1 and 2. Chemical tests were performed by the applicant on the

Zone IIA saprolites to determine corrosiveness toward buried steel and aggressiveness toward buried concrete. Finally, the applicant conducted RCTS tests on selected saprolite samples to determine the properties of shear modulus and damping ratio variation with cyclic strain. FSAR Table 2.5-209 summarizes the type and number of tests, and FSAR Appendix 2.5.4AA includes details and results of the laboratory tests with Appendix 2.5.4AAS1 presenting the RCTS test results.

Engineering Properties

FSAR Section 2.5.4.2.5 describes the engineering properties of selected materials in subsurface Zones IIA, IIB, III, III-IV, and IV based on the outcomes of Unit 3 field exploration and laboratory testing programs. Table 2.5.4-1 of this SER summarizes the main engineering properties of the site soil and rock layers based on FSAR Table 2.5-212 and related descriptions. The following sections describe the various test programs or field observations employed to derive the material properties.

Rock Properties. The applicant determined that the rock strength and stiffness values from the field and laboratory testing of the Unit 3 rock are generally higher than the values obtained during the ESP site investigation. This finding suggested to the applicant that less fractured or weathered rock may underlie the Unit 3 site, or better rock coring equipment and techniques produced better quality cores. The applicant based the recovery and RQD on the results for each core in the boring logs, which are summarized in SER Table 2.5.4-2.

The applicant based unconfined compressive strengths, unit weights, and elastic modulus values on the rock strength test results. The elastic modulus values using Poisson's ratio values were utilized by the applicant to derive the shear modulus values. The applicant also determined that the high and low strain shear modulus values are essentially the same for high strength rock (Zones IV and III-IV). Finally, the applicant based the shear and compression wave velocities on suspension P-S velocity logging performed during the COL site investigation program.

Soil Properties. The applicant presented the engineering properties of Unit 3 site soils in FSAR Table 2.5-212 (SER Table 2.5.4-1) and described, in FSAR Section 2.5.4.2.5.b, the methods used to determine the properties. The applicant combined laboratory test and field test (SPT and CPT) results to determine the undrained shear strength of soil. The shear wave velocities were determined based on down hole seismic test and suspension P-S velocity measurements. The applicant calculated the low strain, defined as a strain level of 10^{-4} percent, and the shear modulus of the soil using the relationship between shear wave velocity and soil density. The applicant derived the low-strain elastic modulus using the relationship between the elastic modulus, shear modulus, and Poisson's ratio; the shear modulus value was derived in the same way. The applicant determined the high-strain—defined as the strain level in the range of 0.25 to 0.5 percent—elastic modulus values by applying the relationship with the SPT N-value in Davie and Lewis (1988).

RCTS Testing. The applicant performed three RCTS tests, two on Zone IIA saprolites and one on Zone IIB saprolite, to determine soil degradation properties under seismic loading conditions. The test results were then used by the applicant to generate curves of normalized shear modulus (G/Gmax) and material damping ratio, D, versus shear strain. The applicant compared these results with generic curves in FSAR Section 2.5.4.7, summarized in Section 2.5.4.2.7 of this SER.

Table 2.5.4-1 Engineering Properties of North Anna Unit 3 Site Subsurface Materials (FSAR Table 2.5-212)

STRATUM	FILL	ZONE IIA	ZONE IIB	ZONE III	ZONE III-IV	ZONE IV
General description	Gravelly materials	Saprolite (10% of core stone)	Saprolite (10 – 50 % of core stone)	Weathered rock	Moderately to slightly weathered rock	Parent rock
USCS symbol	GW	SM	SC	SM	-	-
Top of layer elevation	76.2-102.1 m (250-335 ft)	70.7-102.1 m (232-335 ft)	65.5-91.7 m (215-301 ft)	62.8-86.9 m (206-285 ft)	57.0-89.0 m (187-292 ft)	53.0-84.7m (174-278 ft)
Percent fines (%)	0-5	25	20	-	-	-
Moisture content (%)	-	19	14	-	-	-
Total unit weight (kg/m^3 (pcf))	2,082 (130)	2,002 (125)	2,082 (130)	2,403 (150)	2,611 (163)	2,627 (164)
Measured SPT N-value (blows/ft)	-	15	75	-	-	
Adjusted SPT N60-value (blows/ft)	50	20	100	-	-	-
Unconfined compressive strength, q_u	-	-	-	6.8 MPa (1.0 ksi)	62.0 MPa (9.0 ksi)	117 MPa (17.0 ksi)
Effective cohesion, c’	0	5.9 kPa (0.125 ksf)	0	-	-	-
Effective friction angle, ‘ (degrees)	40	33	40	-	-	-
Shear wave velocity, *Vs*	335 m/s (1,100 fps)	259 m/s (850 fps)	488 m/s (1,600 fps)	914 m/s (3,000 fps)	1,372 m/s (4,500 fps)	2,743 m/s (9,000 fps)
Compression wave velocity, *Vp*	732 m/s (2,400 fps)	549 m/s (1,800 fps)	1,067 m/s (3,500 fps)	2,225 m/s (7,300 fps)	2,743 m/s (9,000 fps)	4,877 m/s (16,000 fps)
Poisson’s ratio, *u* (high strain)	0.3	0.35	0.3	0.4	0.33	0.27
Poisson’s ratio, *u* (low strain)	0.37	0.35	0.37	0.4	0.33	0.27
Elastic modulus (high strain), E_h	86.2 MPa (1,800 ksf)	34.5 MPa (720 ksf)	172.4 MPa (3,600 ksf)	2,757 MPa (400 ksi)	13,100 MPa (1,900 ksi)	49,987 MPa (7,250 ksi)
Elastic modulus (low strain), E_l	622 MPa 13,000 ksf	359 MPa 7,500 ksf	1,340 MPa 28,000 ksf	5,515 MPa 800 ksi	13,100 MPa 1,900 ksi	49,987 MPa 7,250 ksi
Shear modulus (high strain), G_h	33.5 MPa 700 ksf	12.9 MPa 270 ksf	67.0 MPa 1,400 ksf	1,034 MPa 150 ksi	4,826 MPa 700 ksi	19,994 MPa 2,900 ksi

STRATUM	FILL	ZONE IIA	ZONE IIB	ZONE III	ZONE III-IV	ZONE IV
Shear modulus (low strain), G_l	239 MPa 5,000 ksf	134 MPa 2,800 ksf	478 MPa 10,000 ksf	2,068 MPa 300 ksi	4,826 MPa 700 ksi	19,994 MPa 2,900 ksi
Coefficient of subgrade reaction, k_1	32.03 kg/cm^3 (2,000 kcf)	4.16 kg/cm^3 (260 kcf)	32.03 kg/cm^3 (2,000 kcf)	-	-	-
Coefficient of sliding	0.55	0.35	0.45	0.6	0.65	0.7
Static earth pressure coefficients						
Active, K_a	0.22	0.30	0.22	-	-	-
Passive, K_p	4.60	3.40	4.60	-	-	-
At-rest, K_0	0.36	0.50	0.36	-	-	-

Table 2.5.4-2 Recovery and RQD Based on Boring Logs in Appendix 2.5.4AA

ROCK ZONE	RANGE OF RQD (%)	AVERAGE RQD (%)	AVERAGE RECOVERY VALUE (%)
Zone III	0 – 50	20	55
Zone III-IV	50 – 90	65	90
Zone IV	80 – 99	95	98

Electrical Resistivity and Chemical Properties. The applicant assessed corrosion potential by using field electrical resistivity and laboratory chemical tests on the Zone IIA and Zone IIB saprolites. The test results indicated a low corrosion potential. Therefore, the applicant concluded that special sulfate resisting cement would not be necessary.

2.5.4.2.3 Foundation Interfaces

FSAR Section 2.5.4.3 describes the locations of site exploration points for the Unit 3 subsurface investigation, including borings, observation wells, CPTs, electrical resistivity tests, and test pits made in the power block area. While FSAR Figure 2.5-211 illustrates these locations, FSAR Figure 2.5-214 shows the excavation plan for the safety-related structures and other major facilities. The applicant included the outline of these structures, plant dimensions, and the bottom of foundation elevations for the major structures and their locations on six subsurface profiles (see FSAR Figures 2.5-215 through 2.5-220). Finally, the applicant presented cross sections of the structure foundations with the proposed excavation and backfilling limits superimposed (see FSAR Figures 2.5-229 through 2.5-234).

2.5.4.2.4 Geophysical Surveys

FSAR Section 2.5.4.4 describes the geophysical testing conducted for Unit 3, which included field electrical resistivity testing, geophysical down hole testing, and seismic CPTs. These survey programs and investigations are summarized in the following subsections.

Field Electrical Resistivity Testing

FSAR Section 2.5.4.4.1 describes the field electrical resistivity tests performed along two crossing lines in the site area. The applicant used four electrodes equidistant from a central point and inserted approximately 0.3 meters (1 foot) into the ground to measure the voltage recorded at two inner electrodes after a current was sent through two outer electrodes. The applicant used these results, included in FSAR Appendix 2.5.4AA, to describe corrosion potential in FSAR Section 2.5.4.2.5.

Geophysical Down Hole Testing

For the Unit 3 site geophysical investigation, the applicant performed geophysical down hole tests in three borings with depths of 91.4 m (300.0 ft), 61.1 m (200.5 ft), and 61.5 m (201.9 ft). FSAR Section 2.5.4.4.2 describes these tests, which included natural gamma, 3-arm caliper, resistivity, spontaneous potential, borehole acoustic televiewer, boring deviation, and suspension P-S velocity logging.

Natural Gamma and 3-Arm Caliper. The applicant used a Model 3ACS 3-leg caliper probe to continuously measure natural gamma emissions from the borehole wall at 0.015 m (0.05 ft) intervals. This probe was described by the applicant as capable of measuring boring diameter and volume; locating hard and soft formations; identifying fissures; caving, pinching and casing damage; identifying bed boundaries; correlating strata between borings; and providing natural gamma measurements. The applicant conducted these tests by dropping the probe to the bottom of the borehole and collecting data during the return to the surface at a rate of 3 m (10 ft) per minute.

Resistivity, Spontaneous Potential, and Natural Gamma. The applicant used a Model ELXG electric log probe to measure single point resistance, short and long normal resistivity, spontaneous potential, and natural gamma at 0.015 m (0.05 ft) intervals. The data were used by the applicant to identify bed boundaries, correlate strata between borings, identify strata geometry (shale indication), and provide natural gamma measurements. Similar to the 3-arm caliper test, the applicant started this test at the bottom of the borehole and collected data while surfacing at a rate of 3 m (10 ft) per minute.

Acoustic Televiewer and Borehole Deviation Measurement. A High Resolution Acoustic Televiewer probe was used by the applicant to measure boring inclination and deviation based on acoustic images and boring deviation data collected at 0.0024 m (0.008 ft) intervals. The applicant used this data to determine the need to correct soil and geophysical log depths to true vertical depths; provide acoustic imaging of the borehole to identify fractures, dikes, and weathered zones; and determine the dip and azimuth of these features. Again, the applicant conducted the survey by first dropping the instruments to the bottom of the borehole and then resurfacing at a rate of 0.91 m (3 ft) per minute.

Suspension P-S Velocity Logging. The applicant also performed P-S velocity logging tests to directly determine the average in-situ horizontal shear and compressional wave velocity measurements of a 1.0 m high (3.3 ft) segment of the soil and rock column surrounding the borehole. This method was described by the applicant as involving a source and two receivers, all of which are dropped to a specific depth in the borehole where the source creates a pressure wave and the receivers record the resulting seismic waves from the borehole wall.

Seismic Tests with Cone Penetrometer

FSAR Section 2.5.4.4.3 describes the CPTs conducted by the applicant for Unit 3. The applicant developed the profiles of shear and compression wave velocities, along with calculated Poisson's ratio, at the Unit 3 site based on the results of seismic CPT tests coupled with the results of the suspension P-S velocity logging described in the previous section. The applicant presents those profiles in FSAR Figures 2.5-227, 2.5-235, 2.5-236, 2.5-237, 2.5-238, and 2.5-239. Table 2.5.4-3 summarizes the ranges of shear wave velocity for each layer.

Table 2.5.4-3 Layer Shear Wave Velocity of North Anna Unit 3 Site

STRATUM	ZONE IIA	ZONE IIB	ZONE III	ZONE III-IV	ZONE IV
Shear Wave Velocity m/s (f/s)	15.2–366 (500–1,200)	366–762 (1,200–2,500)	610–1,219 (2,000–4,000)	914–2,438 (3,000–8,000)	2,438–3,048 (8,000–10,000)

2.5.4.2.5 Excavation and Backfill

FSAR Section 2.5.4.5, "Excavation and Backfill," describes the extent of seismic Category I excavations, fills and slopes; methods of excavation and stability; and sources of backfill including quantities, compaction specifications, and quality control.

Extent of Excavations, Fills, and Slopes

FSAR Subsection 2.5.4.5.1 describes the extent of excavations, fills, and slopes at the Unit 3 site. In this section, the applicant included numerous figures to illustrate this information, including FSAR Figure 2.5-214 showing the extent of excavations, fills, and slopes for Unit 3 and FSAR Figures 2.5-229 through 2.5-234 showing cross sections of the excavations. The applicant stated that up to 12.2 m (40 ft) of soil will be excavated to reach the design plant grade of elevation 88.4 m (290 ft), but some lower areas may need to be backfilled. The applicant estimated the total cut at about 550,500 cubic meters (720,000 cubic yards), with backfilling of about 336,400 cubic meters (440,000 cubic yards). The excavation plan was described by the applicant as having 3-horizontal to 1-vertical (3H:1V) slopes extending up from the plant grade around the southern perimeter of the area, and a two percent slope (roughly 50H:1V) northeast of the Unit 3 grade extending down toward the grade for Units 1 and 2.

Excavation Methods and Stability

FSAR Subsection 2.5.4.5.2 describes the methods of excavation and plans to maintain stability along the excavation surfaces. The applicant included plans for the excavation of both soil and rock zones at the Unit 3 site. These excavation methods are summarized in the following subsections.

<u>Excavation in Soil</u>. The applicant stated that conventional equipment will be used for excavation in soil Zones IIA and IIB and any existing fills. For excavation of less than 6.1 m (20 ft) in height, the applicant stated that U.S. Office of Safety and Health Administration (OSHA) regulations will be followed. The applicant further described plans to use a vertical soil cut and tie-back system to stabilize the power block excavation. Due to the erosive potential of the saprolitic soils, the applicant concluded that even temporary slopes cut into the saprolite will need to be sealed and protected.

Excavation in Rock. Based on lessons learned from the Unit 1 and 2 constructions, the applicant stated that techniques will be used to reduce vibrations during rock excavation. The applicant's rock excavation goals are three-fold: first, to control blasting techniques; second, to preserve the integrity of the rock outside the excavations; and third, to reinforce the rock to ensure adequate support and safety. The applicant used cushion blasting, presplitting, and line drilling with appropriately dimensioned bench lifts to control the blasting techniques. The applicant described plans to keep the blasted faces vertical, except where foliations dip into the excavation. To preserve the integrity of the rock, the applicant maintained peak particle velocity within specific limits to prevent damage to existing structures, equipment, and freshly poured concrete. The applicant accomplished the third goal of reinforcing the rock by including the installation of rock bolts in finished rock faces and by using welded wire mesh. The applicant stated that additional measures may be used when weathered or fractured zones are encountered. The applicant also indicated that slope indicators and extensometers to monitor rock movements will be installed.

Backfill Sources, Compaction, and Quality Control

FSAR Subsection 2.5.4.5.3 describes the sources of backfill, compaction requirements, and quality controls for the Unit 3 site. The applicant illustrated the anticipated extent of structural fills on the foundation cross-section plots (see FSAR Figures 2.5-229 to 2.5-234). Concrete fill will be used by the applicant to replace moderately to severely weathered Zone III rock exposed at the bottom of the excavations for the seismic Category I RB and FBs and CB foundation mats. It was explicitly stated by the applicant that saprolitic soil material found onsite will not be used as structural fill to support or backfill seismic Category I, II, or any other major structures, except as provided for under EPS VAR 2.5-2. Because backfill material is not naturally available at the site, the applicant described plans to set up a crushing and blending plant onsite to produce crushed aggregate to the required specifications for use as structural fill. The applicant also described the grain size (less than 5 percent passing through the number 200 sieve); angularity (angular to subangular); and the compaction method to be used. Finally, the applicant estimated the properties of the backfill material as N_{60} = 50 blows per 0.3 meter (1 foot) and effective internal friction angle φ' = 40 degrees. The applicant also referred to a technical specification that addresses fill placement and compaction control procedures.

Control of Groundwater during Excavation

Although FSAR Subsection 2.5.4.5.4 briefly describes the applicant's plans for controlling groundwater during the excavations, FSAR Section 2.5.4.6.2 provides significantly more detail. The applicant described plans to slope back the tops of excavations to prevent runoff down the excavated slopes during heavy rainfall and to construct dewatering sumps and ditches which, due to the erosive nature of the saprolitic soil, will be lined.

2.5.4.2.6 Groundwater Conditions

In FSAR Section 2.5.4.6, the applicant briefly describes the groundwater conditions at the Unit 3 site. This section includes groundwater measurements and elevations, construction dewatering and seepage, and the effect of groundwater conditions on foundation stability. FSAR Section 2.4.12 describes the groundwater conditions at the Unit 3 site in greater detail.

Groundwater Measurements and Elevations

FSAR Section 2.5.4.6.1 describes the groundwater measurements and elevations at the North Anna Unit 3 site. The applicant stated that groundwater is present in unconfined conditions in both the surficial sediments and underlying bedrock. In addition to the nine wells installed as part of the ESP subsurface investigation, the applicant installed seven OWs during the COL site investigation. The applicant stated that the groundwater level in the OWs ranged from an elevation of 72.5 m (238 ft) to an elevation 95.7 m (314 ft) between December 2002 and August 2007. The applicant concluded that the depth of surface groundwater in the Unit 3 power block area ranges from about 5.5 m (18 ft) to 7.6 m (25 ft) below the present surface.

The applicant performed slug tests and obtained hydraulic conductivity values for saprolite and bedrock in the range of 0.076 m (0.25 ft) to 3.02 m (9.9 ft) per day with a geometric mean value of 0.53 m (1.74 ft) per day, and from 0.15 m (0.5 ft) to 1.92 m (6.3 ft) per day with a geometric mean value of 0.62 m (2.05 ft) per day, respectively. Based on this information, the applicant concluded that groundwater movement at the site is generally to the north and east, towards Lake Anna.

The applicant stated that the maximum allowable groundwater level for operation of the power block area of Unit 3 is at an elevation of 87.8 m (288 ft), or 0.6 m (2 ft) below the design plant grade at an elevation of 88.4 m (290 ft). The maximum groundwater level in the power block area of Unit 3, at an elevation of 86.3 m (283 ft), is in FSAR Section 2.4.12.4.

Construction Dewatering and Seepage

FSAR Subsection 2.5.4.6.2 describes dewatering plans during construction and the method used to reduce seepage in both the soil and rock zones at the site. The applicant stated that the relatively low permeability of the saprolite and underlying rock allows the use of gravity-type systems to accomplish the necessary dewatering for all major excavations. Specifically, the applicant concluded that sump-pumping ditches will be adequate to dewater the soil. For rock, the applicant described plans to use sump-pumping to collect water from relief drains to be installed in the major rock excavation walls to prevent the buildup of hydrostatic pressure. Although a head of approximately 12.2 m (40 ft) was noted between the excavation grade and Lake Anna during the final excavation stages for abandoned Units 3 and 4, the applicant stated that no dewatering difficulties were encountered. The applicant attributed this to the tight nature of the joints in the rock below an elevation of about 73.2 m (240 ft). The applicant further concluded that negligible seepage effects from the lake are anticipated since the excavation for Unit 3 is at least 305 m (1,000 ft) from Lake Anna.

Effects of Groundwater Conditions on Foundation Stability

FSAR Subsection 2.5.4.6.3 considers the maximum allowable groundwater level, measured from bearing capacity and settlement analyses, and the effects of the groundwater on the stability of the foundation. Although the applicant concluded that no permanent dewatering system will be needed, based on the estimated groundwater levels and the subsurface material properties at the site, a temporary dewatering system will be necessary during construction of Unit 3.

