2 SITE CHARACTERISTICS

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2.0 North Anna 3 Site

This chapter of the U.S. Nuclear Regulatory Commission's (NRC's) safety evaluation report (SER) provides the NRC staff evaluation of the North Anna 3 Combined License (COL) Final Safety Analysis Report (FSAR) which 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 reviewed by the staff to determine whether the applicant has accurately described the site characteristics and site parameters together with site-related design parameters and design characteristics in accordance with Title 10 of the *Code of Federal Regulations* (10 CFR) Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants." The review is focused on the site characteristics and site-related design characteristics needed to enable the staff to reach a safety conclusion on the siting of North Anna 3. The North Anna 3 combined license application (COLA) references the Economic Simplified Boiling-Water Reactor (ESBWR) Design Control Document (DCD), referenced in Appendix E to 10 CFR Part 52 as well as the North Anna 3 early site permit (ESP), specifically ESP-003, the ESP for the North Anna 3 site, issued pursuant to 10 CFR 52.24, "Issuance of early site permit." For a COLA referencing a design certification (DC) and an 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, "Site Characteristics," of the North Anna 3 COL FSAR, Revision 8, incorporates by reference Section 2.0 of the ESBWR DCD, Revision 10. In addition, North Anna 3 FSAR Section 2.0 incorporates by reference ESP-003. The staff review of the North Anna 3 site ESP Application includes the site safety analysis report (SSAR), Revision 9 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML062580096)), which describes the applicant's safety assessment of the site, as required by 10 CFR 52.17, "Contents of application; technical information." The staff documented its review of the North Anna 3 ESP SSAR in NUREG-1835, "Safety Evaluation Report for an Early Site Permit (ESP) at the North Anna ESP Site" (ADAMS Accession No. ML052710305), the staff Final Safety Evaluation Report (FSER) for the North Anna 3 ESP and NUREG-1835 Supplement 1 (ADAMS Accession No. ML063170371).

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

<u>*COL Items:*</u>

- 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 North Anna 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) North Anna 3 site characteristic values fall within DCD site parameter values; and (3) North Anna 3 site characteristic values fall within ESP site characteristic values.

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

The applicant provided detailed information related to North Anna 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 Standard Review Plan (SRP) by ESBWR Design," and identifies specific COL items to be addressed in subsequent FSAR sections. In Table 2.0-2R, the COL Item from the DCD is replaced with information responding to the specific North Anna 3 COL item and identifying the FSAR section that addresses the SRP section invoked by the respective COL item.

Supplemental Information:

- NAPS SUP 2.0-1 Site Specific Parameter Values not in DCD

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 North Anna 3 site characteristic or facility design value falls within the ESP site characteristic or ESP design parameter value.

- NAPS SUP 2.0-2 Site Specific Parameter Values not in DCD or ESP

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 North Anna 3 site characteristic or facility design value falls within the SSAR Table 1.9-1 site characteristic or design parameter value which has been incorporated by reference into the North Anna 3 FSAR.

Early Site Permit Variance:

The following variance from the ESP SSAR is discussed in Section 2, "Variances," of Part 7 to the COLA:

- NAPS ESP VAR 2.0-7 Coordinates/Removal of abandoned mat foundations

This variance is discussed in the Variances Section of the Departures Report (Part 7) of the COLA and contains two parts as discussed below:

The COL applicant requested a variance from one of the coordinate systems that define the "ESP Plant Parameter Envelope" shown in the ESP, Appendix A, Figure 1, which lists the coordinates of the site in State NAD 83 South Zone, as well as in the North Anna 3 site Grid coordinates. In the variance, the COL applicant requested to use the values given in North Anna 3 COL FSAR Figure 2.0-205 as "COORDINATES (STATE PLANE NAD 83 VA SOUTH ZONE)," to replace those in the ESP given as "Coordinates (State NAD 83 South Zone)." The review of this part of the variance request is discussed below in Section 2.4.1.

The COL applicant requested a variance from ESP, Appendix A, Figure 1, Note 2, which states, “Abandoned Unit 3 and 4 Reactor Building Mat Foundations are to be removed.” The applicant requests to not remove the abandoned mat foundations for the originally planned North Anna Units 3 and 4 unless a Unit 3 Seismic Category I or II structure would be located above an abandoned foundation. The review of this part of the variance request is discussed below.

2.0.3 Regulatory Basis

The regulatory basis of the information incorporated by reference is in NUREG–1966, “Final Safety Evaluation Report Related to the Certification of the Economic Simplified Boiling Water Reactor” and in NUREG-1835. In addition, the acceptance criteria associated with the relevant requirements of the Commission regulations for the site characteristics, and the associated acceptance criteria, are given in Section 2.0 of NUREG-0800, “Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants (LWR Edition),” the SRP.

The acceptance criteria for the additional information presented in the FSAR beyond that presented in the staff FSER related to the ESBWR DCD and the North Anna 3 site ESP are based on meeting the following relevant requirements of 10 CFR Parts 52 and 100, Reactor Site Criteria”:

The applicable regulatory requirements are the following:

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

- 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 COLA 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 staff reviewed Section 2.0 of the North Anna 3 COL FSAR, Revision 8, and checked the referenced ESBWR DCD, Revision 10 and the North Anna 3 site ESP SSAR, Revision 9, to ensure that the combination of the information in the North Anna 3 COL FSAR and the information in the ESBWR DCD and North Anna 3 site ESP appropriately represents the complete scope of information relating to this review topic.[1]

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.

The staff reviewed the information in the North Anna 3 COL FSAR as follows:

COL Items:

- NAPS COL 2.0-1-A Site Characteristics Demonstration

The ESBWR DCD site parameter values for the standard plant are identified in DCD Tier 2, Table 2.0-1 and DCD Tier 1, Table 5.1-1.

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

Information on North Anna 3 site characteristics is provided in Section 2.1 through Section 2.5 of this SER. This information addresses NRC guidance in NUREG 0800 as identified in Table 2.0-2R. In the "COL Information" column, the COL item from the DCD is replaced with information responding to the COL item and identifying the FSAR section which addresses the SRP section invoked by the COL item.

The staff reviewed the COL information in North Anna 3 COL FSAR Section 2.0, "Site Characteristics," describing the characteristics and site-related design parameters for the North Anna 3 site. The appropriateness of the site characteristic values presented by the applicant for the North Anna 3 site is reviewed by the staff in Section 2.1 through 2.5 of this SER. The applicant compared its site-specific characteristics to the DCD site parameters from DCD Tier 2, Table 2.0-1 and DCD Tier 1, Table 5.1-1 in North Anna 3 COL FSAR Table 2.0-2R and Table 2.0-201.

The staff reviewed the applicant's comparison of site-specific characteristics against the ESBWR DCD and North Anna 3 site ESP for site-specific design parameters and finds the applicant provided in its FSAR Tables 2.0-2R, and 2.0-201 the applicable North Anna 3 site and design specific information that show that the COL design parameters are bounded or are addressed further in specific FSAR sections as noted and therefore is acceptable.

Supplemental Information:

- NAPS SUP 2.0-1 Site Specific Parameter Values not in DCD

In North Anna 3 FSAR Table 2.0-201 Part 2 the applicant provided an evaluation of ESP site characteristics and design parameters for which there is no corresponding DCD site parameter and provided a reference as to where these parameters were evaluated in the North Anna 3 ESP or addressed in the North Anna 3 FSAR as applicable.

[1] See *"Finality of Referenced NRC Approvals"* in SER Section 1.2.2 for a discussion on the staff's review related to verification of the scope of information to be included in a COL application that references a design certification.