2.5.4.2.7 Response of Soil and Rock to Dynamic Loading

In FSAR Section 2.5.4.7, the applicant described the seismic ground motion amplification/attenuation estimated from the shear wave velocity profiles of the subsurface materials, the variation of shear modulus and damping with strain, and the site specific acceleration-time histories. The applicant stated the RB and FBs and the CB will be founded on Zone III-IV rock, Zone IV rock, or on concrete placed on the bedrock, although thin layers of Zone III material may be present under the CB. The applicant also indicated the fire water service complex (FWSC), another seismic Category I structure, will be founded on compacted structural fill placed on top of Zone III weathered rock.

Shear Wave Velocity Profile

FSAR Subsection 2.5.4.7.1 describes the development of shear wave velocity profiles for the soil and bedrock at the Unit 3 site. To develop the profiles, the applicant compiled various measurements to determine shear wave velocities in the soil and rock at the Unit 3 site, as described in FSAR Section 2.5.4.4 and summarized in Table 2.5.4-3 of this SER. Because the bedrock supports the majority of the seismic Category I structures, the applicant considered the shear wave velocity profile for the bedrock first. Other materials of interest to the applicant included all zones summarized in Section 2.5.4.2.2 of this SER.

Bedrock. The applicant considered the Zone IV bedrock to be the base rock because the site investigation indicated that below an elevation of 44.2 m (145 ft), the shear wave velocity is fairly constant (2,740 m/s to 3,050 m/s [9,000 fps to 10,000 fps]). Figure 2.5.4-2 of this SER, taken from FSAR Figure 2.5-240, shows the best-fit values applied to the measured shear wave velocity profiles in FSAR Figure 2.5-237. Above an elevation of 56.1 m (184 ft), the applicant used two shear wave velocity profiles—one profile representing pristine rock and the other representing more weathered and fractured rock. The applicant used median shear wave velocities in the randomization model to generate inputs for the site response analysis, which is illustrated in FSAR Figure 2.5-241.

Soil. The applicant used two shear wave velocity profiles for soil in the site response analysis—a natural soil profile and an engineered structural fill profile. The applicant stated that the natural soil profile is outside of the power block and on the planned 3H:1V slope to the southeast of the FWSC, while the engineered structural fill profile is beneath the FWSC foundation. The applicant determined the ground elevation for the natural soil profile to be about 96.0 m (315 ft), with the top of the competent rock 20 m (65 ft) below. The applicant also used this natural soil profile in the slope stability and liquefaction analyses in FSAR Sections 2.5.5 and 2.5.4.8, respectively. Because shear wave velocities are not available for the engineered fill, the applicant used a method developed by Seed and colleagues (1983) and Imai and Tonouchi (1982) to estimate the shear wave velocity profile range using the relationship between the SPT N-value adjusted for overburden pressure and shear wave velocity. The applicant assumed that all Zone IIB saprolite would be removed then used an SPT N-value of N_{60} = 50 blows per 0.3 m (1 ft) to model a site soil profile for structural fill placed above the top of weathered rock from an elevation of 73.2 m (240 ft) to the bottom of the FWSC (elevation 86.0 m [282 ft]). The applicant randomized the soil profiles with the bedrock profile described in the previous section to extend the site shear wave velocity profile below an elevation of 76.2 m (250 ft). The applicant then used the composite as inputs for the site response analyses. The upper and lower bounds used by the applicant in the randomization were 1.225 and 0.816 times the mean shear wave velocity, respectively, which corresponded to 1.5 and 0.67 times the shear modulus.

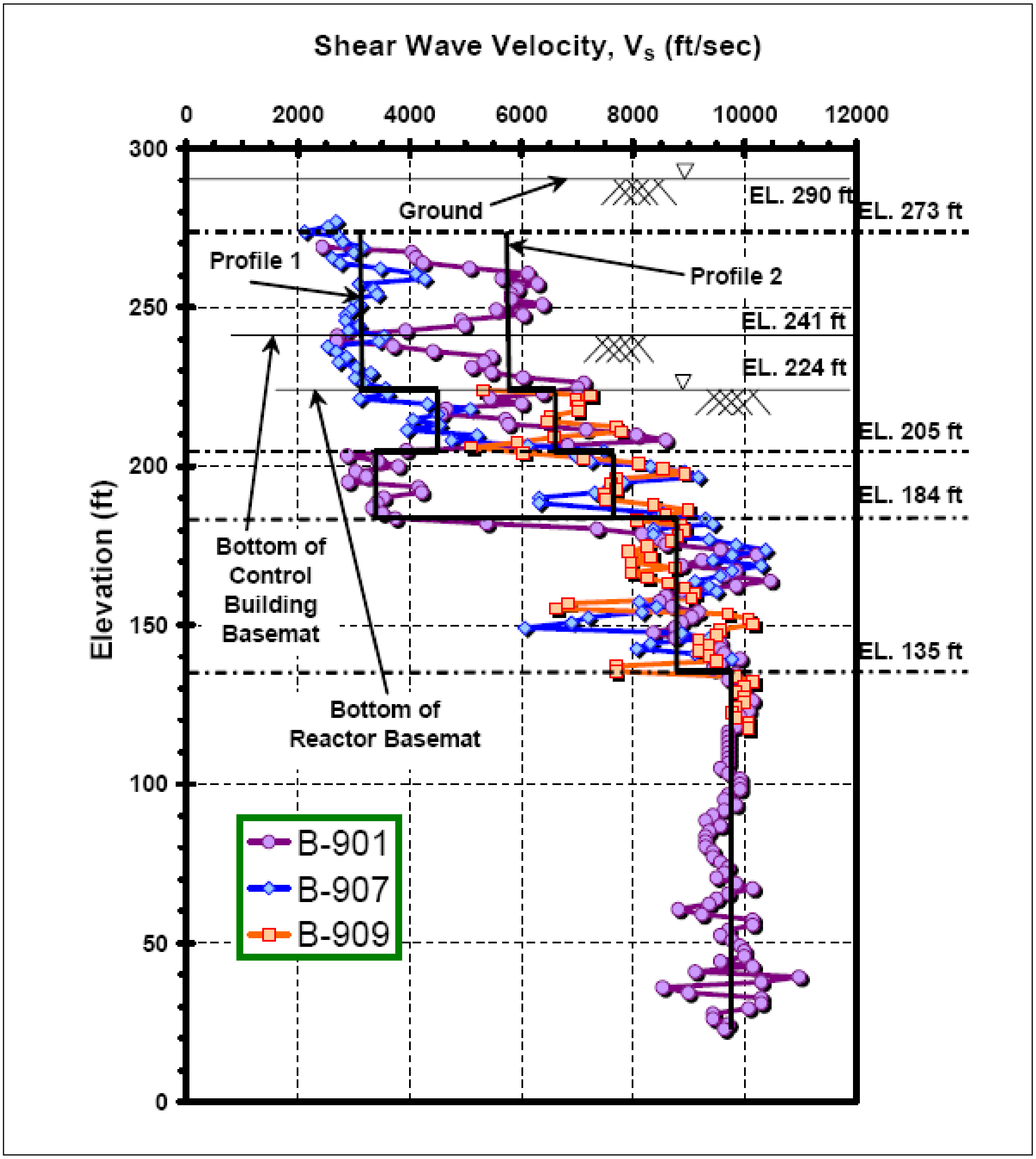

Figure 2.5.4-2 Design Bedrock Shear Wave Velocity Profile (FSAR Figure 2.5-240)

Variation of Shear Modulus and Damping with Strain

FSAR Subsection 2.5.4.7.2 describes the effect of strain on both the shear modulus and damping. The soil degradation properties, the variations of soil shear modulus and damping ratio with shear strain levels, are important inputs considered by the applicant in site seismic response analysis. The applicant divided the section into two subsections to discuss the variations specific to the shear modulus and damping ratio.

Shear Modulus. The applicant used the same shear modulus reduction curve as in the ESP SSAR for the Zone IIA saprolite, which was the mean of a 1970 Seed and Idriss (1970) average curve for sand and five curves from a 1993 Electric Power Research Institute (EPRI) report. In combining these studies, the applicant took into account several factors, including reference strain and effective vertical stress. Unlike ESP site investigations, in which the Zone IIB contained more gravel than Zone IIA, the applicant found no appreciable gravel in either Zone IIA or IIB during the COL investigations. Therefore, the applicant applied the same shear modulus reduction curve to both Zone IIA and IIB soils. The applicant used shear modulus reduction curves from the ESP SSAR to model structural fill and weathered rock. The applicant illustrated these curves, as well as the curve for saprolite, in FSAR Figure 2.5-246 (Figure 2.5.4-3).

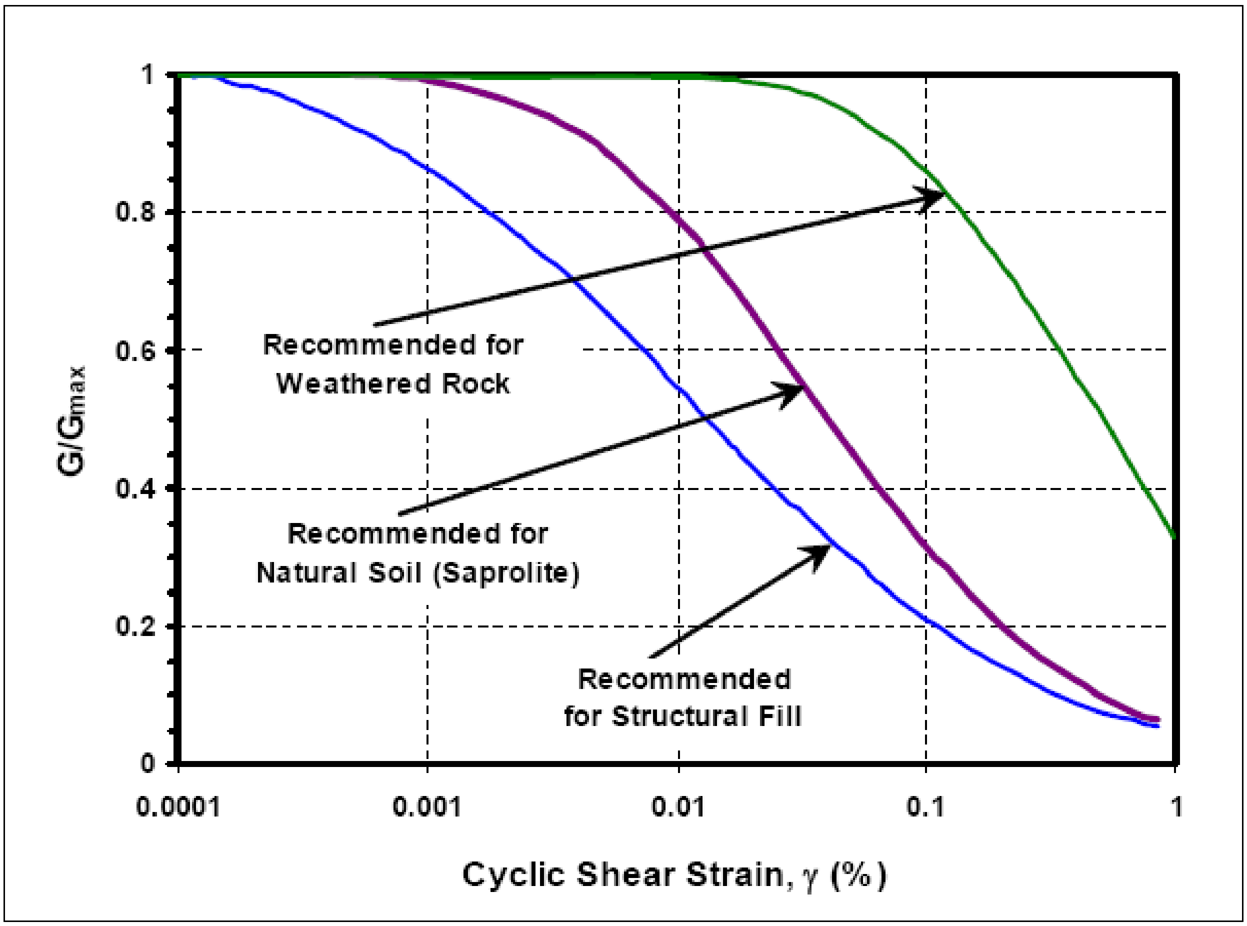

Figure 2.5.4-3 Shear Modulus Reduction Design Curves (FSAR Figure 2.5-246)

To confirm the suitability of the generic EPRI soil reduction curves for the Unit 3 site soils, the applicant performed additional RCTS tests. FSAR Figure 2.5-247 illustrates one set of the comparisons of the RCTS test results and applied 1993 EPRI curves, which showed a normalized shear modulus (G/Gmax) and damping ratio versus shear strain curves. Based on the comparison of RCTS test results and the generic soil degradation curves used in the ESP analyses, the applicant concluded that additional site response runs using the RCTS shear modulus reduction curves are unnecessary. Finally, the applicant concluded that solid rock did not exhibit the strain-softening characteristics; therefore, there is no modulus reduction curve for Zone III-IV rock.

Damping Ratio. The applicant used two different sources to show the damping ratio versus shear strain curves for the various types of rock in the Unit 3 area; the 1993 EPRI curves for granular material, including Zone IIA and IIB saprolites, and curve 3 from the ESP SSAR for Zone III weathered rock. FSAR Figure 2.5-248 illustrates these curves (Figure 2.5.4-4). The applicant concluded that the damping ratio of the Zone III-IV rock does not vary with cyclic shear strain. However, a damping ratio of 1 percent was used due to some intrinsic damping properties of the rock.

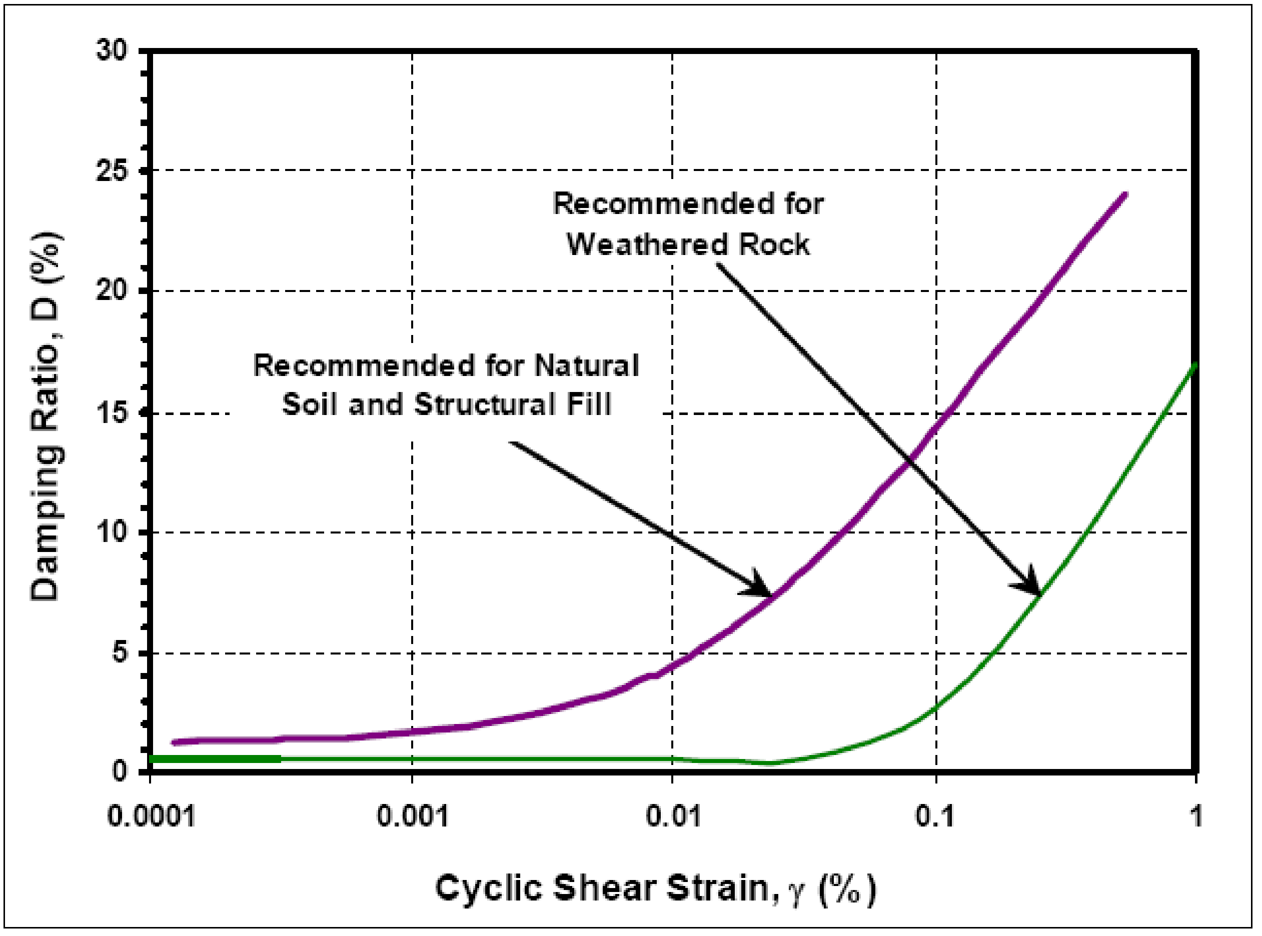

Figure 2.5.4-4 Damping Ratio versus Cyclic Shear Strain (FSAR Figure 2.5-248)

Site Specific Acceleration-Time Histories

FSAR Subsection 2.5.4.7.3 references two single horizontal-component acceleration time histories, as described in the ESP SSAR. The applicant used these two acceleration time histories in the soil column amplification analysis described below.

Rock and Soil Column Amplification/Attenuation Analysis

FSAR Section 2.5.4.7.4 describes the soil and rock amplification/attenuation analyses performed for the Unit 3 site. The applicant estimated the site dynamic responses using the SHAKE2000 computer program and the previously described soil and rock profiles and the soil degradation properties, as well as the site specific acceleration-time histories. In the analyses, the applicant used one rock profile and two soil profiles (one natural soil, the other structural fill) and two acceleration time histories, a low-frequency earthquake time history (moment magnitude of 7.2 with acceleration at bedrock of 0.15g) and a high-frequency earthquake time history (moment magnitude of 5.4 with acceleration at bedrock of 0.39g).

The applicant generated 60 randomized rock profiles in the site response analysis to obtain the seismic responses at the top of competent material at an elevation of 83.2 m (273 ft) and the response spectra for the bottom of the basemats of both the RB and FB foundations and the CB foundation. Soil profiles were generated by the applicant using the shear wave velocity profile, shear modulus, and damping ratio relationships with strain as inputs to the site response analysis. The applicant also produced a maximum acceleration versus depth profiles and determined that the peak accelerations at the natural ground surface were 0.30g and 0.56g for the low- and high-frequency earthquakes, respectively. The applicant then used the mean values of these profiles as inputs for the slope stability analyses (see SER Section 2.5.5) and the mean peak ground acceleration as inputs for the liquefaction analysis described in the following section.

2.5.4.2.8 Liquefaction Potential

FSAR Section 2.5.4.8 describes the liquefaction potential of the soil at the Unit 3 site, including the analyses performed and the conclusions reached based on the results. Soil liquefaction is a process where wet sediment behaves as a liquid due to the loss of shear strength and increased pore pressure often associated with severe shaking; it can lead to foundation bearing failures and excessive settlements. The applicant concluded that due to the density of Zone IIB saprolitic soils and the high percentage of core stone in Zone III weathered rock, neither material has liquefaction potential. The applicant further concluded that the structural fill was not liquefiable because of its angularity and degree of compaction. Although it will not be used to support any seismic Category I structures, the applicant analyzed the liquefaction potential of the Zone IIA saprolitic soil for unexcavated soils outside of the power block. A summary of the results and conclusions is described in the following sections.

Liquefaction Analyses Performed for Unit 3

FSAR Subsection 2.5.4.8.1 describes the liquefaction analyses performed during the site investigations for Unit 3. The applicant determined the magnitude and acceleration values for Unit 3 liquefaction analyses, performed seismic margin assessments, and analyzed samples and CPT results to estimate the liquefaction potential at the Unit 3 site. The applicant followed the guidelines in RG 1.198 regarding the acceptable factor of safety (FS) against liquefaction.