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- NAPS SUP 2.0-2 Site Specific Parameter Values not in DCD or ESP

In North Anna 3 FSAR Table 2.0-201 Part 3 the applicant provided an evaluation of site-specific design parameters that were not included as part of the North Anna DCD or ESP. These parameters are described in the North Anna 3 ESP SSAR Table 1.9-1 which was incorporated by reference into the North Anna 3 FSAR and are not specifically evaluated by the staff.

The staff's review confirms that the applicant has addressed the required information, and no outstanding information is expected to be addressed in the COL FSAR related to this introductory section.

- NAPS ESP VAR 2.0-7 Coordinates/Removal of abandoned mat foundations

The COL applicant requested a variance from one of the coordinate systems that define the "ESP Plant Parameter Envelope" shown in the ESP, Appendix A, Figure 1, which lists the coordinates of the site in State NAD 83 South Zone, as well as in the North Anna 3 site Grid coordinates. In the variance, the COL applicant requested to use the values given in North Anna 3 COL FSAR Figure 2.0-205 as "COORDINATES (STATE PLANE NAD 83 VA SOUTH ZONE)," to replace those in the ESP given as "Coordinates (State NAD 83 South Zone)." The review of this part of the variance request is discussed below in Section 2.4.1.

The COL applicant requested a variance from ESP, Appendix A, Figure 1, Note 2, which states, "Abandoned Unit 3 and 4 Reactor Building Mat Foundations are to be removed." In the variance request, the COL applicant states that North Anna Unit 3 Site characteristics are such that removal of abandoned mat foundations is not necessary because the arrangement of a single ESBWR unit selected for this site allows the power block Seismic Category I and II structures to be located away from the abandoned mat foundations.

According to the layout of the ESBWR plant design at the North Anna Unit 3 site, COL site investigation results and the excavation and backfill plan of the applicant, all Seismic Category I structures will be founded on new concrete fill with underlying sound rock, and all safety-related or Seismic Category I or II structures will be away from the abandoned foundations. In view of the plant design layout, and insofar as the requested variance would allow the applicant to leave the abandoned Unit 3 and 4 Reactor Building Mat Foundations in place, the staff finds the variance acceptable because the abandoned foundations will have no adverse effect on Seismic Category I or II structures at the North Anna Unit 3 site.

The requested variance, however, also indicates that the applicant would "not remove the abandoned mat foundations . . . unless a Unit 3 Seismic Category I or II structure would be located above an abandoned foundation." In this regard, FSAR Figure 2.4-201 shows the site layout, and shows Unit 3 Seismic Category I and II structures in locations where they will not be adversely affected by the abandoned mat foundations. Changes to the site layout in FSAR Figure 2.4-201 are subject to control under the provisions of 10 CFR 50.59, and this control is sufficient to ensure that Dominion will account for any effect the abandoned mat foundations might have with respect to Unit 3 Seismic Category I and II structures as a result of an change to the site layout. Accordingly, the staff finds the requested variance acceptable in regard to removal of the abandoned mat foundations.

2.0.5 Post Combined License Activities

There are no post COL activities associated with this section.

2.0.6 Conclusion

The staff's finding related to information incorporated by reference is in NUREG–1966 and NUREG-1835. The staff reviewed the application and checked the referenced DCD and the North Anna 3 site ESP. The staff's review confirms that the applicant has addressed the required information, and no outstanding information is expected to be addressed in the COL FSAR related to this section. Pursuant to 10 CFR 52.63(a)(5) and 10 CFR Part 52, Appendix E, "Design Certification Rule for the ESBWR Design," Section VI.B.1, all nuclear safety issues relating to this section that were incorporated by reference are resolved.

In addition, the staff compared the additional COL information in the application, and the applicant's supplemental COL information to the relevant NRC regulations, the guidance in Section 2.0 of NUREG–0800, and other NRC regulatory guides (RGs). The staff concludes that North Anna 3 COL FSAR, Section 2.0 is acceptable and meets NRC regulatory requirements in 10 CFR 52.79(a)(1)(i) - (vi), 10 CFR 52.79(d)(1), 10 CFR Part 100, and Section 2.0 of NUREG-0800.

Conclusions related to the staff's evaluation of information contained in North Anna Power Station (NAPS) COL 2.0-2-A - 2.0-30-A are provided in Sections 2.1 through 2.5 of this SER.

2.1 <u>Geography and Demography</u>

Section 2.1 of the North Anna 3 FSAR, Revision 8, discusses the site characteristics that could affect the safe design and siting of the plant and includes information about the site boundaries and location of the site with respect to prominent natural and man-made features.

The 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 man-made 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 10 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 Introduction

Section 2.1, "Geography and Demography," of the North Anna 3 COL FSAR addresses site-specific information related to the site location and description, exclusion area authority and control, and population distribution.

2.1.2 Summary of Application

Section 2.1 of the North Anna 3 COL FSAR incorporates by reference the ESP SSAR Section 2.1.1 and includes supplemental information.

COL Items:

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

The proposed location for North Anna 3 is located within the existing North Anna Power Station site (North Anna site) located in Louisa County, Virginia, adjacent to North Anna 1 and 2. The North Anna 3 FSAR specifies the latitude, longitude, and coordinates for the North Anna 3 site.

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

The applicant provided supplemental information on the site location and the site area pertaining to ownership and control; and the coordinates of the North Anna 3 Reactor Building (RB) to address ESP COL Action Item 2.1-1.

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

The North Anna 3 Exclusion Area Boundary (EAB) is the perimeter of a 5,000ftradius circle from the center of the abandoned North Anna 3 containment. This is the same as the exclusion area for the existing units.

- 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 North Anna site and exclusion area under an existing agreement with Old Dominion Electric Co-operative (ODEC), so no approvals are required by State law for shared control of the exclusion area. As the owners of the North Anna site, Dominion and ODEC possess the right to implement the site redress plan.

- NAPS COL 2.0-4-A Population Distribution

The permanent population data presented in this section are primarily derived using the 1990 Census and 2000 Census data as the basis.

2.1.3 Regulatory Basis

The acceptance criteria associated with the relevant requirements of the Commission regulations for the site characteristics are given in Section 2.0 of NUREG-0800.

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

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

- 10 CFR Part 50, “Domestic Licensing of Production and Utilization Facilities,” 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)).

- 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, “Definitions”); (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.

- 10 CFR 100.20(a) and 10 CFR 100.20(b) as they relate to population densities.

- 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:

- 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.

- 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 Sections 2.1.2 and 2.1.3 of NUREG-0800, and Chapter 15) that the applicant has met the requirements of 10 CFR 50.34(a)(1) and 10 CFR Part 100.

- Establishment of Authority:

  The information submitted by the applicant is adequate and meets the requirements of 10 CFR 50.33, “Contents of applications; general information,” 10 CFR 50.34(a)(1), 10 CFR 52.79, “Contents of application; technical information in final safety analysis report,” 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.

- 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.

- 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.

- 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, "Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants, LWR Edition," and in accordance with RG 1.206, "Combined License Applications for Nuclear Power Plants," (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.

- Exclusion Area:

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

- Low-Population Zone (LPZ):

  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.

- 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. Population Density: If the population density exceeds the guidelines in Regulatory Position C.4 of RG 4.7, "General Site Suitability Criteria for Nuclear Power Stations," the applicant must give special attention to the consideration of alternative sites with lower population densities.

- 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.