<u>Magnitude and Acceleration Values for Unit 3 Liquefaction Analyses</u>. Based on rock and soil column analyses described in the previous section, the applicant obtained the peak accelerations at the natural ground surface of 0.30 g and 0.56 g for the low- (M = 7.2) and high- (M = 5.4) frequency earthquake, respectively. The applicant rounded 0.30 g to a more conservative value of 0.31 g for use in a liquefaction analysis, while leaving the high-frequency value the same. These values were used as the peak ground accelerations for the liquefaction analyses.

<u>Updated Seismic Margin Assessment</u>. For the seismic margin assessment, the applicant modified the analyses for the Units 1 and 2 power block area by substituting the Unit 3 design accelerations and moment magnitudes, while maintaining the same assumptions used in the original study. Due to the change in peak ground accelerations, the applicant employed magnitude scaling factors of 1.13 and 2.5 in the analysis for the low- and high-frequency

earthquakes, respectively. The analyses conducted by the applicant yielded FS values ranging from 1.05 to 2.95, with an average of 1.6.

Analysis of ESP SSAR Samples and CPT Results. The applicant analyzed ESP SSAR samples and CPT results using the method proposed by Youd and colleagues (2001). A correction factor ($K\sigma$) for high overburden pressures with a relative density of 60 percent was used by the applicant in the analysis. To analyze the SPT results from the ESP SSAR, the applicant used the magnitude scaling factors for low- and high-frequency earthquakes and the Unit 3 peak ground accelerations to determine an FS value against liquefaction of greater than 1.1 for liquefiable samples. Of the eight CPTs considered, the applicant identified five zones in three CPTs with an FS of less than 1.1.

Analysis of Unit 3 SPT Samples and CPT Results. The applicant performed 18 liquefaction analyses for the SPT samples and 9 liquefaction analyses for the CPT results to determine the FS against liquefaction for borings outside the vertical cut excavation zone. The applicant followed the same method used for the ESP SSAR samples, including the same scaling factors for high- and low-frequency earthquakes and the same $K\sigma$. Upon completion of the analyses, the applicant determined that 2 of 18 SPT results and three of nine CPTs analyzed showed an FS against liquefaction of less than 1.1. Finally, the applicant estimated the maximum dynamic settlement of Zone IIA saprolites to be approximately 41 mm (1.6 in).

Conclusions about Liquefaction

The applicant stated that the aforementioned liquefaction analyses do not consider the beneficial effects of age, structure, fabric, and mineralogy. The applicant therefore concluded that the chance of any liquefaction occurring in the Unit 3 site area is very low. Furthermore, the applicant determined that only the Zone IIA saprolite has a potential for liquefaction based on low- and high-frequency seismic characteristics. Finally, the applicant concluded that any liquefaction of the Zone IIA saprolite will not impact the stability of any Unit 3 seismic Category I or II structures, because the safety-related structures will not be founded on Zone IIA material, which will be removed entirely during excavation at the site.

2.5.4.2.9 Earthquake Site Characteristics

FSAR Section 2.5.4.9 refers to FSAR Sections 2.5.2.6.7 and 2.5.2.7, which derive from and discuss the SSE and OBE for the Unit 3 site, respectively. Section 2.5.2 of this SER contains the staff's summary and review of that information.

2.5.4.2.10 Static Stability

FSAR Section 2.5.4.10 describes the allowable bearing capacities and the estimated settlement for each subsurface zone, as well as the earth pressures on below-ground plant walls. The applicant stated that reactor containment buildings at the Unit 3 site will be founded on Zone III-IV or Zone IV bedrock. Additionally, the applicant indicated that if Zone III weathered rock or fractured rock is encountered at the foundation subgrade level, it will be removed and replaced with lean concrete. The applicant also stated that depending on the elevation and location, other seismic Category I structures as well as seismic Category II structures may be founded on different zones. But any Zone IIA saprolite beneath the structures will be removed and replaced with engineered backfill to improve foundation stability and to reduce potential settlement. The applicant identified the RB and FB, CB, and Fire Water Service Complex as the seismic Category I structures; the Service and Ancillary Diesel Buildings as seismic Category II structures; and Turbine and Radwaste Buildings as nonseismic structures.

Bearing Capacity

FSAR Section 2.5.4.10.1 describes the estimation of allowable static and dynamic bearing capacity values for bedrock and soil.

Bedrock. Table 2.5-214 in the FSAR gives the allowable static bearing capacity values for each bedrock zone. The applicant determined that the dynamic allowable bearing capacity was 20 percent of the ultimate crushing strength for rock. Using various building codes for moderately weathered to freshly foliated rock (D'Appolonia et al., 1975), the applicant assumed static bearing capacities of 3,830 kPa (80 ksf) for Zone III-IV and 7,660 kPa (160 ksf) for Zone IV. In order to determine the dynamic bearing capacity for Zone III-IV and Zone IV bedrock, the applicant assumed 20 percent of the design unconfined compressive strengths (62 MPa [1296 ksf] and 117 MPa [2448 ksf]), respectively, resulting in dynamic bearing capacity values of 12,400 kPa (259 ksf) for Zone III-IV and 23,460 kPa (490 ksf) for Zone IV. Finally, the applicant determined that the allowable bearing capacity for concrete fill is 10,240 kPa (214 ksf) for both static and dynamic loading.

Soil. The applicant used Terzaghi's bearing capacity equations, modified by Vesic (1975), to determine the bearing capacity for granular soils including engineered fill. As part of these equations, the applicant used input parameters such as undrained shear strength for clay, cohesion intercept for soil, effective overburden pressure at the base of foundation, effective unit weight of soil, depth from surface to base of the foundation, width of foundation, and multiple bearing capacity and shape factors. Due to the reliance of the equations on foundation size and depth, the applicant determined a different bearing capacity for each foundation.

Allowable Bearing Capacity for Structures. The applicant stated that the allowable static bearing capacity values were conservatively determined. For example, the allowable static bearing capacity for the CB was conservatively chosen as the mean of the values for Zone III and Zone III-IV, even though there may be a limited thickness of Zone III material beneath the foundation. FSAR Table 2.5-215 presents values of allowable bearing capacity under both static and dynamic or transient loading conditions for each zone. The applicant concluded that the values for the Category I foundations exceed the design soil or rock applied bearing stresses listed in FSAR Table 2.5-213.

Groundwater Effects. Assuming that the groundwater table is 0.6 m (2 ft) below grade, the applicant stated that there may be a hydrostatic uplift force on any buried structure. However, the applicant concluded that for the below-ground structures in FSAR Table 2.5-213, the applied foundation loads of at least 287 kPa (6 ksf) resulted in no net uplift forces. The applicant indicated that uplift forces can be significant in the design of buried piping, particularly empty pipes. The applicant concluded that the weight and strength of the backfill above the pipe would need to be analyzed to ensure satisfactory resistance to uplift forces (FS = 3).

Settlement Analysis

FSAR Section 2.5.4.10.2 describes the pseudo-elastic method of analysis used for settlement estimates, an approach suitable for both granular soils and bedrock. The applicant calculated the settlement of discrete layers using a stress-strain model of analysis that determined settlement to a depth where the increase in vertical stress due to the applied load was equal to or less than 10 percent of the applied foundation pressure. FSAR Table 2.5-216 (Table 2.5.4-4 of this SER) summarizes the estimated settlements for major structures. Based on the analysis, the applicant concluded that the settlement of structures founded on Zone III-IV or Zone IV bedrock was negligible; therefore, total and differential settlements under the RB and FB, CB, and FWSC are well within the design limits of the ESBWR DCD.

Table 2.5.4-4 Estimated Settlements for Major Structures

STRUCTURE	APPLIED LOAD KPA (KSF)	SETTLEMENT MM (IN.)			
		CENTER	EDGE	AVERAGE(1)	CORNER
Reactor/Fuel Building	699 (14.6)	3 (0.12)	2 (0.08)	3 (0.10)	1 (0.05)
Control Building	292 (6.1)	1 (0.04)	1 (0.03)	1 (0.035)	0.5 (0.02)
Fire Water Service Complex	165 (3.45)(2)	24 (0.94)	13 (0.51)	19 (0.73)	7 (0.26)
	110 (2.30)(3)	16 (0.62)	9 (0.34)	12 (0.48)	4 (0.17)
Turbine Building	287 (6)	57 (2.24)	29 (1.14)	43 (1.69)	15 (0.58)
Radwaste Building	287 (6)	19 (0.75)	10 (0.38)	14 (0.57)	5 (0.19)
Service Building	192 (4)	40 (1.56)	21 (0.83)	30 (1.20)	11 (0.43)
Ancillary Diesel Building	192 (4)	3.5 (0.14)	1.7 (0.07)	2.8 (0.11)	1 (0.04)

Notes: (1) Average is average of center and edge settlements.
(2) Applied load including weight of basemat.
(3) Applied load excluding weight of basemat.

Earth Pressures

FSAR Section 2.5.4.10.3 describes the estimations made for static and seismic lateral earth pressures for plant below-ground walls. The applicant considered both active and at-rest cases in the calculations. As part of the earth pressure calculations, the applicant used Rankine values as earth pressure coefficients. The applicant assumed that backfill was level with a friction angle between the soil and the wall of zero, hydrostatic pressures were 0.6 m (2 ft) below grade, and the surcharge pressure was 23.9 kPa (500 psf).

The applicant used two methods to estimate active lateral earth pressure cases. The first method (Seed and Whitman, 1970) treated the seismic-induced ground motion as a pseudo-static force acting on yielding walls (with the wall movement about 0.5 percent of the height of the wall). The second method (Ostadan and White, 1998) estimated the seismic soil pressure on building walls rather than on soil-retaining walls, while assuming parameters such as limited wall movement and other soil properties. Because the vertical acceleration in the former method is negligible, the applicant only considered earthquake-induced horizontal ground accelerations. The applicant estimated the seismic lateral at-rest pressures against the buried structure walls, incorporating the response spectrum at the bottom of the RB and FB into the analysis using the latter method, which the applicant concluded was more realistic because it allowed for consideration of soil nonlinear effects that can be significant.

The applicant illustrated lateral earth pressure diagrams for the active and at-rest cases in FSAR Figures 2.5-253 and 2.5-254, respectively, and indicated that the lateral pressures in the figures are best estimates with FS = 1. The applicant concluded that the factor of safety against a gravity wall or structure foundation sliding, as well as for a wall overturning, is normally taken as 1.1 when seismic pressures are included.

2.5.4.2.11 Design Criteria

FSAR Section 2.5.4.11 summarizes the geotechnical design criteria discussed in other sections of the FSAR. FSAR Section 2.5.4.8 specifies that the acceptable FS against liquefaction of site soils should be 1.1. FSAR Section 2.5.4.10 presents bearing capacity and settlement criteria. For static bearing capacity and to prevent the failure of a buried pipe due to uplift forces, the applicant indicated that a minimum FS of 3 is required. For soils, the applicant reduced this FS to 2.25 under dynamic or transient loading conditions. FSAR Section 2.5.4.10 also specifies an FS for lateral earth pressures (FS = 1) and sliding and overturning due to these lateral loads when the seismic component is included (FS = 1.1). FSAR Section 2.5.5.2 concludes that the minimum acceptable long-term static FS against slope stability failure is 1.5. Finally, FSAR Section 2.5.5.3 indicates that 1.1 is the minimum acceptable long-term seismic FS against slope stability failure.

2.5.4.2.12 Techniques to Improve Subsurface Conditions

FSAR Section 2.5.4.12 describes plans to remove Zone IIA saprolite beneath or within the zone of influence of seismic Category I or II structures and replace the saprolite with compacted structural fill. Furthermore, the applicant described plans to remove zones of weathered or fractured rock beneath the RB and FB basemat and replace the rock with concrete. Finally, for nonseismic Category I and II structures, the applicant indicated that improvement of the Zone IIA saprolite will follow the methods described in ESP SSAR Section 2.5.4.12.

2.5.4.3 *Regulatory Basis*

The applicable regulatory requirements for reviewing the applicant's discussion of stability of subsurface materials and foundations are:

1. 10 CFR 50.55a – "Codes and Standards" requires that structures, systems, and components be designed, fabricated, erected, constructed, tested, and inspected in accordance with the requirement of applicable codes and standards commensurate with the importance of the safety function to be performed.

2. 10 CFR Part 50, Appendix A, General Design Criterion 1 (GDC 1), "Quality Standards and Records," requires that structures, systems, and components important to safety be designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety functions to be performed. It also requires that appropriate records of the design, fabrication, erection, and testing of structures, systems, and components important to safety be maintained by or under the control of the nuclear power unit licensee throughout the life of the unit.

3. 10 CFR Part 50, Appendix A, General Design Criterion 2 (GDC 2), "Design Bases for Protection Against Natural Phenomena," relates to the consideration of the most severe of the natural phenomena that have been historically reported for the site and

surrounding area, with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.

4. 10 CFR Part 50, Appendix A, General Design Criterion 44 (GDC 44), “Cooling Water,” requires that a system be provided with the safety function of transferring the combined heat load from structures, systems, and components important to safety to an ultimate heat sink under normal operating and accidental conditions.

5. 10 CFR Part 50, Appendix B, “Quality Assurance Criteria for Nuclear Power Plants and Fuel Processing Plants,” establishes quality assurance requirements for the design, construction, and operation of those structures, systems, and components of nuclear power plants that prevent or mitigate the consequences of postulated accidents that could cause undue risk to the health and safety of the public.

6. 10 CFR Part 50, Appendix S, “Earthquake Engineering Criteria for Nuclear Power Plants,” applies to the design of nuclear power plant structures, systems, and components important to safety to withstand the effects of earthquakes.

7. 10 CFR Part 100, “Reactor Site Criteria,” provides the criteria which guide the evaluation of the suitability of proposed sites for nuclear power and testing reactors.

8. 10 CFR 100.23, “Geologic and Seismic Siting Criteria,” provides the nature of the investigations required to obtain the geologic and seismic data necessary to determine site suitability and identify geologic and seismic factors required to be taken into account in the siting and design of nuclear power plants.

The related acceptance criteria are summarized from SRP Section 2.5.4:

1. **Geologic Features:** In meeting the requirements of 10 CFR Parts 50 and 100, the section defining geologic features is acceptable if the discussions, maps, and profiles of the site stratigraphy, lithology, structural geology, geologic history, and engineering geology are complete and are supported by site investigations sufficiently detailed to obtain an unambiguous representation of the geology.

2. **Properties of Subsurface Materials:** In meeting the requirements of 10 CFR Parts 50 and 100, the description of properties of underlying materials is considered acceptable if state-of-the-art methods are used to determine the static and dynamic engineering properties of all foundation soils and rocks in the site area.

3. **Foundation Interfaces:** In meeting the requirements of 10 CFR Parts 50 and 100, the discussion of the relationship of foundations and underlying materials is acceptable if it includes (1) a plot plan or plans showing the locations of all site explorations, such as borings, trenches, seismic lines, piezometers, geologic profiles, and excavations with the locations of the safety-related facilities superimposed thereon; (2) profiles illustrating the detailed relationship of the foundations of all seismic Category I and other safety-related facilities to the subsurface materials; (3) logs of core borings and test pits; and (4) logs and maps of exploratory trenches in the application for a COL.

4. **Geophysical Surveys:** In meeting the requirements of 10 CFR 100.23, the presentation of the dynamic characteristics of soil or rock is acceptable if geophysical

investigations have been performed at the site and the results obtained therefrom are presented in detail.

5. **Excavation and Backfill:** In meeting the requirements of 10 CFR Part 50, the presentation of the data concerning excavation, backfill, and earthwork analyses is acceptable if: (1) the sources and quantities of backfill and borrow are identified and are shown to have been adequately investigated by borings, pits, and laboratory property and strength testing (dynamic and static) and these data are included, interpreted, and summarized; (2) the extent (horizontally and vertically) of all Category I excavations, fills, and slopes are clearly shown on plot plans and profiles; (3) compaction specifications and embankment and foundation designs are justified by field and laboratory tests and analyses to ensure stability and reliable performance; (4) the impact of compaction methods are incorporated into the structural design of the plant facilities; (5) quality control methods are discussed and the quality assurance program described and referenced; (6) control of groundwater during excavation to preclude degradation of foundation materials and properties is described and referenced.

6. **Groundwater Conditions:** In meeting the requirements of 10 CFR Parts 50 and 100, the analysis of groundwater conditions is acceptable if the following are included in this subsection or cross-referenced to the appropriate subsections in SRP Section 2.4 of the SAR: (1) discussion of critical cases of groundwater conditions relative to the foundation settlement and stability of the safety-related facilities of the nuclear power plant; (2) plans for dewatering during construction and the impact of the dewatering on temporary and permanent structures; (3) analysis and interpretation of seepage and potential piping conditions during construction; (4) records of field and laboratory permeability tests as well as dewatering-induced settlements; (5) history of groundwater fluctuations determined by periodic monitoring of 16 local wells and piezometers.

7. **Response of Soil and Rock to Dynamic Loading:** In meeting the requirements of 10 CFR Parts 50 and 100, descriptions of the response of soil and rock to dynamic loading are acceptable if: (1) an investigation has been conducted and discussed to determine the effects of prior earthquakes on the soils and rocks in the vicinity of the site; (2) field seismic surveys (surface refraction and reflection and in-hole and cross-hole seismic explorations) have been accomplished and the data presented and interpreted to develop bounding P and S wave velocity profiles; (3) dynamic tests have been performed in the laboratory on undisturbed samples of the foundation soil and rock sufficient to develop strain-dependent modulus reduction and hysteretic damping properties of the soils and the results included.

8. **Liquefaction Potential:** In meeting the requirements of 10 CFR Parts 50 and 100, if the foundation materials at the site adjacent to and under Category I structures and facilities are saturated soils and the water table is above bedrock, then an analysis of the liquefaction potential at the site is required.

9. **Static Stability:** In meeting the requirements of 10 CFR Parts 50 and 100, the discussions of static analyses are acceptable if the stability of all safety-related facilities has been analyzed from a static stability standpoint including bearing capacity, rebound, settlement, and differential settlements under deadloads of fills and plant facilities, and lateral loading conditions.

10. **Design Criteria:** In meeting the requirements of 10 CFR Part 50, the discussion of criteria and design methods is acceptable if the criteria used for the design, the design methods employed, and the factors of safety obtained in the design analyses are described and a list of references presented.

11. **Techniques to Improve Subsurface Conditions:** In meeting the requirements of 10 CFR Part 50, the discussion of techniques to improve subsurface conditions is acceptable if plans, summaries of specifications, and methods of quality control are described for all techniques to be used to improve foundation conditions (such as grouting, vibroflotation, dental work, rock bolting, or anchors).

In addition, the geologic characteristics should be consistent with appropriate sections from the following: RG 1.27, "Ultimate Heat Sink for Nuclear Power Plants"; RG 1.28, "Quality Assurance Program Requirements (Design and Construction)"; RG 1.132, "Site Investigations for Foundations of Nuclear Power Plants"; RG 1.138, "Laboratory Investigations of Soils for Engineering Analysis and Design of Nuclear Power Plants"; RG 1.198, "Procedures and Criteria for Assessing Seismic Soil Liquefaction at Nuclear Power Plant Sites"; and RG 1.206, "Combined License Applications for Nuclear Power Plants (LWR Edition)."

2.5.4.4 *Technical Evaluation*

This section provides the staff's evaluation of the geophysical and geotechnical investigations carried out by the applicant to determine the static and dynamic engineering properties of the materials that underlie the Unit 3 site. The staff reviewed the resolution to the COL specific items related to the properties and stability of the soil and rock underlying the site that could affect the safe design and siting of the plant, specifically the Permit Conditions identified in NUREG-1835. The staff also reviewed the applicant's field and laboratory investigations used to determine the geotechnical properties of the soil and rock underlying the Unit 3 site. In addition, the staff observed some of the applicant's onsite borings and field explorations to determine whether the applicant had followed the guidance in RG 1.132.

The staff also evaluated the information provided to resolve DCD COL Item 2.0-29-A and ESP Permit Conditions 3.E(6) and 3.E(7). DCD COL Item 2.0-29-A requires the COL applicant to complete additional borings at the COL site to address the provisions listed in ESBWR DCD Table 2.0-1 regarding stability of subsurface material and foundation requirements, which was resolved in Section 2.5.4.4.3 of this SER. Permit Condition 3.E(6) requires the applicant to include information on geologic mapping of future excavations for safety-related structures and to evaluate any unforeseen geologic features encountered at the site area, which was resolved in Section 2.5.4.4.5 of this SER. Permit Condition 3.E(7) requires the applicant to improve Zone II saprolitic soils to reduce any liquefaction potential if safety-related structures are to be founded on them, which was resolved in Section 2.5.4.4.8 of this SER.