2.1.4 Technical Evaluation

As documented in NUREG-1966, the staff reviewed and approved Section 2.1 of the certified ESBWR DCD, Revision 9. The staff reviewed Section 2.1 of the North Anna 3 COL FSAR, Revision 8, and checked the referenced ESP SSAR, Revision 9 and the referenced ESBWR DCD to ensure that the combination of the information in the North Anna 3 COL FSAR, the ESP SSAR, and the information in the ESBWR DCD appropriately represents the complete scope of information relating to this review topic.[1]

The staff's review confirmed that the information contained in the application address the relevant information related to this section. The staff reviewed the information in the North Anna 3 COL FSAR as follows:

COL Items:

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

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

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.

- NAPS ESP COL 2.1-1 Location Coordinates for the Unit 3

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

> The site layout and boundary for the proposed North Anna 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 North Anna 3 RB is approximately 450 meters (m) (1,476 feet (ft)) southwest of the center of the Unit 2 Containment Building.
>
> The staff has independently estimated and verified the following latitude and longitude and universal transverse Mercator (UTM) coordinates of the proposed North Anna 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; 4,216,007 meters north; 254,783 meters east	38 03 31.01 north; 77 47 41.8 west

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

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

The applicant incorporated by reference ESP SSAR Section 2.1.2 to address DCD COL Item2.0-3-A. The staff finds the information incorporated by reference in the ESP acceptable because the information provided and reviewed in the ESP are still relevant and applicable to this COLA.

- 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. ODEC has sold to Dominion its interest in the portion of NAPS on which Unit 3 will be located. Further ODEC will not jointly own entire site.

In order 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.

As a part of resolving NAPS ESP Permit Condition 3.E(1), the applicant supplemented the information by stating that as the owners of NAPS, Dominion possesses the right to implement the site redress plan under its agreement with ODEC.

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 North Anna 3.

The 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 Condition 3.E(1), pertaining to exclusion area authority and control and the site redress plan.

- NAPS ESP COL 2.1-2

The applicant supplemented the third paragraph in the ESP SSAR by addressing arrangements with appropriate agencies for emergencies.

To resolve NAPS 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 Commonwealth 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.

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.

Since the supplemental information from the applicant addressed arrangements for controlling only Lake Anna on July 15, 2008, the staff issued a Request for Additional Information (RAI) 02.01.02-1 (ADAMS Accession No. ML081970390), which requested additional information on controls for portions of the WHTF within the exclusion area. The applicant responded to RAI 02.01.02-1 on August 28, 2008 (ADAMS Accession No. ML082460847), by stating that Lake Anna consists of both the WHTF and North Anna Reservoir, which are both partially within the NAPS exclusion area, and the VDGIF is responsible for controlling the portions of the North Anna Reservoir and the WHTF that are within the exclusion area. Therefore, RAI 02.01.02-1 is resolved and closed. Based on the staff's review of the supplemental information provided, the staff concludes that the applicant has appropriately resolved ESP COL Action Item 2.1.2.

- 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. 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 North Anna 3 COL FSAR.

The staff reviewed Section 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.

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.

2.1.5 Post Combined License Activities

There are no post COL activities related to this section.

2.1.6 Conclusion

The 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 discussed 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. In addition to the COL actions addressed above, the staff further concluded that the applicant had provided sufficient details in the ESP SSAR Section 2.1.3 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. 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. 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 incorporated by reference, 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 is addressed in three subsections: Section 2.2.1 provides information on locations and routes; Section 2.2.2 describes nearby industrial transportation facilities (airports, airways, roadways, railways, etc.) and military facilities; and Section 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 addressed 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:

COL Items:

- 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 5 miles of NAPS, three (3) airports within 10 miles of NAPS, and other significant facilities beyond 5 miles of NAPS. In addition, it is stated that no hazardous industrial facilities have been added at the industrial development near the North Anna 3 EAB.

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 COLA 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:

- 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.

- 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.

- 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:

- 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.

- 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 Section III of Section 2.2.1-2.2.2 of NUREG-0800.

- 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

The staff reviewed Section 2.2.2 of the North Anna 3 COL FSAR and checked the referenced ESP SSAR, Revision 9. 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's technical evaluation of this application is limited to reviewing the supplemental information pertaining to NAPS COL Item 2.0.5-A and NAPS ESP COL Action Item 2.2-1.