2.5.4.4.1 Description of Site Geologic Features

FSAR Section 2.5.4.1 references FSAR Sections 2.5.1.1 and 2.5.1.2. The staff's evaluations of and conclusions for these sections are presented in Section 2.5.1.4 of this SER.

2.5.4.4.2 Properties of Subsurface Materials

FSAR Section 2.5.4.2 describes the subsurface materials and the field investigations and laboratory tests used to determine the static and dynamic engineering properties of these materials at the Unit 3 site. The staff reviewed the applicant's description of the four zones of subsurface rock and the methods used to determine the engineering properties and to develop the subsurface profile (see SER Figure 2.5.4-1). The applicant utilized multiple field and laboratory investigations including boring sample analysis, observation wells, and CPTs. The staff also reviewed the applicant's use of the latest field and laboratory methods, in accordance with RGs 1.132 and 1.138, to determine the properties of the subsurface materials. The staff determined that the information is acceptable because the applicant had followed the guidelines of RGs 1.132 and 1.138.

In addition, the staff reviewed the engineering properties that were the result of the numerous field and laboratory investigations. In **RAI 2.5.4-1**, the staff asked the applicant to justify the use of an effective cohesion value (c') of 6.0 kPa for Zone IIA soil, given that the SPT and C-U test results imply very little effective cohesion (interpreted as c' = 0). In response to this RAI, the applicant stated that the effective cohesion value was derived from various data sources. The applicant stated that given the mineralogy, texture, and fabric of the Zone IIA saprolite, some effective cohesion was assumed. To determine the effective cohesion value, the applicant performed consolidated-undrained triaxial tests on samples of the Zone IIA saprolite and used the results—combined with the mineralogy, texture, and fabric observations—to select the effective cohesion value of 6 kPa for the Zone IIA saprolite.

The staff considered the applicant's response, and although it is not a conservative approach, the staff concluded it was reasonable. Based on the results of the staff's independent confirmatory analysis, the staff noted that the small effective cohesion value does not produce notable changes in slope stability analyses with relatively large internal friction angles. The staff also noted, based on the results of the confirmatory analysis, that with a decrease of c' value from 6.4 to 5.5 kPa (135 to 115 psf), the factor of safety for slope stability only decreases from 1.29 to 1.26. Section 2.5.5.4.2 of this SER provides additional information regarding the staff's confirmatory analysis. Based on the results of the confirmatory analysis, which suggest that the applicant's approach to determining the effective cohesion value is reasonable, the staff concluded that the applicant has provided adequate information to resolve **RAI 2.5.4-1**.

Based on the acceptable determination of the subsurface properties and the resolution of **RAI 2.5.4-1**, the staff concluded that the field investigations and laboratory testing performed by the applicant to determine the subsurface profile are sufficient to meet the criteria of 10 CFR Parts 50 and 100 and were performed in accordance with RGs 1.132 and 1.138.

2.5.4.4.3 Foundation Interfaces

Section 2.5.4.3 in the FSAR describes and illustrates the location of site exploration points for the Unit 3 subsurface investigation including borings, observation wells, CPTs, electrical resistivity tests, and test pits made in the power block area; the excavation plan for the safety-related and other major facilities including the plan outline of these structures, plan dimensions, and the bottom of foundation elevations for the major structures; the location of six subsurface profiles; and cross sections of the structure foundations and the proposed excavation and backfilling limits.

The staff reviewed the additional borings performed by the applicant to confirm engineering properties and the stability of soil and rock underlying future plant structures, systems, and components. As part of this review, the staff also examined the site exploration points for the Unit 3 subsurface investigations, including FSAR Figure 2.5-221 (see Figure 2.5.4-5 of this SER), which shows the locations of additional boreholes, observation wells, CPTs, electrical resistivity tests, and test pits. This information was considered by the staff in concert with the exploration points outside of the power block area (see FSAR Figure 2.5-222). The staff

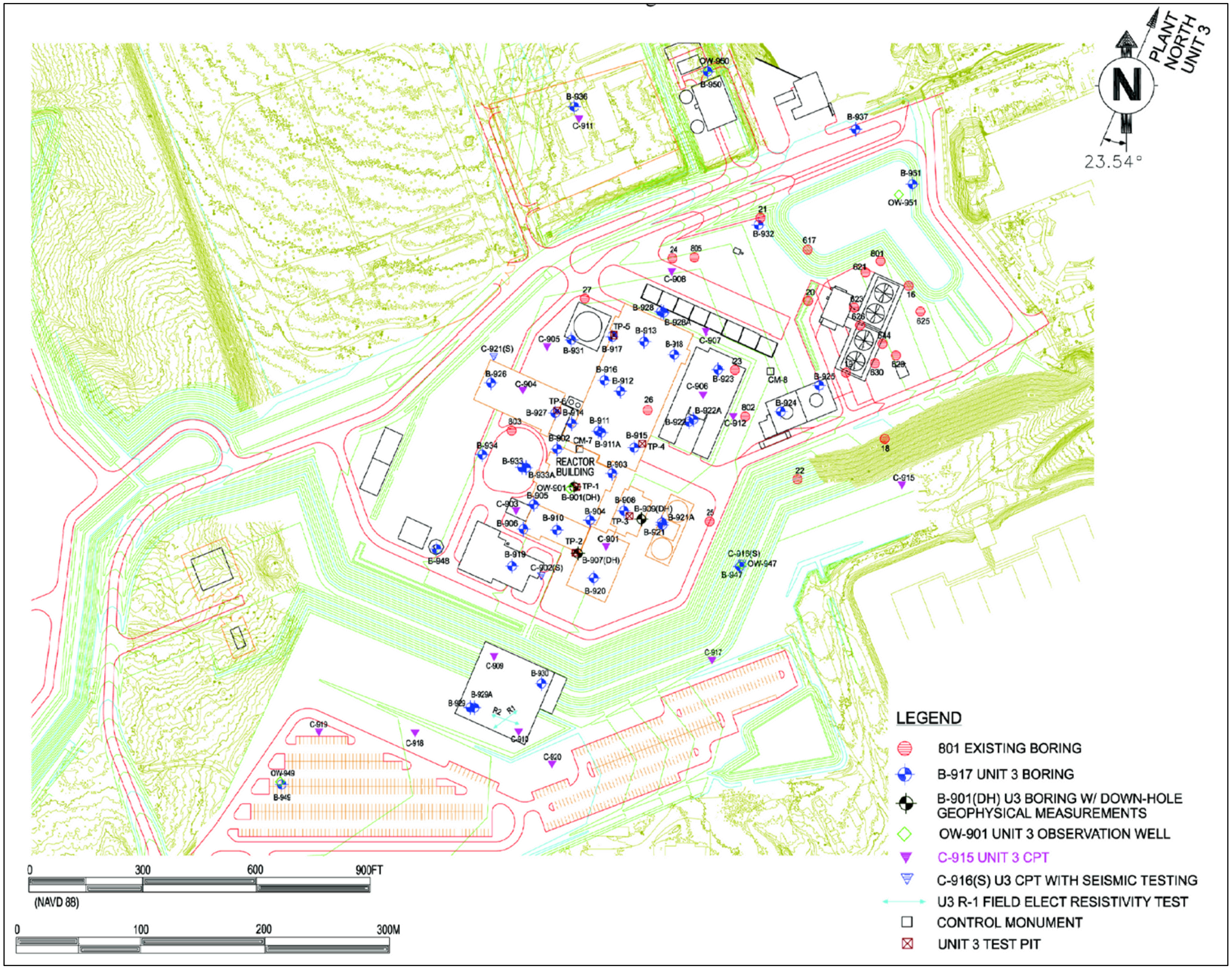

Figure 2.5.4-5 Unit 3 Boring Locations (FSAR Figure 2.5-221)

concluded that the additional boreholes are sufficient to resolve DCD COL Item 2.0-29-A, which requires the COL applicant to complete additional borings at the COL site to address the provisions listed in ESBWR DCD Table 2.0-1, regarding stability of subsurface material and foundation requirements.

In addition, the staff reviewed the boring logs submitted in Appendix 2.5.4AA for completeness, in accordance with 10 CFR Parts 50 and 100. These regulations also require the applicant to submit plot plans and profiles of all seismic Category I facilities for comparison with the subsurface profiles and material properties at the Unit 3 site. The staff reviewed the subsurface profiles and cross sections in FSAR Figures 2.5-215 through 2.5-220 (see sample Figure 2.5.4-1) and plot plans in FSAR Figure 2.5-214. The staff concluded that the information is acceptable and satisfies the previously mentioned requirements.

Finally, the staff reviewed the future excavation and backfill plans for the Unit 3 site. This review included the applicant's excavation and backfill plans as presented in FSAR Figures 2.5-214 and 2.5-229 through 2.5-234 (see Figure 2.5.4-6 of this SER for an example). The staff concluded that the information illustrated in these figures, together with the description in FSAR Section 2.5.4.3, meets the minimum acceptability requirements of 10 CFR Parts 50 and 100.

Resolution of ESP COL Action Items 2.5-1 through 2.5-3

ESP COL Action Item 2.5-1 was resolved in Section 2.5.1.4 of this SER.

ESP COL Action Item 2.5-2 requires the applicant referencing the North Anna ESP to submit plot plans and profiles for all Seismic Category I structures for comparison with the subsurface profile and material properties. FSAR Section 2.5.4.3 describes the locations of site exploration borings and provides the excavation plan for the safety-related structures, plan dimensions, and bottom of foundation elevations for those structures (see FSAR Figure 2.5-214).

FSAR Figures 2.5-215 through 2.5-220 show the subsurface profiles with the cross sections of foundation structures superimposed for comparison. Because the applicant has included the plot plans and profiles that compare the foundations of safety-related structures to the subsurface profiles at the Unit 3 site, the staff concluded that the applicant has provided sufficient information to satisfy the requirements of ESP COL Action Item 2.5-2. Accordingly, the staff considers ESP COL Action Item 2.5-2 to be resolved.

ESP COL Action Item 2.5-3 requires the applicant referencing the North Anna ESP to provide detailed excavation and backfill plans for the Unit 3 site. In FSAR Section 2.5.4.3, the applicant provided the plot plans and comparison figures of the excavation, subsurface profiles, and safety-related foundations. The plot plans and excavation and backfill plans were presented in FSAR Figure 2.5-229, reproduced as SER Figure 2.5.4-6. In FSAR Section 2.5.4.5.3, the applicant described the backfill sources, compaction, and quality control measured to be implemented during the period of excavation and backfilling. The applicant included necessary details such as the source and type of backfill, the extent of excavations, and the compaction specifications that the backfill will be designed to meet. The applicant also described the quality control measures that will be employed to ensure the backfill met the design values. The staff concluded that the applicant has provided adequate information to describe the excavation and backfill plans for the Unit 3 site as required by ESP COL Action Item 2.5-3. Accordingly, the staff considers ESP COL Action Item 2.5-3 to be resolved.

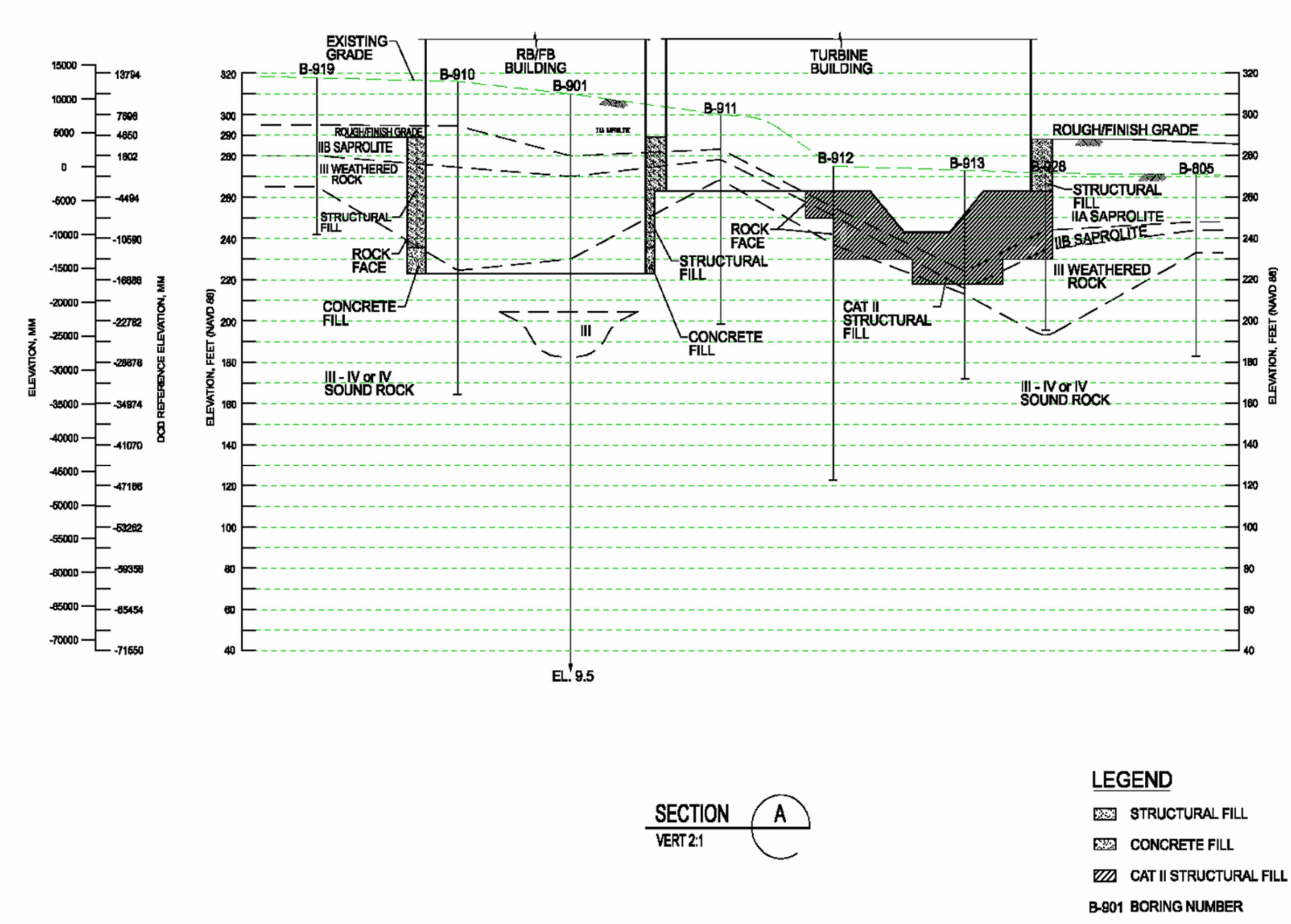

Figure 2.5.4-6 Excavation and Backfill Plan for Cross Section A-A’ (FSAR Figure 2.5-229)

Based on the information and findings above, the staff concludes that the discussion of the foundation interfaces, including the subsurface investigations at the Unit 3 site, is acceptable and meets the criteria of 10 CFR Parts 50 and 100.

2.5.4.4.4 Geophysical Surveys

FSAR Section 2.5.4.4 describes the geophysical investigations undertaken by the applicant to determine soil and rock dynamic properties. The applicant used field electrical resistivity testing, geophysical downhole testing, and seismic CPTs during both ESP and COL site investigations, as well as laboratory measurements of soil and rock properties to determine the shear wave velocities.

The staff reviewed the applicant's use of the latest geophysical and geotechnical measurement methods and equipment in accordance with RGs 1.132 and 1.138, as well as the results that detail the dynamic properties of the soil and rock underlying the site, in accordance with 10 CFR 100.23. The staff concluded that the applicant had used acceptable methods to measure the shear wave velocity for each of the soil and rock zones at the Unit 3 site. The staff further concluded that the applicant had adequately detailed the results of laboratory analyses to confirm the validity of the dynamic properties obtained from field explorations and tests.

The staff concluded that the results of the geophysical surveys completed as part of the COL application and presented in the FSAR are acceptable and in accordance with 10 CFR 100.23. However, the staff noted a discrepancy between the previous ESP site investigations and those completed in support of the COL application. In **RAI 2.5.4-2**, the staff requested the applicant to explain the difference in the Unit 3 site median shear wave velocity determined in the ESP SSAR versus the 36 to 50 percent higher median shear wave velocity in the FSAR.

The applicant's response stated that the reasons for the difference in median shear wave velocity values between the ESP SSAR and FSAR are two-fold. First, the applicant stated that the shear wave velocity values in the ESP SSAR were taken across a widely spaced area that does not reflect the conditions of the Unit 3-specific location. Also, the applicant noted that with the FSAR values, the measurements in rock were taken from closely spaced boreholes at the specific location of Unit 3 seismic Category I structures. Second, the applicant stated that there was a difference in the equipment used to measure the ESP SSAR and FSAR values. The applicant used P-S suspension logging equipment to measure the FSAR median shear wave velocity, a more sophisticated method than the crosshole and downhole testing methods used during the ESP investigations and reported in the ESP SSAR.

The staff noted that the values incorporated into the site response analysis were higher than those in the ESP. However, the staff concluded that this difference did not matter because the site response was used to determine the GRMS for the site. Therefore, the staff concurs with the applicant's conclusion that the P-S suspension logging equipment will yield a better constrained measurement of median shear wave velocity. The staff also considered the refined locations of boreholes used to measure velocity values and agrees with the applicant that a broader distribution of boreholes, coupled with a less sophisticated testing method, would explain the variance in median shear wave velocity between the ESP SSAR and FSAR. Accordingly, the staff considers **RAI 2.5.4-2** to be resolved.

Based on the review of FSAR Section 2.5.4.4, the acceptability of the results of geophysical surveys performed in support of the COL application and the applicant's response to **RAI 2.5.4-2**, the staff concluded that the applicant has adequately determined the dynamic properties of soil and rock through the geophysical surveys of the Unit 3 site to satisfy the criteria of 10 CFR 100.23.

2.5.4.4.5 Excavation and Backfill

FSAR Section 2.5.4.5 describes the extent of seismic Category I excavations, fills, and slopes, the excavation methods and stability, and the backfill sources including quantity, compaction, and quality control. The applicant also addressed Permit Condition 3.E(6), as identified in the North Anna ESP, in this section. This permit condition requires the applicant to include information on geologic mapping of future excavations for safety-related structures and to evaluate any unforeseen geologic features encountered at the site area.

The staff reviewed the extent of seismic Category I excavations, fills, and slopes, especially FSAR Figure 2.5-214 (Figure 2.5.4-7 of this SER), which shows the planned excavations relative to power block foundations. The staff compared the excavation plans with the requirements of 10 CFR 100.23 and concluded that the description of the extent of the excavations, fills, and slopes is acceptable. The staff also concluded that this information satisfies Permit Condition 3.E(6), which requires the applicant to provide information on geologic mapping of future excavations. The staff then reviewed the excavation methods and stability for the Unit 3 site, which included a review of the soil excavation methods as well as the blasting techniques used for rock excavations against the requirements of 10 CFR 100.23 and guidance contained in RG 1.132. The staff concluded that the methods of excavation and stability are acceptable because the applicant has described plans to follow OSHA regulations when excavating into soil and will use conventional and widely accepted industry equipment to accomplish the excavation. Furthermore, the staff concluded that the applicant's plans to monitor blasting, including the use of controlled blasting techniques as part of the excavation into rock, are acceptable to reduce vibrations at the site during the period of excavation.

The staff also considered the resolution of ESP COL Action Item 2.5-3, which required the applicant to provide the details of the excavation and backfill plans to be used at the NAPS Unit 3 site. The staff resolved ESP COL Action Item 2.5-3 in Section 2.5.4.4.3 of this SER.

The staff also reviewed the descriptions of fill the applicant proposed to use in place of the removed weathered rock at the site. The staff determined that the applicant did not provide adequate information regarding the concrete fill that would make up the seismic Category I foundation building mats. Nor did the staff find sufficient information to confirm that the proposed fill met the requirements of the ESBWR DCD and the required parameter values.

In **RAI 2.5.4-3**, the staff requested the applicant to provide additional material and engineering properties for the concrete fill that will replace weathered rock exposed at the bottom of excavation for seismic Category I building foundation mats. The applicant's response stated that the properties of the concrete fill were yet to be determined. However, the applicant also stated that the concrete mix will be designed to have a shear wave velocity within the same range as the Zone II-IV rock at the NAPS site. The applicant also stated that the FSAR will be revised to include a statement that the shear wave velocity of the concrete fill will be within the range of Zone III-IV rock.

The staff considered this information, including the applicant's statement that although the concrete may have a lower strength, the shear wave velocity will be the same as the Zone III-IV rock. The staff noted that in addition to having a shear wave velocity within the same range as the bedrock, the concrete fill should also have a similar strength. In order for the staff to fully

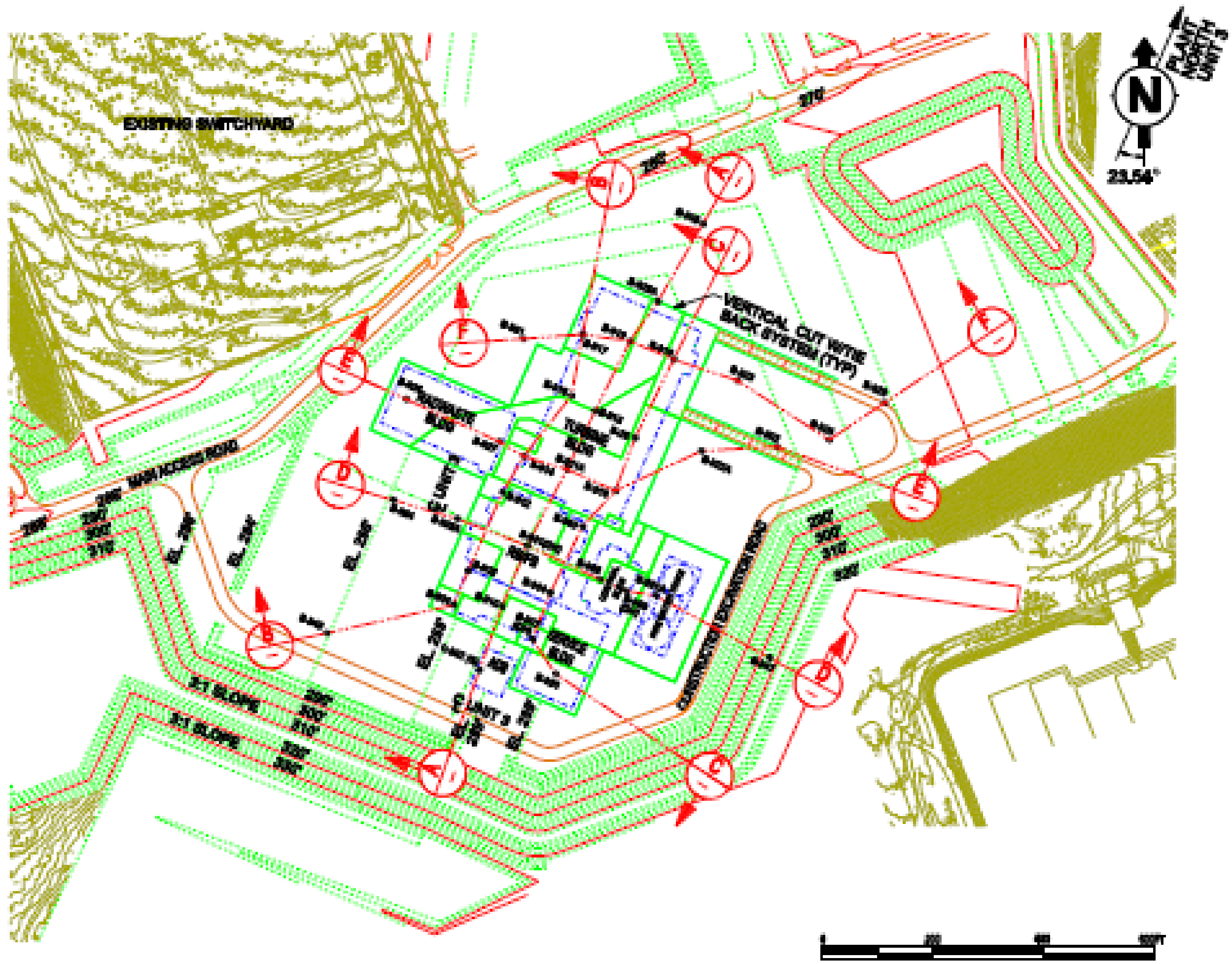

Figure 2.5.4-7 Plans for Excavation (FSAR Figure 2.5-214)

evaluate and determine the acceptability of the engineering properties of the concrete fill, the strength of the fill needs to be considered along with the shear wave velocity of the fill material. Accordingly, in supplemental **RAI 2.5.4-12**, the staff asked the applicant to provide the engineering properties of concrete fill, and, if the properties are assumed, to clarify how to ensure the in-place concrete fill will have the same engineering properties as that assumed in stability analyses. This RAI is being tracked as **Open Item 2.5.4-12**.

In **RAI 2.5.4-4**, the staff asked the applicant to provide additional information to ensure that the static and dynamic properties of the backfill soil will meet or exceed the requirements of the ESBWR DCD, as well as the parameter values used for other site estimates, such as site seismic response or bearing capacity. In the response, the applicant first addressed how the requirements of the ESBWR DCD will be met or exceeded. The applicant clarified that the FWSC is the only seismic Category I structure that will be founded on backfill; all other seismic Category I structures will be founded on bedrock. The applicant described the method that was used to determine the shear wave velocity beneath the FWSC. The applicant estimated a lower bound velocity within the fill of between 300 m/s (1,000 fps) and 335 m/s (1,100 fps), which is above the minimum shear wave velocity of 300 m/s (1,000 fps) stated in the ESBWR DCD. Second, the applicant's response addressed how the parameter values would be met or exceeding at the NAPS site. The applicant stated that with respect to the site seismic response, the shear wave velocity would be within the ESBWR DCD requirements. The applicant also stated that due to the high blow counts (greater than 30 blows per foot) measured at the site, liquefaction would not occur. The applicant also estimated bearing capacity and earth pressures and stated that settlement of the FWSC would be measured by the settlement monitoring program.

The staff reviewed the response, and although the applicant stated that the design parameters and ESBWR DCD requirements would be met during and after construction, the applicant had not provided the means by which the successful meeting of these criteria would be proven during and after construction. Accordingly, in supplemental **RAI 2.5.4-13**, the staff asked the applicant to provide (1) a detailed description on how to ensure that the static and dynamic properties of the backfill soil will meet or exceed both the requirements of the ESBWR DCD and the parameter values used in the analyses as described in the application, such as site seismic response analysis, bearing capacity and settlement estimates and SSI analysis; and (2) explain how to confirm that the design criteria of the ESBWR DCD and the parameter values related to backfill have been met during and after construction. This RAI is being tracked as **Open Item 2.5.4-13**.

Backfill ITAAC

The applicant also provided ITAAC in Tables 2.4.1-1 "Compaction Requirements for Backfill under Category I Structures" and 2.4.1-2 "ITAAC for Backfill under Category I Structures" in Part 10 "Tier 1/ITAAC," Section 2.4 "Site Specific ITAAC" of their Combined License Application. The staff reviewed these tables, as well as the applicant's response to RAI 2.5.4-4 regarding the backfill, and concludes that the backfill ITAAC for the NAPS site clearly describes the inspection and testing to be performed to ensure the quality of the backfill compaction and meet the design requirements for backfill material. However, the backfill ITAAC does not specify how the standard design site parameter for the minimum shear wave velocity, as defined in ESBWR DCD Tier 1, Table 5.1-1 and Tier 2, Table 2.0-1 "Envelope of ESBWR Standard Plant Site Design Parameters," will be met beneath the FWSC. The staff considers the need to specify how the standard design site parameter for the minimum shear wave velocity beneath the FWSC will be met to be part of Open Item 2.5.4-13.

The applicant provided ITAAC in Tables 2.4.1-1 “Compaction Requirements for Backfill under Category I Structures” and 2.4.1-2 “ITAAC for Backfill under Category I Structures” in Part 10 “Tier 1/ITAAC,” Section 2.4 “Site Specific ITAAC” of their Combined License Application. The staff reviewed these tables, as well as the applicant’s response to **RAI 2.5.4-4** regarding the backfill, and concludes that the backfill ITAAC for the NAPS site clearly describes the inspection and testing to be performed to ensure the quality of the backfill compaction and meet the design requirements for backfill material. However, the backfill ITAAC does not specify how the standard design site parameter for the minimum shear wave velocity, as defined in ESBWR DCD Tier 1, Table 5.1-1 and Tier 2, Table 2.0-1 “Envelope of ESBWR Standard Plant Site Design Parameters,” will be met beneath the FWSC. The staff considers the need to specify how the standard design site parameter for the minimum shear wave velocity will be met beneath the FWSC as part of **Open Item 2.5.4-13**.

Based on the staff’s review of FSAR Section 2.5.4.5 and the acceptability of the description of the excavation and backfill plans, including the sources and quantities; extent of excavations; compaction specifications; quality control; and groundwater control methods—as well as the resolution of ESP COL Action Item 2.5-3 in SER Section 2.5.4.4.3, and the applicant’s responses to **RAI 2.5.4-3** and **RAI 2.5.4-4**, the staff concluded that the information provided by the applicant related to excavation and backfill is acceptable. The staff’s review of the issues related to **Open Items 2.5.4-12 and 2.5.4-13**, regarding backfill properties, will be completed following closure of the open items.

2.5.4.4.6 Groundwater Conditions

In FSAR Section 2.5.4.6, the applicant described groundwater measurements and elevations and construction dewatering plans. This section also references FSAR Section 2.4.12 for a more detailed description of the groundwater conditions at the Unit 3 site. The staff reviewed the groundwater information in FSAR Section 2.5.4.6, including conditions before, during, and after excavation and the associated dewatering plan, as well as measures to minimize drawdown effects on the surrounding environment. The staff concluded that this information is acceptable and meets the requirements of 10 CFR Part 100 because it includes sufficient detail on the groundwater conditions at the site such as measurements and elevations, as well as dewatering plans for the excavation and construction at the site.

Resolution of ESP COL Action Item 2.5-4

ESP COL Action Item 2.5-4 requires the applicant referencing the North Anna ESP to evaluate the groundwater conditions as they affect foundation stability and to provide detailed dewatering plans. In FSAR Section 2.5.4.6.3, the applicant reviewed the effects of groundwater conditions on foundation stability. The applicant concluded that the maximum allowable groundwater level was at least 0.6 m (2 ft) below the final plant grade, and there were no buoyancy issues with deep buried structures. The applicant also stated that no permanent dewatering system will be required. The staff considered this information and agrees with the applicant that due to the groundwater level below the final grade of the site, there will be no buoyancy issues at the site, and a permanent dewatering program will not be necessary. Therefore, the staff concluded that the applicant had provided sufficient information to address the requirements of ESP COL Action Item 2.5-4. Accordingly, the staff considers ESP COL Action Item 2.5-4 to be resolved.

The staff also considered the criteria of RG 1.132 and 10 CFR 100.23. Based on the level of detail provided to describe the groundwater conditions at the site, including groundwater elevations, dewatering plans, and the proximity of groundwater to the final plant grade and foundations—as well as the resolution of ESP COL Action Item 2.5-4—the staff concluded that the applicant's assessment of groundwater conditions is acceptable and meets the criteria of 10 CFR Parts 50 and 100.

2.5.4.4.7 Response of Soil and Rock to Dynamic Loading

FSAR Section 2.5.4.7 describes the applicant's shear wave velocity design profiles to determine the response of the soil and rock underlying the Unit 3 site to dynamic loading. The applicant also described shear modulus and damping variations with strain, and amplification/attenuation analyses performed for rock and soil.

The staff reviewed the applicant's site dynamic response, particularly the shear wave velocity profiles for the soil and rock to ensure that the velocities meet the minimum criteria of the ESBWR Design. In **RAI 2.5.4-5**, the staff asked for clarification of the differences between the shear wave velocity of the backfill in FSAR Figure 2.5-244 (152 to 724 m/s) and that of FSAR Table 2.0-201 (minimum 1,073 m/s) for the area beneath the FWSC building. The applicant's response stated that the estimated shear wave velocity shown in FSAR Figure 2.5-244 is plotted versus depth, whereas the minimum shear wave velocity beneath the FWSC in Table 2.0-201 is a weighted average of the backfill velocities (between 300 and 335 m/s [1,000 and 1,100 fps]) and the velocities of the underlying units, including the bedrock, which has a lower bound shear wave velocity value of over 2,440 m/s (8,000 fps).

The staff considered the applicant's response and noted that the minimum shear wave velocity listed in FSAR Table 2.0-201 is misleading, because it includes the bedrock in the calculation of the average soil shear wave velocity. Furthermore, the staff noted that, as stated in the ESBWR DCD, the equivalent uniform shear wave velocity is a lower bound value after taking into account uncertainties of soil over the entire soil column underneath the structure at seismic strain, and as such, the averaging of shear wave velocity should be used for similar soils exclusive of the bedrock at the site. The staff concluded that the shear wave velocity presented by the applicant in FSAR Table 2.0-201, which includes the bedrock in the average calculation, is unacceptable and needs to be adjusted to average only the soil layer shear wave velocities. In supplemental **RAI 2.5.4-14**, the staff asked the applicant to provide the minimum shear wave velocity parameter for soil below the foundation so that the staff can evaluate the adequacy of backfill properties used in the site stability analysis. This RAI is being tracked as **Open Item 2.5.4-14**

The staff reviewed the applicant's modeling of the variation of soil shear modulus and damping with cyclic shear strain. The staff compared RCTS test results and the generic soil degradation curves used in ESP analyses, which yielded good agreement with the EPRI curves. The staff also reviewed the curves that the applicant had selected for each of the soil and rock zones to determine whether the appropriate criteria, such as grain size, cohesiveness, confining pressure, and shear wave velocity, were used. The staff concluded that the shear modulus and damping curves selected by the applicant were based on appropriate criteria and are suitable for Zone IIA, IIB, and III soil and rock. The staff further concluded that the damping ratio of 2 percent for the Zone III-IV rock is acceptable, because this is a conservative value for this rock type.

Resolution of ESP COL Action Items 2.5-5 and 2.5-9

ESP COL Action Item 2.5-5 requires the applicant referencing the North Anna ESP to provide soil column amplification/attenuation analyses once the specific locations have been selected for the nuclear power plant structures. FSAR Section 2.5.4.7.4 describes the rock and coil column amplification/attenuation analyses completed for Unit 3 using the SHAKE2000 computer program. The applicant performed the analysis to obtain the seismic response at the top of competent material at the RB and FB location and for the natural soil profile at the site. The staff concluded that the applicant had provided sufficiently detailed descriptions of the amplification/attenuation analyses to be used in the staff's evaluation of the applicant's site response, as discussed in Section 2.5.2.4 of the FSAR, which also meet the requirements of ESP COL Action Item 2.5-5. Therefore, the staff considers ESP COL Action Item 2.5-5 to be resolved.

ESP COL Action Item 2.5-9 requires the applicant referencing the North Anna ESP to ensure that the average shear wave velocity of the material underlying the foundation for the reactor containment equals or exceeds that of the chosen design. FSAR Section 2.5.4.7.1 describes the shear wave velocity determinations the applicant made for both soil and bedrock at the Unit 3 site. The applicant compared the soil and bedrock profiles to the DCD site parameter values in FSAR Table 2.0-201 and concluded that the shear wave velocity values at Unit 3 were greater than the minimum shear wave velocity design values. Based on the comparison of the DCD design values to the site parameters, which illustrate that the site exceeds the minimum design values, the staff concluded that the applicant did not provide sufficient information to address the requirements of ESP COL Action Item 2.5-9. The resolution of ESP COL Action Item 2.5-9 directly relates to the issue addressed in **Open Item 2.5.4-12**. Accordingly, until **Open Item 2.5.4-12** is closed, **ESP COL Action Item 2.5-9** cannot be resolved.

The staff reviewed FSAR Section 2.5.4.7 and concludes that the applicant's modeling of variations in shear modulus and damping ratios with shear strain, as well as the acceptability of the amplification/attenuation analyses to resolve ESP COL Action Item 2.5-5, is acceptable. The staff's review of the issues related to **Open Item 2.5.4-14**, regarding the use of the minimum shear wave velocity beneath the foundation in the site stability analyses, and **Open Item 2.5.4-12**, as it relates to ESP COL Action Item 2.5-9, regarding the shear wave velocity of the material beneath the foundation, will be completed following closure of the open items.

2.5.4.4.8 Liquefaction Potential

The staff reviewed FSAR Section 2.5.4.8 and evaluated the applicant's liquefaction analyses to ensure conformance with the criteria in RG 1.198. The staff's review focused on the applicant's conclusion that only the Zone IIA saprolite is susceptible to liquefaction, and on the applicant's liquefaction analyses for Zone IIA saprolites outside of the power block area for soils that will not be excavated as well as the parameter inputs to these analyses. The staff also determined whether the applicant had met ESP Permit Condition 8. This permit condition requires the applicant to improve Zone II saprolitic soils and to reduce any liquefaction potential if safety-related structures are to be founded on them.

In Section 2.5.4.8 of the FSAR, the applicant stated that all safety-related structures would be founded on rock, concrete on rock, or engineered structural fill. The staff reviewed this statement, along with the applicant's plans to remove Zone II saprolite from beneath building foundations at the Unit 3 site. The staff concluded that the requirements of Permit Condition 8 had been met.

The staff reviewed seismic margin assessments and samples and CPT results analysis to estimate the liquefaction potential at the Unit 3 site. For each analysis, the applicant used the method proposed by Youd et al. (2001) and varied the peak earthquake acceleration and the earthquake magnitude. The staff determined that this method was used in accordance with RG 1.198 and concluded that the applicant had used the latest empirical method for the liquefaction analyses. The staff further concluded that the applicant had adequately varied the significant soil and seismic input parameters and the liquefaction analyses are acceptable.

The staff also reviewed the liquefaction analyses performed for the engineered backfill, which was designed to be granular material that may be saturated, because the designed maximum groundwater level will be above the bottom of the backfill layer. In **RAI 2.5.4-7a**, the staff asked why a liquefaction potential analysis was not performed for the backfill soil, in accordance with the recommendations of RGs 1.206 and 1.198. The applicant's response stated that the analyses for backfill soil at the NAPS Unit 3 site showed that the soil was non-liquefiable. The applicant stated that the non-liquefiable nature of the soil was attributable to the fill beneath the FWSC being both dense and gravelly. The applicant also cited the results of SPTs and CPTs, as well as liquefaction analyses based on shear wave velocity, as further evidence of the non-liquefiable nature of the structural fill. The staff considers the additional information and the staff's previous review of the liquefaction potential for the ESP to be sufficient to conclude that the structural fill is non-liquefiable. Because the information was previously approved as part of the ESP, in which the staff concluded that the structural fill soil was non-liquefiable, the staff concludes that the applicant has provided sufficient information to demonstrate that the backfill soil is non-liquefiable. Accordingly, the staff considers **RAI 2.5.4-7a** to be resolved.

Additionally, the staff reviewed the liquefaction-induced dynamic settlement determined by the applicant using the method outlined in Tokimatsu and Seed (1997) to obtain the maximum dynamic settlement of about 41 mm (1.6 in) for the Zone IIA saprolite caused by earthquake shaking. In **RAI 2.5.4-10**, the staff asked the applicant to explain why this value is significantly smaller than the value determined in the ESP SSAR (127 mm [~5 inches]). In response, the applicant stated that the maximum settlements of the FSAR differed significantly from the FSAR for two reasons. First, the applicant stated that the CPT soundings, which formed the basis for the FSAR settlements, were some distance apart from the soundings used in the ESP SSAR. The applicant also noted that due to the distance separating the locations, the underlying soils (which are both saprolites) did not have identical properties, which further added to the difference. The applicant also stated that the peak ground accelerations used in the FSAR analysis were 40 percent lower than those used in the ESP SSAR analysis. The applicant noted that the relationship between cyclic stress ratio and dynamic settlement was non-linear, so smaller peak accelerations will give equal or lower dynamic settlement values.