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:

<u>Industrial Facilities</u>

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 North Anna 3 exclusion area boundary (EAB). The industrial site poses no hazard to North Anna 3.

<u>Airports</u>

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

A third airport (Seven Gables) within 10 miles of the North Anna 3 site opened in 2007. Seven Gables is a private landing strip with an unlighted 457 m (1,500 ft) turf runway approximately 12.4 km (7.7 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.

<u>Airways</u>

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 North Anna 3. Given that the U.S. Department of Navy projected a total of 306 flight operations for the 2007/2008 year for three of four military training routes, 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

The 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:

COL Items:

- 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. In addition, as a part of NAPS COL 2.0-6-A, an evaluation of potential hazard due to gasoline delivery truck is supplemented. On-site and off-site toxic chemicals, aircraft hazards, explosive hazards (hydrogen) and fire hazards are also addressed.

- 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 COLA 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 FSER 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:

- 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's objective of an order of magnitude of 10^{-7} per year.

- 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

The staff reviewed Section 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:

COL Items:

- 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. In addition, as a part of NAPS COL 2.0-6-A, potential impacts due to gasoline delivery trucks are evaluated and presented as supplement information in new Section 2.2.3.1.1.

- 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 North Anna 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 North Anna 3 structure, system, or component (SSC).

Explosions

The applicant evaluated hydrogen (gas and liquid) and Nalco H-130 (for Unit 3), and acetone, ammonium hydroxide, hydrazine and Nalco H-130, hydrogen, Carboline 2, and gasoline from delivery truck (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, "Evaluations of Explosions Postulated to Occur at Nearby Facilities and on Transportation Routes Near Nuclear Power Plants," 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 typical vapor dispersion assumed a wind speed of 1 meter per second with an atmospheric stability class F, and a 77 degree Fahrenheit (°F) ambient air temperature, a relative humidity of 50 percent, a cloud cover of 50 percent, and an atmospheric pressure condition. However, meteorological sensitivity analysis with variation of wind speed, atmospheric stability and ambient air temperature is also performed to determine potential limiting impact. This dispersion analysis was conducted using the ALOHA model with a spectrum of meteorological conditions (stability class, wind speed, time of day, and cloud cover) to ensure the worst-case is captured. The meteorological sensitivity analysis includes the stable meteorological class, F, at a wind speed of 1 meter per second. 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.

The staff noted that there are two 10,000 gallon underground gasoline storage tanks onsite at the North Anna site as listed in FSAR Revision 1 Table 2.2-202 at existing North Anna 1 and 2. The applicant did not address the hazards posed by these tanks from either a confined vapor explosion or a flammable vapor cloud explosion. On June 3, 2004, the staff requested additional information in RAI 2.2.3-1 (ADAMS Accession No. ML050660242), the applicant to address the potential hazards of these tanks due to fuel storage and onsite delivery of fuel to the tanks. The response to RAI 2.2.3-1 provided in Dominion letter NA3-08-118 (ML082980061) documented that a vapor cloud explosion from underground gasoline tank was not a credible event. The applicant provided the information in an FSAR update and calculated the probability of 7.8 x 10^{-7} for an explosion from a gasoline tanker truck delivery resulting in an overpressure of 1 psi at the nearest North Anna 3 safety-related structure. However, in the FSAR Revision 8, the applicant performed the impact evaluation and determined the impacts by calculating the minimum safe distance of 227.7 m (747 ft) to 1 psi overpressure due to potential unconfined vapor cloud explosion, and 82.9 m (272 ft) due to confined vapor explosion from the gasoline delivery truck. Both the calculated minimum distances are lower than the actual distance to the nearest North Anna 3 safety-related structure. The staff performed independent confirmatory calculations and found the minimum safe distance determined by the applicant comparable to the staff's calculated distance. Therefore, staff considers the applicant analysis, assumptions, and conclusions are reasonable and acceptable in meeting the requirements and regulatory guidance. The applicant performed deterministic analysis by calculating the minimum safe distances to 1 psi overpressure, instead of screening out the potential accident based on originally calculated low probability basis. Therefore, the applicant requested that the original probability calculations addressed are no longer considered to be applicable or required. The staff considers this acceptable. The staff considers RAI 2.2.3-1 resolved and closed.