The staff considered this information and although the CPTs were performed at different locations with different soil property variations between ESP SSAR and FSAR data, the differences were not significant. The ESP SSAR showed even higher strength parameters for the saprolite soil by comparing FSAR Table 2.5-212 and ESP SSAR Table 2.5-45. As the applicant indicated, "the value of cyclic stress ratio used as input to the dynamic settlement analysis is directly proportional to the peak ground acceleration." However, even the peak ground accelerations used in the FSAR analysis were more than 40 percent lower than those used in the ESP SSAR. The applicant did not explain why the ESP SSAR estimated dynamic settlement was close to 3 times that of the dynamic settlement presented in the FSAR. Accordingly, in supplemental **RAI 2.5.4-18**, the staff asked the applicant to explain why the ESP SSAR estimated dynamic settlement was almost 3 times of that estimated in the FSAR while there is only a 40 percent difference for peak ground accelerations used in these two calculations. This RAI is being tracked as **Open Item 2.5.4-18.**

The staff reviewed FSAR Section 2.5.4.8 and concludes that the liquefaction analyses at the site, such as the seismic margin assessment and the analysis of CPT results, are acceptable. The staff further concludes that the applicant's response to RAI 2.5.4-7A, regarding the non-liquefiable nature of the backfill, is acceptable and the removal of potentially liquefiable layers from the site area is sufficient to satisfy Permit Condition 8. The staff's review of the issues related to **Open Item 2.5.4-18**, regarding the differences between the ESP SSAR and the COL FSAR with respect to dynamic settlement and peak ground accelerations, will be completed following closure of the open items.

2.5.4.4.9 Earthquake Design Basis

FSAR Section 2.5.2.6 presents the applicant's derivation of the SSE and OBE. Section 2.5.2.4 of this SER summarizes the staff's evaluation and conclusions.

2.5.4.4.10 Static Stability

The staff reviewed FSAR Section 2.5.4.10. The review focused on the applicant's determination of the bearing capacities for each of the soil and rock zones as well as the applicant's settlement and lateral earth pressure analysis. The applicant also presented bearing capacities and earth pressures for each of the zones and described how these results were obtained.

Bearing Capacity

The staff reviewed the sample bearing capacity calculations and identified several deficiencies in the information. One deficiency was the difference in dynamic bearing capacity for the RB and FB, which was stated as both 10,200 kPa (214 ksf) in FSAR Table 2.5-215 and 12,401 kPa (259 ksf) in FSAR Table 2.0-201. In **RAI 2.5.4-6**, the staff asked the applicant to clarify the values of allowable dynamic bearing capacity for the RB and FB. The applicant's response stated that the dynamic bearing capacity value of 10,200 kPa (214 ksf) was the computed value for concrete while the 12,401 kPa (259 ksf) value was calculated for the Zone III-IV bedrock. The applicant also stated that since the value for the concrete was lower, FSAR Table 2.0-201 would be revised to reflect the concrete dynamic bearing capacity. The applicant also noted that the allowable dynamic bearing capacity was estimated as the least value of the allowable bearing capacity of the underlying strata, regardless of thickness. In the case of the RB and FB, this least value stratum is the concrete fill. The staff reviewed the applicant's response regarding how the allowable bearing capacity was determined and concluded that it is acceptable. However, less clear to the staff is how the applicant determined the properties of the concrete fill layer to be used in the analyses, because there is 3-D information available about the fill layer nor has the applicant finalized the design of the concrete fill. Accordingly, in supplemental **RAI 2.5.4-15**, the staff asked the applicant to clarify how the properties of the concrete fill, such as engineering properties and thickness underneath the foundation in all directions, were determined and used in the allowable bearing capacity calculation without knowing the actual concrete fill design and placement at foundation. This RAI is being tracked as **Open Item 2.5.4-15**.

The staff also reviewed the applicant's use of the widely accepted bearing capacity formulas developed by Terzaghi, as described by Coduto (2001). Although this method is commonly used in foundation bearing capacity analysis under the normal shear failure assumption, the

ESBWR DCD Tier 2 Section 2.5.4 states that bearing capacity should be estimated "particularly due to overturning forces." In **RAI 2.5.4-7b**, the staff requested the applicant to clarify whether the overturning forces were considered in the foundation allowable bearing capacity analysis.

The applicant's response stated that overturning forces were considered in the foundation allowable bearing capacity analysis. The applicant noted that dynamic bearing capacity values were much higher than static bearing capacity values due to the transient forces acting on the structure. The applicant also determined that for all major structures, the minimum dynamic values exceeded the ESBWR DCD design values that included overturning moment effects. The applicant stated that "local failure will not occur in the 2.5-m (8.2-ft) thick reinforced concrete mat foundation of the FWSC." In conclusion, the applicant computed the minimum dynamic bearing capacity value to be 11,985 kPa (250 ksf) using the equation of Terzaghi, as modified by Vesic (1975).

The staff reviewed this information, particularly the applicant's statement that local failure would not occur in the concrete mat foundation. The staff noted that local failure not occurring in the concrete mat does not exclude the possibility of local failure in the backfill layers beneath the concrete mat. Accordingly, in supplemental **RAI 2.5.4-16**, the staff asked the applicant to address the possibility of local failure within the backfill layer beneath the concrete mat in the foundation stability analysis. This RAI is being tracked as **Open Item 2.5.4-16**.

Regarding the allowable dynamic bearing capacity, the applicant stated that "[f]or soils, the values represent an increase of one third over the allowable static bearing capacity values." In **RAI 2.5.4-11**, the staff asked the applicant to justify why dynamic bearing capacity can be estimated by adding one third over static bearing capacity. The applicant's response explained the capacity-to-demand (c/d) adjustment for static pressures by stating that the foundation bearing pressure (d) is the pressure that is applied to the soil, and the ability of the soil beneath the foundation to resist the applied pressure is the bearing capacity (c). Based on this explanation, the applicant stated that the c/d adopted for the static pressures needs to be very conservative, which the applicant took as 3. The applicant concluded that since dynamic foundation bearing pressures occur infrequently, it is reasonable to adopt a lower c/d for dynamic bearing pressures that is equivalent to a higher applied bearing pressure.

The staff reviewed this information. Although the staff agrees that the c/d ratio under dynamic loading condition can be smaller than that under static loading condition, increasing one-third to allowable foundation pressure values that are listed in Table 1804.2 of the *International Building Code* (2003) and using it as dynamic bearing capacity does not mean that only one and one-third of the calculated static bearing capacity as dynamic bearing capacity should be used in the calculation. This is because the *International Building Code,* which the applicant's response cited, clearly indicates that this bearing capacity must be estimated using "the alternate load combinations in Section 1605.2.2 that include wind or earthquake loads." Accordingly, in supplemental **RAI 2.5.4-19**, the staff asked the applicant to provide details on what load combinations were used in the dynamic bearing capacity estimate and why one and one-third of static bearing capacity can be used as dynamic bearing capacity for this site without actual analysis. This RAI is being tracked as **Open Item 2.5.4-19**

Settlement Analysis

During the review of the settlement analyses performed by the applicant, the staff identified three areas requiring additional review. In FSAR Section 2.5.4.10.2, the applicant estimated settlement using a formula that included the layer elastic modulus E. In **RAI 2.5.4-7c**, the staff asked the applicant to clarify and justify the type of E values, corresponding to small or large strains, that were used in the settlement calculations. In response to this RAI, the applicant stated that the large strain values were used in the settlement analyses. The applicant noted that for the Zone III-IV and IV rock, the E values were not strain dependent, although the E values for the Zone III weathered rock were strain dependent and therefore, the large strain values were used as these values yielded higher estimated settlements. Because the large strain values used in the analysis yielded higher estimated settlements, the staff concluded that the use of the large strain values was a more conservative approach to settlement estimates and is therefore acceptable. The staff reviewed this information and concluded that the applicant had adequately clarified that the large strains were used in the settlement calculations. Therefore, the staff considers **RAI 2.5.4-7c** to be resolved.

Also in FSAR Section 2.5.4.10.2, the applicant estimated the differential settlement for the FWSC, excluding the weight of the basemat. In **RAI 2.5.4-7d**, the staff sought justification as to why the weight of the basemat was not included in the settlement calculation. The applicant's response stated that the weight of the basemat was excluded from the settlement analysis following the guidance in Note 15 of Table 2.0-1 of the ESBWR DCD, which states that the design of the foundation mat accommodates immediate and long-term differential settlements after installation of the basemat. Although DCD Table 2.0-1 excludes the weight of the basemat in the differential settlement calculations, FSAR Table 2.5-216 provides estimated settlements that include the basemat. The staff reviewed this response, including the information presented in DCD Table 2.0-1 and FSAR Table 2.5-216, and concluded that since the DCD does not include the basemat in the settlement calculations, and because the applicant had included the basemat in the settlement calculations in FSAR Table 2.5-216, the applicant has provided sufficient information to resolve **RAI 2.5.4-7d**.

Finally, in **RAI 2.5.4-7e**, the staff asked the applicant to explain why the seismic settlement of the FWSC foundation was not considered in the settlement analysis. The applicant's response referred to the response to **RAI 2.5.4-7a**, which described the structural fill as well-graded, highly compacted, angular to sub-angular gravel-sized particles of crushed rock. The applicant stated that the fill would be compacted to a high degree using a heavy vibratory steel-drummed roller. Although the applicant anticipated some small settlement of the fill under the FWSC due to tank loading, the high relative density of the fill would prevent any significant densification or settlement during a seismic event. The staff reviewed this response, particularly the physical description of the fill and the compaction techniques to be used, and concurred with the applicant's conclusion that the texture and high degree of compaction of the structural fill would preclude further settling during a seismic event. Therefore, the staff concluded that the applicant has adequately addressed **RAI 2.5.4-7e** and considers the RAI to be resolved.

Earth Pressures

In reviewing the earth pressure determinations of FSAR Section 2.5.4.10.3, the staff identified two areas where the information provided was insufficient for evaluation. The staff reviewed the FS against sliding of gravity wall or structure foundation against the criteria of the ESBWR DCD. The applicant stated the FS against sliding was taken as 1.1, while the ESBWR detailed the need for waterproofing material at the basemat-underlying the material boundary. In **RAI 2.5.4-8**, the staff requested the applicant to provide further clarification and justification of the coefficient of friction used to calculate the FS against sliding for the aforementioned interface. The applicant's response stated that the coefficient of friction at the interface of the basemat and the underlying material is dependent on the composition of the mudmat, which the ESBWR vendor, General Electric-Hitachi (GEH), is still designing. The issue is currently being addressed in **DCD RAI 2.8-96 S03**, and the applicant noted that the response to COL **RAI 2.5.4-8** relies on the standard plant design information currently in development. The information will be provided to the staff upon completion of the work by GEH. Accordingly, in supplemental **RAI 2.5.4-17**, the staff asked the applicant to justify and clarify the site specific coefficient of friction used to calculate the site specific factor of safety against sliding between the basemat and underlying material. This RAI is being tracked as **Open Item 2.5.4-17**.

The staff's review of FSAR Section 2.5.4.10.3 included the methods used to determine earth pressures as well as the results. The applicant used the Ostadan method to estimate the seismic lateral at-rest pressures against the buried structure walls; active earth pressures due to the Zone IIA and IIB saprolites were included when applicable. In **RAI 2.5.4-9**, the staff asked the applicant to provide detailed information on this method of analysis when both at-rest and active seismic lateral earth pressure were involved.

The applicant's response stated that, as shown in FSAR Figure 2.5-232, there is structural fill between the vertical excavation support wall and the below-ground RB wall that generated at-rest lateral pressures on the RB wall. The applicant also noted that active lateral earth pressures against the outside of the vertical support wall would also have some influence as well. The applicant used the method developed by Ostadan and White (1998) to compute the at-rest lateral earth pressures. This method is a three-step process in which a free-field soil column analysis is performed to obtain the ground response motion at depth. The total mass is then computed using Poisson's ratio. And finally, the lateral seismic force is obtained from the product of the results of the two previous steps. To determine the seismic active lateral earth pressure, the applicant used the method developed by Mononobe-Okabe and described by Seed and Whitman (1970). The Mononobe-Okabe method uses a Coulomb wedge acted upon by both horizontal and vertical forces, with the total earth pressure measured as the force equilibrium on the soil wedge. The applicant provided detailed equations on both the Ostadan and White and Mononobe-Okabe methods.

The staff reviewed this information, especially the calculations of the earth pressures. The staff also considered the applicant's use of two different methods of computing the earth pressures and determined that the use of both the Ostadan and White and Mononobe-Okabe methods was appropriate, as the two methods are widely-accepted methods for determining the at-rest lateral earth pressures and seismic active lateral earth pressures, respectively. Based on the calculations included in response to the RAI, as well as the staff's observations of the calculations during the site audit, and the use of widely-accepted methods to calculate the at-rest and seismic active lateral earth pressures, the staff concluded that the applicant had provided sufficient information that suitable methods were used in keeping with current industry practices for the calculation of lateral earth pressures. Accordingly, the staff considers **RAI 2.5.4-9** to be resolved.

Resolution of ESP COL Action Item 2.5-6

ESP COL Action Item 2.5-6 requires the applicant referencing the North Anna ESP to analyze the stability of all planned safety-related facilities, including bearing capacity, rebound, settlement, and differential settlements under deadloads of fills and plant facilities, as well as lateral loading in the COL application. FSAR Section 2.5.4.10 describes the static stability of the Unit 3 site, including the bearing capacity, rebound, settlement, and differential settlement. The applicant also discussed lateral earth pressures at the Unit 3 site. The staff reviewed this information and concluded that there were sufficient details to satisfy the requirements of ESP

COL Action Item 2.5-6. Therefore, the staff considers ESP COL Action Item 2.5-6 to be resolved.

The staff reviewed FSAR Section 2.5.4.10 and concludes that the settlement analyses and the method used to determine the earth pressures at the site are acceptable to satisfy the requirements of 10 CFR Parts 50 and 100. The staff also concludes that the stability analyses were adequate to resolve ESP COL Action Item 2.5-6. The staff's review of the issues related to **Open Items 2.5.4-15, 2.5.4-16, 2.5.4-19, and 2.5.4-17**, regarding the allowable bearing capcity, local failure in the foundation stability analysis, dynamic bearing capcity, and the coefficient of friction used to calculate the factor of safety against sliding, will be completed following closure of the open items.

2.5.4.4.11 Design Criteria

In FSAR Section 2.5.4.11, the applicant provided general geotechnical criteria such as an acceptable FS against liquefaction, allowable bearing capacities, acceptable total and differential settlements, and an FS against slope stability failure, sliding, and overturning.

Resolution of ESP COL Action Item 2.5-7

ESP COL Action Item 2.5-7 requires the applicant referencing the North Anna ESP to include the design-related criteria that pertain to structural design in the COL application, such as wall rotation, sliding, and overturning. FSAR Section 2.5.4.11 describes the design criteria to be applied to NAPS Unit 3. These criteria include a minimum FS against sliding and overturning of 1.1, as well as an FS against liquefaction and slope stability, among others. The staff reviewed this information and concluded that because the applicant had provided the applicable factors of safety against sliding and overturning, as well as other design criteria, the requirements of ESP COL Action Item 2.5-7 have been met. Therefore, the staff considers ESP COL Action Item 2.5-7 to be resolved.

The staff reviewed the factors of safety provided by the applicant and compared these values with those of RG 1.198, the SRP and standard industry practices, and concluded that the factors of safety are acceptable. The staff reviewed this information, including the resolution of ESP COL Action Item 2.5-7, and determined that the applicant had provided sufficiently detailed descriptions of the design criteria for the NAPS Unit 3 site, such as the factors of safety against liquefaction, allowable bearing capacities, settlements, slope stability failure, sliding, and overturning to meet the requirements of 10 CFR Part 50. Therefore, based on this review of the information provided and the requirements of the applicable regulations, the staff concluded that the design criteria presented for the Unit 3 site is acceptable and meets the criteria of 10 CFR Part 50.

2.5.4.4.12 Techniques to Improve Subsurface Conditions

FSAR Section 2.5.4.12 describes the removal of any Zone IIA saprolite beneath or within the zone of influence of seismic Category I or II structures and the replacement of the saprolite with compacted structural fill for Unit 3. The staff reviewed the plans to improve the Zone IIA saprolite beneath nonseismic Category I and II structures in accordance with the methods described in the ESP SSAR.

Resolution of ESP COL Action Item 2.5-8

ESP COL Action Item 2.5-8 requires the applicant referencing the North Anna ESP to provide specific plans for each proposed ground improvement technique to be used, so that the staff may determine whether the chosen technique will ensure that Zone II saprolitic soils will be able to support a safety-related foundation. In FSAR Section 2.5.4.12, the applicant described the techniques to be used to improve the subsurface conditions at the Unit 3 site. The applicant described plans to remove the Zone IIA saprolitic soil, the only liquefiable material identified at the site, and replace the excavated area with structural backfill. The applicant stated that zones of fractured or weathered rock would also be removed from the areas immediately beneath the RB and FB basemat and replaced with concrete. The staff concluded that because the applicant had provided a description of the techniques to improve the site, which includes the removal of the liquefiable material from the foundation areas of the Unit 3 structures, the reporting requirements of ESP Col Action Item 2.5-8 have been met. Therefore, the staff considers ESP Col Action Item 2.5-8 to be resolved.

The staff concluded that the methods described for subsurface improvements in FSAR Sections 2.5.4.12 and 2.5.4.5 are sufficiently detailed in the vertical and horizontal extent, as well as in the removal of the liquefiable material at the site, to be acceptable and to satisfy the requirements of 10 CFR Part 50.

2.5.4.5 *Post Combined License Activities*

To ensure the quality of the backfill, the applicant provided ITAAC in Table 2.4.1-1, “Compaction Requirements for Backfill under Category I Structures”; Table 2.4.1-2, “ITAAC for Backfill under Category I Structures”; Part 10, “Tier 1/ITAAC”; and Section 2.4, “Site Specific ITAAC” of the COL application.

2.5.4.6 *Conclusion*

NRC staff reviewed the application and checked the referenced ESP SSAR and staff’s ESP SER. The staff’s review confirmed that the applicant has addressed the relevant information although there is outstanding information expected to be addressed in the COL FSAR related to this section.

As described above, the staff specified **Open Items 2.5.4-12 through 2.5.4-19**. These open items pertain to the engineering properties of backfill material, bearing capacity calculations, foundation stability analyses, the factor of safety against sliding, and differences between the ESP SSAR and the COL FSAR with respect to dynamic settlement and peak ground acceleration. The staff outlined additional information that needs to be reflected in sections of the FSAR, as appropriate. The staff’s review of FSAR Section 2.5.4 will be complete after these two open items have been resolved.

2.5.5 GroundwaterStability of Slopes

2.5.5.1 *Introduction*

Section 2.5.5 of this SER provides slope stability information related to the North Anna 3 site. Section 2.5.5.2 of this SER provides a summary of relevant geologic and seismic information contained in FSAR Section 2.5.5 of the North Anna 3 COL application. SER Section 2.5.5.3 provides a summary of the regulations and guidance used by the applicant to perform the investigation. SER Section 2.5.5.4 provides a review of the staff's evaluation of FSAR Section 2.5.5, including any RAIs, open items, and confirmatory analyses. SER Section 2.5.5.5 discusses any post COL activities. Finally, SER Section 2.5.5.6 provides an overall summary of the applicant's and the staff's conclusions, restates any bases covered in the application, and confirms that the applicant has met the requirements or fulfilled the regulations.

2.5.5.2 *Summary of Application*

In FSAR Section 2.5.5, the applicant provided the following:

<u>*COL Items*</u>

- NAPS COL 2.0-30-A

NAPS COL 2.0-30-A addresses the provisions in COL Item 2.0-30-A listed in ESBWR DCD Table 2.0-1, regarding stability of slopes requirements.

- NAPS ESP COL 2.5-10

ESP COL Action Item 2.5-10 requires the COL applicant to perform a more detailed dynamic analysis of the stability of the existing slope and any new slopes using the SSE ground motion for the NAPS site.

- NAPS ESP COL 2.5-11

ESP COL Action Item 2.5-11 requires the COL applicant to provide plot plans and cross-sectional profiles of all safety-related slopes and to specify the measures that would be taken to ensure the safety of the slopes and the adjacent structures.