The minimum safe separation distances for flammable and explosive materials in relation to the actual distance to the nearest North Anna 3 safety related-structure are presented in the FSAR Table 2.2-204. The results indicate that a fire or explosion from identified hazardous chemicals and materials stored or transported at Units 1, 2, and 3 would not adversely affect the safe operation or shutdown of North Anna 3, with an exception of liquid hydrogen stored at North Anna 3 and a 13,000 gallon liquid hydrogen delivery truck.

North Anna 3 COLA FSAR Table 2.2-204 indicates that for the 6,000 gallon liquid hydrogen tank, the minimum safe distance to reach an over pressure of 1 psi due to source explosion is estimated to be 612 m (2,009 ft), which is greater than the actual distance to the safety-related structure of 228.6 m (750 ft). Therefore, the applicant performed further analysis using Appendix B of the Electric Power Research Institute (EPRI) Guideline NP-5283-SR-A, "Guidelines for Permanent BWR Hydrogen Water Chemistry Installations, " to determine the minimum safe distance of 150.9 m (495 ft) from source explosion and of 206.3 m (677 ft) from vapor cloud explosion. Since these two distances are less than the distance to the nearest safety-related structure distance of 228.6 m (750 ft), the applicant concluded that the storage of liquid hydrogen would not adversely affect the safe operation of North Anna 3. The staff reviewed the EPRI methodology and the applicant's approach and assumptions, and requested additional information on July 18, 2014, in RAI 2.2.3-10 (ADAMS Accession No. ML14283A550). In a letter dated September 3, 2014 (ADAMS Accession No. ML14251A060), the applicant responded and staff reviewed the information. The staff requested further supplemental information to complete the review as some information provided was unclear and inconsistent. In a letter dated February 16, 2015 (ADAMS Accession No. ML15051A288), the applicant provided information and associated inspections, tests, analyses, and acceptance criteria (ITAAC) and revision to the North Anna 3 FSAR. The revision to the response by the applicant included an ITAAC for verifying the minimum static lateral load capacity of 3 psi for the radwaste building (RW). Based on the review of the information provided and future ITAAC consideration, the staff considers the applicant approach reasonable and acceptable in meeting the requirements and guidance. Therefore this RAI 2.2.3-10 is resolved and closed.