ESP Variance

- NAPS ESP VAR 2.5-1

This FSAR section presents the slope stability analyses for the Unit 3 site, which combine reviews of reports for the existing units and the originally planned Units 3 and 4, geotechnical literature, the ESP subsurface investigation, and the Unit 3 subsurface investigation, so the results were different from those presented in ESP SSAR Section 2.5.5. To that end, the applicant also requested a variance from the information in the ESP SSAR relating to the stability of slopes, which was identified as NAPS ESP VAR 2.5-1 in the COL application. In this request, the applicant asked that the information presented in FSAR Section 2.5.5 be used in place of the information presented in ESP SSAR Section 2.5.5 for the stability of slopes. The applicant stated that this request was based on the differences in slopes near Unit 3 from the anticipated slopes in the ESP SSAR. Due to these differences, the applicant stated that for the seismic slope stability analysis, the peak ground acceleration applied at Unit 3 is also different from the ESP, although the method of analysis remains the same. The main differences are smaller peak ground acceleration use in the seismic slope stability analysis than that used in ESP SSAR Section 2.5.5 and differences in the changed slopes characteristics. Because the same method was used in the analyses but with a shallower slope and a smaller applied seismic acceleration, the analyses yielded a higher computed factor of safety against failure under both long-term static and short-term seismic conditions.

2.5.5.2.1 Slope Characteristics

FSAR Section 2.5.5.1 describes the characteristics of the existing and new slopes, their subsurface conditions, and impacts of the slope instability on the seismic Category I structures at the Unit 3 site. The applicant performed slope stability analyses for existing slopes and new slopes under static and dynamic (seismic) loadings to demonstrate that the minimum factors of safety meet the requirements defined in the DCD. FSAR Figure 2.5-255, reproduced as Figure 2.5.5-1 in this SER, illustrates that no slopes will contribute to the support of any of the Unit 3 seismic Category I structures or any of the other major power block structures.

Existing Slope Characteristics

FSAR Figure 2.5-255 also shows existing slopes, including one that runs in a northeasterly direction, to the south of abandoned Units 3 and 4 and existing Units 1 and 2. The applicant performed a new topographic survey for Unit 3 showing that the slope is about 2.4-horizontal to 1-vertical (2.4h:1v), with a maximum height of 13.1 m (43 ft) based on the final grade for Unit 3. The applicant stated that the maximum depth of the storm water basin to the northeast of the main plant area is 6.7 m (22 ft), cut at a 3h:1v slope. The applicant did not address the stability of this slope because the storm water basin sides do not affect the safety of the plant or its peripheral structures. The existing 2.4h:1v slope (Slope ES on Figure 2.5.5-1) was excavated during the construction of Units 1 and 2. Because the top of this slope is about 61 m (200 ft) from the top of the existing service water reservoir (SWR) embankment, the applicant concluded that any potential instability of the slope will not impact the stability of the embankment. However, the applicant acknowledged that material from sloughing or collapse of these slopes could impact the new diesel tanks and/or service water cooling tower.

New Slope Characteristics

The applicant identified the only slopes that could impact facilities at the Unit 3 site as cut slopes that surround and ascend from the southern edges of the plant. The applicant described these new slopes as cut at 3h:1v into the existing natural ground surrounding the plant, with a height of 10.7 m (35 ft) to the southeast of the FWSC (Slope A-A' on Figure 2.5.5-1). The applicant also stated that, in general, the instability of this slope will not impact the foundation stability of seismic Category I facilities because the facilities are either founded on stable compacted crushed rock fill, or are far away from the Category I structures. However, material from sloughing or collapse of the slope could impact the facility, because the base is about 16.8 m (55 ft) from the FWSC. Therefore, the applicant concluded that Slope A-A should be considered the critical slope in the area.

Slope Subsurface Conditions

In addition to the slope borings conducted for the Unit 1 and 2 site investigation, the applicant performed a CPT at C-915 near the top of the existing (2.4h:1v) slope, and drilled boring

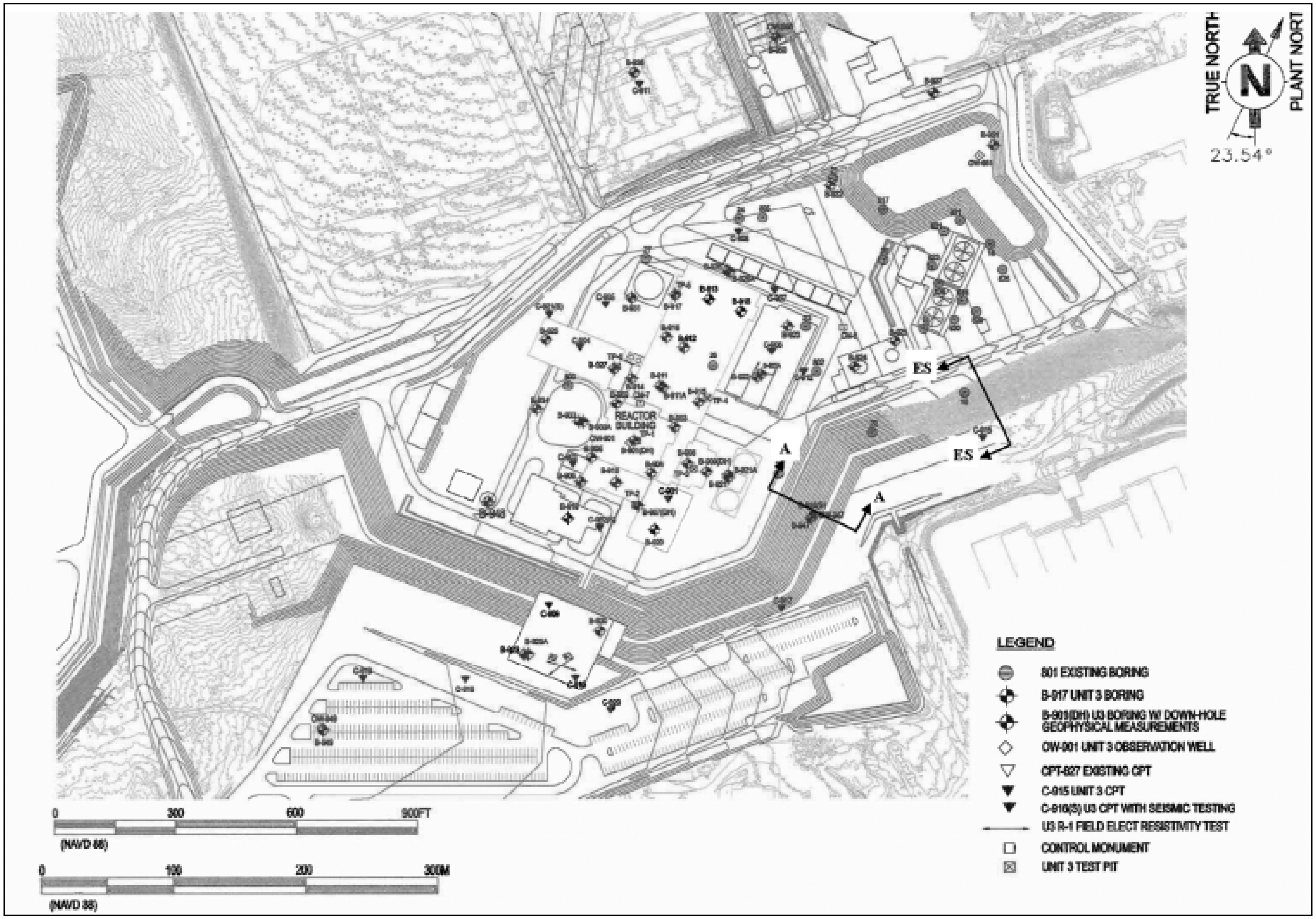

Figure 2.5.5-1 Excavation Grading Plan with Boring Locations (FSAR Figure 2.5-255)

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(B-947) to the west, at a similar elevation and within the same terrain as C-915 as part of the subsurface investigations at the Unit 3 site. CPT C-915 and OW-947 are located adjacent to B-947, close to the area of the slope. Based on the site investigation data, the applicant determined that the soils in the slope consisted almost entirely of Zone IIA saprolites and were classified as coarse grained (sands and silty sands). The applicant briefly summarized the engineering properties of the site soils and bedrock as described in FSAR Section 2.5.4.2 and Table 2.5-212, as well as the liquefaction characteristics of all of the Zone IIA saprolites estimated in FSAR Section 2.5.4.8.

Slope Phreatic Surface

FSAR Figures 2.5-256 and 2.5-257 in Section 2.5.5.1.4 illustrate the phreatic, or groundwater, surfaces for existing and new slopes. The applicant developed these surfaces using water table levels measured in OW-947 and derived in FSAR Section 2.4.12. Based on this information, the applicant concluded that the depth of the phreatic surface precluded any potential for liquefaction of the near-surface soils in the slopes.

2.5.5.2.2 Design Criteria and Analyses

FSAR Section 2.5.5.2 presents the design criteria for the new and existing slopes, as well as an analysis of the static and dynamic (seismic) stability analysis. The applicant presented the required FS, the stability of the existing slope, and analyses for both the existing and new slopes.

Required Factor of Safety

The applicant stated that the design criteria for the slopes are defined in the ESBWR DCD with minimum FS for static and dynamic loading of 1.5 and 1.1, respectively.

Stability of Existing Slope

The applicant stated that the existing slope (2.4h:1v) was thoroughly inspected during the ESP site investigation and shows no signs of distress.

Analysis of Existing Slopes

The applicant used the computer program SLOPE/W, a commercial software product that computes the FS of earth and rock slopes, to analyze the static and dynamic stability of the slopes. The applicant used the soil and rock properties in Table 2.5.5-1 in the analyses.

Table 2.5.5-1. Soil and Rock Properties for Static and Dynamic Stability Analyses.

Rock	Unit Weight (γ)	Angle of Internal Friction (φ’)	Effective Cohesion (c’)
Zone IIA	2,002 kg/m^3 (125 pcf)	33^o	6.0 kPa (0.125 ksf)
Zone IIB	2,082 kg/m^3 (130 pcf)	40^o	0
Old Fill	2,002 kg/m^3 (125 pcf)	30^o	0
Underlying weathered rock	2,323 kg/m^3 (145 pcf)	-	3,350 kPa (70 ksf)

Long-Term Static Analysis. The applicant used the Bishop method, which is available in the SLOPE/W program. The method divides the slope into slices and is based on the moment equilibrium assumption to compute long-term static stability. The applicant noted that the resulting FS of the static analysis for the existing slope was 2.09, which was above the minimum FS of 1.5 for long-term static stability.

Seismic Slope Stability Analysis. For the seismic slope stability analysis, the applicant used a pseudo-static approach that assumed the horizontal and vertical seismic forces act on the slope in a static manner as a constant force. The applicant used an average peak horizontal acceleration of 0.23 g and a vertical acceleration of 0.115 g in the top 13.1 m (43 ft) of soil for a low-frequency earthquake, resulting in an FS of 1.29, more than the minimum 1.1 required. For the high-frequency earthquake, the equivalent peak horizontal acceleration used was 0.50 g with a vertical acceleration of 0.25 g and yielding an FS of about 0.90, less than the minimum 1.1. Because an actual seismic event would last only seconds, with the peak motions occurring for a small portion of the total duration, the applicant considered the pseudo-static approach to be conservative.

The applicant also used a pseudo-static approach recommended by Kramer (1996), which uses half of the peak acceleration value rather than a set peak value based on magnitude. The applicant concluded that the resulting FS against slope failure was above the required minimum of 1.1 at 1.59 and 1.24, respectively, for the low and high frequency inputs.

As an alternative to applying the peak acceleration values for the pseudo-static analysis, the applicant applied the acceleration values recommended by Seed (1979) and used horizontal accelerations of 0.10 g and 0.15 g for high- and low-frequency earthquakes with a vertical acceleration of zero. From these inputs, the applicant computed an FS of 1.63 and 1.47 for high-and low-frequency earthquakes, respectively, which the applicant concluded were greater than the required minimum of 1.1.

The results of the applicant’s analyses showed that the only case that gave a factor of safety lower than the required minimum was the pseudo-static analysis using the high frequency peak acceleration. However, the applicant considered that to be a conservative approach and concluded that the existing 2.4h:1v slope to the north of the SWR will remain stable under long-term static and design seismic conditions.

Analysis of New Slope

FSAR Subsection 2.5.5.2.4 analyzes the static and dynamic stability of the new 10.7 m (35 ft) high 3h:1v slope (Slope A-A) to the southeast of the FWSC, using the same methods as the existing slope analysis.

Long-Term Static Analysis

For long-term static stability, the applicant concluded that the calculated FS of 2.23 was well above the minimum (FS = 1.5) required for safety.

Seismic Slope Stability Analysis

The applicant utilized three different methods to determine the FS for the stability of the new slope under seismic conditions. Using a pseudo-static analysis that incorporated an average peak ground acceleration, the applicant determined the FS for both low-and high-frequency earthquakes of 1.30 and 0.90, respectively. The applicant also used Seed's (1979) reduced peak acceleration and determined the FS for low- and high-frequency earthquakes of 1.64 and 1.44, respectively. Finally, the applicant utilized the reduced peak acceleration of Kramer (1996) and determined an FS of 1.63 for the low-frequency earthquake and 1.25 for the high-frequency earthquake. Based on the results and the considerations used for the existing slope, the applicant concluded that the new 3h:1v slope to the southeast of the FWSC will remain stable under long-term static and design seismic conditions.

2.5.5.2.3 Boring Logs

FSAR Section 2.5.5.3 briefly summarizes the boring logs, CPT logs, OWs, and laboratory test results for two borings, two CPTs, and one groundwater OW in the area of the existing and new slopes. The applicant stated that borehole B-18 and CPT C-915 were drilled close to the toe of the existing 2.4h:1v slope to the north of the SWR. The applicant also described the location of boring B-947, CPT C-916, and OW-947 as being near the top of the proposed new 3h:1v slope southeast of the FWSC. The applicant performed grain sized tests for the saprolites in boring B-947.

2.5.5.2.4 Compacted Fill

FSAR Section 2.5.5.4 states that the existing 2.4h:1v slope is a cut slope and does not contain fill materials in any significant quantity. The applicant stated that the new 3h:1v slope will require fill along the top 2.1 m (7 ft) and will consist of re-compacted saprolitic soils obtained from plant excavations. For the slope stability analysis, the applicant assumed the same properties for the fill as for the Zone IIA saprolite soil.

2.5.5.2.5 Conclusion

FSAR Section 2.5.5.5 describes the applicant's conclusions regarding stability of the slopes at the Unit 3 site. The applicant concluded that the new slopes, such as those in the storm water basin, as well as temporary slopes and excavations would not adversely affect the safety of Unit 3. The applicant identified the only slope whose failure could adversely affect the safety of Unit 3 as the existing 2.4h:1v slope that descends from the north of the SWR down to the south of the excavation made for abandoned Units 3 and 4. The applicant indicated the only analysis that gave a factor of safety lower than the required minimum was the pseudo-static analysis, which was overly conservative. The applicant concluded that this slope would remain stable under long-term static and design seismic conditions.

2.5.5.3 *Regulatory Basis*

The applicable regulatory requirements for reviewing the applicant's discussion of stability of the slopes are:

1. 10 CFR 50.55a, "Codes and Standards," requires that structures, systems, and components shall be designed, fabricated, erected, constructed, tested, and inspected in accordance with the requirement of applicable codes and standards commensurate with the importance of the safety function to be performed.

2. 10 CFR Part 50, Appendix A, General Design Criterion 1 (GDC 1), "Quality Standards and Records," requires that structures, systems, and components important to safety be designed, fabricated, erected, and tested to quality standards commensurate with the

importance of the safety functions to be performed. It also requires that appropriate records of the design, fabrication, erection, and testing of structures, systems, and components important to safety be maintained by or under the control of the nuclear power unit licensee throughout the life of the unit.

3. 10 CFR Part 50, Appendix A, General Design Criterion 2 (GDC 2), “Design Bases for Protection Against Natural Phenomena,” relates to the consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area, with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.

4. 10 CFR Part 50, Appendix A, General Design Criterion 44 (GDC 44), “Cooling Water,” requires that a system be provided with the safety function of transferring the combined heat load from structures, systems, and components important to safety to an ultimate heat sink under normal operating and accidental conditions.

5. 10 CFR Part 50, Appendix B, “Quality Assurance Criteria for Nuclear Power Plants and Fuel Processing Plants,” establishes quality assurance requirements for the design, construction, and operation of those structures, systems, and components of nuclear power plants that prevent or mitigate the consequences of postulated accidents that could cause undue risk to the health and safety of the public.

6. 10 CFR Part 50, Appendix S, “Earthquake Engineering Criteria for Nuclear Power Plants,” applies to the design of nuclear power plant structures, systems, and components important to safety to withstand the effects of earthquakes.

7. 10 CFR Part 100, “Reactor Site Criteria,” provides the criteria which guide the evaluation of the suitability of proposed sites for nuclear power and testing reactors.

8. 10 CFR 100.23, “Geologic and Seismic Siting Criteria,” provides the nature of the investigations required to obtain the geologic and seismic data necessary to determine site suitability and identify geologic and seismic factors required to be taken into account in the siting and design of nuclear power plants.

The related acceptance criteria are summarized from SRP Section 2.5.5:

1. **Slope Characteristics:** In meeting the requirements of 10 CFR Parts 50 and 100, the discussion of slope characteristics is acceptable if the subsection includes: (1) cross sections and profiles of the slope in sufficient quantity and detail to represent the slope and foundation conditions; (2) a summary and description of static and dynamic properties of the soil and rock comprised by seismic Category I embankment dams and their foundations, natural and cut slopes, and all soil or rock slopes whose stability would directly or indirectly affect safety-related and Category I facilities; and (3) a summary and description of groundwater, seepage, and high and low groundwater conditions.

2. **Design Criteria and Analyses:** In meeting the requirements of 10 CFR Parts 50 and 100, the discussion of design criteria and analyses is acceptable if the criteria for the stability and design of all seismic Category I slopes are described and valid static and dynamic analyses have been presented to demonstrate that there is an adequate margin of safety.

3. **Boring Logs:** In meeting the requirements of 10 CFR Parts 50 and 100, the applicant should describe the borings and soil testing carried out for slope stability studies and dam and dike analyses.

4. **Compacted Fill:** In meeting the requirements of 10 CFR Part 50, the applicant should describe the excavation, backfill, and borrow material planned for any dams, dikes, and embankment slopes.

In addition, the geologic characteristics should be consistent with appropriate sections from: RG 1.27, "Ultimate Heat Sink for Nuclear Power Plants"; RG 1.28, "Quality Assurance Program Requirements (Design and Construction)"; RG 1.132, "Site Investigations for Foundations of Nuclear Power Plants"; RG 1.138, "Laboratory Investigations of Soils for Engineering Analysis and Design of Nuclear Power Plants"; RG 1.198, "Procedures and Criteria for Assessing Seismic Soil Liquefaction at Nuclear Power Plant Sites"; and RG 1.206, "Combined License Applications for Nuclear Power Plants (LWR Edition)."

2.5.5.4 *Technical Evaluation*

NRC staff reviewed the resolution to the COL specific items related to the stability of all earth and rock slopes—natural and manmade—whose failure under any conditions to which they could be exposed during the life of the plant, could adversely affect the safety of the plant. To that end, the staff reviewed the applicant's descriptions of the slope characteristics, design criteria, slope stability analyses, and conclusions drawn by the applicant.

Resolution of NAPS ESP VAR 2.5-1

NRC staff reviewed the applicant's variance request to use the information in FSAR Section 2.5.5 in place of the information in ESP SSAR Section 2.5.5, as it related to the stability of slopes. Based on the shallower slopes, and therefore an increased FS against slope failure, the staff concluded that the use of FSAR Section 2.5.5 in place of ESP SSAR Section 2.5.5 is acceptable.

2.5.5.4.1 Slope Characteristics

FSAR Section 2.5.5.1 describes the characteristics of the existing and new slopes, their subsurface conditions, and impacts of the slope instability on the seismic Category I structures at the Unit 3 site. The staff reviewed this information as well as the characterizations of the phreatic surfaces for new and existing slopes. The staff concluded that the information provided meets the minimum requirements for slope characterization in 10 CFR Part 100. The staff further concluded that the subsurface investigations adhered to the criteria of RG 1.132.

Resolution of ESP COL Action Item 2.5-11

ESP COL Action Items 2.5-11 requires the applicant referencing the North Anna ESP to provide plot plans and cross sections/profiles of the safety-related slopes and to specify what measures are needed at the site to ensure the safety of the safety-related structures adjacent to the slopes. In FSAR Section 2.5.5.1.2, the applicant describes the location of the new 3h:1v slope to the southeast of the FWSC. FSAR Figure 2.5-255 illustrates the plan view of this slope, while Figure 2.5-257 shows the cross section of this slope. The staff considered this information, including the plot plans and cross section through the new slope. The staff also considered the physical characteristics of the slope and concluded that the failure of the slope would not affect the safety-related structures at the site. The staff also concluded that the applicant has provided adequate plot plans and cross sections of the new slope to satisfy the criteria of ESP COL Action Item 2.5-11. Accordingly, the staff considers ESP COL Action Item 2.5-11 to be resolved.

The staff also considered the results and interpretations of the borings, CPTs, and OWs conducted at the site. During the review of FSAR Section 2.5.5.1.3, the staff noted that the applicant had identified two different lithologies in the same CPT and borehole analyses. In **RAI 2.5.5-1**, the staff asked the applicant to clarify the lithology of CPT C-916, located adjacent to boring B-947, which was alternatively identified as silty clays and clays and silty sand saprolite. The applicant's response stated that although the CPTs provided valuable information about the soil, the test had not obtained samples from the soil. The applicant stated that the interpretation of soil type from the friction ratio was empirical and based on historical interpretations, but the interpretation is not considered exact. Accordingly, although the friction ratio measured during the CPT indicated that the soil was mainly silty clays and clays, the visual observation and grain size testing concluded that the soil was mainly silty sand. The applicant also clarified that the silty sand profile of the soil was the profile used in the slope stability analysis.

The staff reviewed this information, including the applicant's suggestion that the visual inspection of the soil type is more reliable than the empirical interpretation of CPT results. The staff concurred with the applicant's assessment of the visual inspection and laboratory test as a more reliable determination of soil type, and therefore finds the use of the silty sand profile for slope stability analyses to be acceptable. Accordingly, the staff considers **RAI 2.5.5-1**, to be resolved.

Based on the slope characterization provided and the response to the RAI, the staff concluded that the applicant's characterization of the slopes at the Unit 3 site area is acceptable.

2.5.5.4.2 Design Criteria and Analyses

FSAR Section 2.5.5.2 describes the design criteria and analyses performed for the Unit 3 site. The applicant used SLOPE/W commercial software and three different approaches to slope stability in the analyses: a conservative pseudo-static approach, Seed's approach (1979), and the approach recommended by Kramer (1996). The results of these approaches are summarized in Section 2.5.5.2.2 of this SER. In reviewing FSAR Section 2.5.5.2, the staff focused on the design criteria for adequacy of the applicant's slope stability analyses, both static and dynamic (seismic) stability for existing and new slopes adjacent to the Unit 3 site. The applicant used the design criteria, as defined in the ESBWR DCD, with a minimum slope stability FS of 1.5 for static (nonseismic) and 1.1 for dynamic (seismic) loading conditions. The staff identified two areas that required additional information.

The applicant stated that for the Long-Term Static Analysis, Bishop's method was the only method used. The staff compared this statement to the criteria in RG 1.206, which state that classic and contemporary methods of analysis should be used to determine slope stability. In **RAI 2.5.5-2**, the staff asked the applicant to explain why the only method used for the Long-Term Static Analysis was Bishop's method, which only considers moment magnitude and, depending on the slope geometry, may not yield conservative results. The applicant's response stated that although there are various methods of computing slope stability commonly in use, the methods differ mainly in the type and degree of underlying assumptions. The applicant also stated that a more accurate model will give a higher factor of safety, and lower factors of safety are not indicative of a conservative approach but of a less accurate approach. The applicant concluded that all methods use the same slope geometry and soil parameters. Thus, the applicant chose the Bishop method for the long-term static analysis because this method is recognized for its high degree of accuracy. Finally, the applicant noted that the use of the Bishop method has been previously reviewed and approved of in the North Anna ESP.

The staff considered the applicant's statement that all slope stability analysis methods have their own advantages and limitations, and the Bishop method may or may not give the most conservative results. Accordingly, the staff conducted an independent confirmatory analysis for a selected slope using the information in Figure 2.5-266 of the FSAR. The staff obtained the FS using GeoSlope—the same computer software used by the applicant. The calculated FS values are listed below, and the results from one of the analyses are illustrated in Figure 2.5.5-2.

Method	Factor of Safety
Ordinary	1.091
Bishop	1.098
Janbu	1.026
General Limit Equilibrium (GLE)	1.105
Spencer	1.105
Morgenstern-Price	1.105

The staff noticed that the GLE formulation is generally considered to be a more rigorous method. This finding satisfies two FS equations: the FS with respect to moment equilibrium and the FS with respect to horizontal force equilibrium. In addition, interslice shear and normal forces were both considered and computed in the analysis. Because the Bishop method ignores interslice shear forces and only satisfies the moment equilibrium, the comparison of the factors of safety for all methods enabled the staff to better evaluate the slope stability. The results from the confirmatory analysis show that (1) there is little variation among the factors of safety for the slope stability—about 7 percent among all the methods used—but higher than the applicant's estimate (about 1 percent); (2) the applicant's analysis yielded the FS of 1.30, which is higher than the FS obtained by the staff. This difference is likely caused by possible slope geometry differences, because the staff did not request the input file from the applicant. Instead, the staff generated the inputs from information presented in FSAR Figure 2.5-266 and from the different options of analytical settings in the software; and (3) all FS values are greater than 1.0 under the given seismic loads (i.e., the slope will not fail under the given conditions), therefore, the conclusion regarding the stability of the slopes is acceptable. Accordingly, the staff considers **RAI 2.5.5-2**, to be resolved.

The staff also reviewed the assumptions used for the seismic stability analysis of slopes in the Unit 3 area. Some of the assumptions stated by the applicant include (1) no liquefaction was considered in the analysis, (2) the use of average peak acceleration as opposed to peak accelerations at the surface, and (3) the consideration of reduced accelerations. These assumptions are contrary to the guidance in RG 1.206, which states that the applicant should demonstrate the reliable performance of slopes during all conditions during the life of the plant. In **RAI 2.5.5-3**, the staff asked the applicant to describe the impact of the possible maximum dynamic settlement of the slope soil on slope stability, and to describe how the assumptions used in the pseudo-static method of analysis were verified.

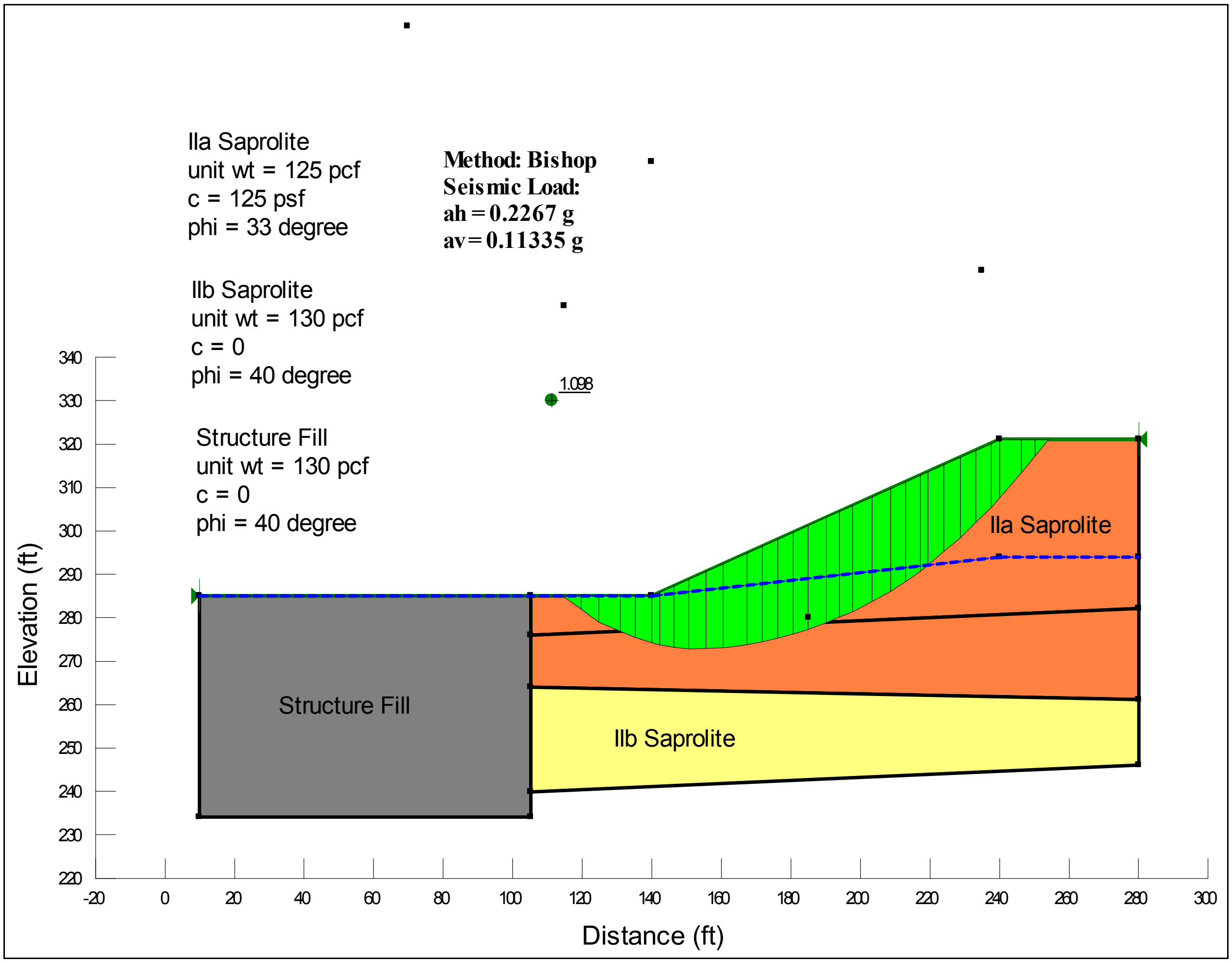
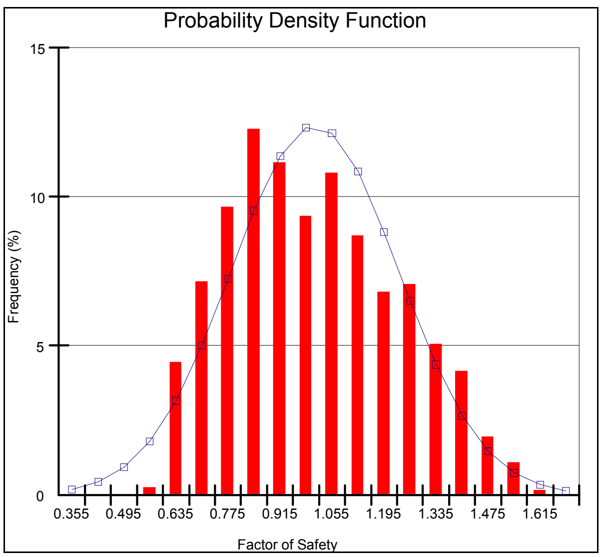


Figure 2.5.5-2 Output of Slope Stability Analysis Using the Bishop Method

The applicant's response stated that the possible maximum dynamic settlement of 41 mm (1.6 in.), corresponding to a reduction in slope height of between 0.38 and 0.31 percent, would not impact the slope stability. The applicant also stated that the reason the slope failure during a seismic event is not a slip failure is because during a seismic event, the slope loses strength due to liquefaction. Although the applicant noted that liquefaction would weaken the slope, a large portion of the slope is not prone to liquefaction because 8.5 m (28 ft) of the slope is above the groundwater table. In addition, the applicant concluded that, based on the low- and high-frequency seismic characteristics, the chances of any liquefaction occurring in the Zone IIA saprolitic soils are very low. Due to the low chance of liquefaction, the applicant concluded that the strength loss of the slope from liquefaction was remote. Therefore, the slopes will remain stable during the design earthquake at the Unit 3 site.

The staff also conducted reliability analyses by assigning probability distribution (uncertainties) to each input parameter and to examine how the uncertainties affect the reliability of the calculated FS. During the reliability analysis, the staff used different values of coefficient of variation (COV)—the ratio of standard deviation to mean value—and assumptions of normal distribution of variables.

The results of the reliability analysis were three-fold. First, the staff noted that due to uncertainties and variations in soil properties, no single factor of safety can represent the actual site condition, therefore, when determining FS using deterministic methods, soil parameters should be conservativly estimated to take the uncertainties and variations into consideration. Second, the staff observed that the smaller the variation, the higher degree of confidence in the slope stability calculation. The confirmatory analysis results showed that a reduction of the coefficient of variation from 1.0 to 0.5 will increase the probability of FS greater than 1.0, or the confidence level from about 42% to 70%, although the mean values of FS keep the same at 1.128. Finally, since the seismic loading used in stability analyses is based on the results of the probabilistic analysis of the site specific maximum ground acceleration, the staff concluded that seismic loading has high uncertainty and great influence on the slope stability analysis results. As shown in SER Figure 2.5.5-3, the reliability analysis results indicate that even with COV of 1.0 for horizontal seismic ground motion of 0.25g, or considering there is 16% of chance that the ground motion acceleration will be double or more (>0.5g), the probability of slope failure is still under percent.



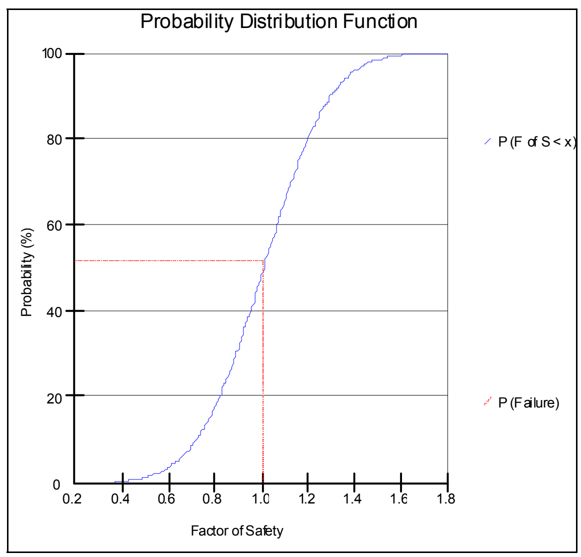


Figure 2.5.5-3 Probability Density and Distribution Functions of FS. Probabilistic Seismic Loading of a_h=0.25g and a_v = 0.125g with COV = 1.0

Based on the staff's independent confirmatory analysis, and the applicant's response to **RAI 2.5.5-3**, particularly the use of the pseudo-static methods to determine the seismic slope stability at the NAPS Unit 3 site, the staff concurs with the applicant that the use of the pseudo-static method was appropriate for the Unit 3 site. The staff also concurs with the applicant's assessment of the liquefaction potential and slope stability at the Unit 3 site. Finally, since the applicant's conclusions considered both the groundwater interaction and the weakening of the slope during the design seismic event, the staff considers **RAI 2.5.5-3** to be resolved.

Resolution of ESP COL Action Item 2.5-10

ESP COL Action Item 2.5-10 requires the applicant referencing the North Anna ESP to conduct a more detailed dynamic analysis for existing and new slopes at the site using the SSE ground motion. In FSAR Section 2.5.5.2.3.b, the applicant presented the seismic slope analysis for the existing 2.4h:1v slope, which used SLOPE/W as part of a pseudo-static approach. From these results, the applicant determined that the existing slope at the site would remain stable under long-term static and design seismic conditions. In FSAR Section 2.5.5.2.4.b, the applicant described the seismic slope analysis for the new 3h:1v slope, again using the SLOPE/W program as part of the analysis. From these results, the applicant concluded that the existing slope would also remain stable under long-term static and design seismic conditions. Because the applicant included the dynamic analysis for both the new and existing slopes, both of which demonstrated stability under the design seismic conditions, the staff concluded that the applicant has provided sufficient information to satisfy ESP COL Action Item 2.5-10. Accordingly, the staff considers ESP COL Action Item 2.5-10 to be resolved.

Based on the information provided and the applicant's response to the RAIs listed above, the staff concluded that the applicant's assessments of the design criteria and analyses of the slopes at the Unit 3 site area are acceptable and meet the criteria of 10 CFR Parts 50 and 100 and RG 1.206.

2.5.5.4.3 Boring Logs

The applicant provided boring logs, CPT logs, OWs, and laboratory test results for two borings, two CPTs, and one groundwater OW in the existing and new slopes at the Unit 3 site area. The staff reviewed this information and concluded that the information provided satisfies the requirements of 10 CFR Parts 50 and 100.

2.5.5.4.4 Compacted Fill

FSAR Section 2.5.5.4 states that the existing 2.4h:1v slope is a cut slope and does not contain fill materials in any significant quantity, while the new 3h:1v slope will contain backfill derived from the saprolite on the site. The staff reviewed the applicant's intent to apply the properties of the saprolite to the fill and concluded that this is an acceptable consideration of compacted fill properties that satisfies the requirements of 10 CFR Part 50.

2.5.5.4.5 Conclusions

In FSAR Section 2.5.5.5, the applicant summarized the major conclusions of the slope stability analyses. The applicant concluded that the slopes will remain stable under long-term static and dynamic conditions. The staff considered these conclusions along with the criteria and requirements of 10 CFR Parts 50 and 100, as well as RGs 1.132 and 1.206. The staff concluded that the information provided for FSAR Section 2.5.5 is acceptable.

2.5.5.5 *Post Combined License Activities*

There are no post COL activities related to this section.

2.5.5.6 *Conclusions*

NRC staff reviewed the application and checked the referenced ESP SSAR. The staff's review confirmed that the applicant has addressed the relevant information and there is no outstanding information expected to be addressed in the COL FSAR related to this subsection.

As set forth above, the applicant has presented and substantiated information to establish the stability of all earth and rock slopes—natural and manmade—at the plant site. The staff reviewed the investigations of the slope stability studies and dam and dike analyses, and performed an independent confirmatory analysis. For the reasons given above, the staff concluded the design analyses contain margins of safety that adequately demonstrate both natural and manmade slopes will remain stable under SSE conditions and the safety-related earthwork will function reliably at the site to justify the soil and rock characteristics used in the design. The staff further concluded that the design analyses contain adequate margins of safety for the construction and operation of the nuclear power plant. These analyses meet the requirements of 10 CFR Part 50 Appendix A (GDC 1, 2, and 44); Appendices B and S of 10 CFR Part 50; and 10 CFR 100.23 and address COL Action Item 2.0-30-A. In conclusion, the applicant has provided sufficient information for resolving NAPS ESP VAR 2.5-1, ESP COL Action Item 2.5-10, and ESP COL Action Item 2.5-11 and for satisfying 10 CFR Parts 50 and 100. Therefore, the staff concluded that the Unit 3 site is suitable with respect to the criteria governing the stability of slopes.

2.5.6 Embankments and Dams

2.5.6.1 *Introduction*

Lake Anna is used for normal plant cooling of the new units. The North Anna Dam is designed and constructed to meet the requirements for a seismic Category I structure in support of the existing units.

2.5.6.2 *Summary of Application*

Section 2.5.6, of the North Anna 3 COL FSAR incorporates by reference Section 2.5.6 of ESP SSAR, Revision 9. In addition, in FSAR Section 2.56, the applicant added that no embankments and dams were analyzed because Lake Anna is only used as a source of makeup water for Unit 3. The applicant stated that the North Anna Dam is designed and constructed to meet requirements for a seismic Category I structure in support of the existing Units 1 and 2.

2.5.6.3 *Regulatory Basis*

FSAR Section 2.5.6 states that the applicant did not reanalyze the North Anna Dam because Lake Anna would only be used for normal plant cooling of the new unit. As such, the applicant did not list any regulatory guidance or cite any regulations applicable to this section.

Section 2.5.6 of RG 1.70 describes the necessary information and analysis related to the investigation, engineering design, proposed construction, and performance of all embankments used for plant flood protection or for impounding cooling water. Sections 2.4.4 and 2.5.5 in RS-002 provide similar information and guidance.

2.5.6.4 *Technical Evaluation*

Sections 2.4.4 and 2.5.5 of this SER provide the staff's evaluation of potential dam failures and slope stability, respectively.

2.5.6.5 *Post Combined License Activities*

There are no post COL activities related to this section.

2.5.6.6 *Conclusions*

Section 2.4.4 and 2.5.5 of this SER present the staff's conclusions regarding dam failures and slope stability, respectively.