For the 13,000 gallon liquid hydrogen delivery truck, the applicant determined minimum safe distance is greater than the actual distance of 228.6 m (750 ft) to the nearest SSC. For this reason, the applicant stated in the FSAR that a probability analysis was performed and the probability of accident involving a 13,000 gallon delivery truck is estimated to be less than 10^{-6} per year. The applicant stated that this is sufficiently low, and this scenario need not be considered as a design-basis event. Because no detailed information or calculations were provided, in RAI 2.2.3-10 the staff requested additional information regarding the calculation method, input data, assumptions and results along with the justification of this approach taken, and revisions to the FSAR Section as appropriate. In letters dated September 3, 2014 (ADAMS Accession No. ML14251A060) and February 16, 2015 (ADAMS Accession No. ML15051A288), a detailed and sufficient response of the screening analysis and approach along with committed proposed future revision to the FSAR section is provided by the applicant. The staff reviewed the response provided by the applicant, and confirmed that the calculation methods followed those found in RG 1.91, Revision 2, and that conservative input data and assumptions were used. The staff used data provided in the applicant's references as well as independent data on truck accident rates from the U.S. Department of Transportation to confirm that the applicant's results were reasonable. The applicant performed a screening analysis in accordance with the guidance in RG 1.91, Revision 2, that provides reasonable assurance that the risk of damage to safety-related structures, systems or components caused by an explosion from the 13,000 gallon liquid hydrogen delivery truck is sufficiently low, as defined in RG 1.91, Revision 2, such that further evaluation of the risk is not necessary. Therefore, staff considers the applicant's approach reasonable and acceptable. For the reasons described above, RAI 2.2.3-10 pertaining to the 13,000 gallon delivery truck is resolved and closed. In response to RAI 2.2.3-10, the applicant has proposed revisions to future FSAR Sections 2.2.3 and 3.7.2.8.2 and FSAR Tables 2.2-203, 2.2-204, 2.2.-205, and added a new Table 2.2-206 and revised COLA Part 10, Section 2.4.16 and associated ITAAC. The staff verified that the appropriate COLA revisions are incorporated into the FSAR, Revision 9, and, therefore, Confirmatory Item 2.2-01 from the staff's advanced SER for North Anna 3 is resolved and closed.

The staff performed independent calculations for the chemicals addressed by the applicant, and the staff's calculations confirmed the applicant's results. Therefore, the staff concluded that the applicant's assumptions and methodology are reasonable and acceptable.

Toxic Chemicals

The applicant identified the onsite storage of chemicals for North Anna 3 in FSAR, Revision 0, 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 North Anna 3 control room operators were evaluated. In FSAR, Revision 0, 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, "Evaluating the Habitability of a Nuclear Power Plant Control Room During a Postulated Hazardous Chemical Release," show hazardous concentrations of toxic gas in the control room are not reached." In that version of the application, the applicant did not provide the bases and methodology for calculating the toxic chemical concentrations at the intake of the control room; the 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. The staff requested this information in RAIs 2.2.3-2 and 2.2.3-3 (ADAMS Accession No. ML082250417). The applicant's response in a letter dated December 29, 2008 (ADAMS Accession No. ML083660043), identified two chemicals requiring control room habitability analyses, which were reviewed by the staff and further evaluated in Section 6.4 of this SER. The applicant identified in FSAR, Revision 0, 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. Therefore, the staff issued a subsequent RAI 2.2.3-5 (ADAMS Accession No. ML090680312) requesting the applicant to provide a rationale for screening out those chemicals. In a letter dated May 27, 2009 (ADAMS Accession No. ML091490217), the applicant provided rationale by discussing the nature of the chemicals and addressed screening out of chemicals from further analysis. The staff reviewed and found the applicant's response reasonable and acceptable as it satisfies the NRC guidance provided in RG 1.78. Therefore RAI 2.2.3-5 is resolved and closed. As a follow-up to the applicant's response to RAI 2.2.3-2 and 2.2.3-3, the staff on March 26, 2009, issued RAI 2.2.3-7 (ADAMS Accession No. ML090840271) requesting a revised response regarding the modeling data and assumptions details for its analysis and conclusions. This RAI was superseded by RAI 2.2.3-8, and the applicant in a letter dated January 10, 2011 (ADAMS Accession No. ML110110613), provided response addressing ALOHA model methodology, assumptions and input data used. The staff considers that this information is adequate and acceptable for staff's confirmatory analysis. The staff performed confirmatory calculations and concluded that the applicant's results are comparable. The staff therefore considers the applicant's response acceptable, and RAI 2.2.3-7 and 2.2.3-8 are resolved and closed.

The staff noted that the quantity of sodium hydroxide in FSAR Table 2.2-202 (180 gallons for North Anna 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 on August 12, 2008, clarification in RAI 2.2.3-4 *(*ADAMS Accession No. ML082250417). The applicant's response, dated October 20, 2008 (ADAMS Accession No. ML082980061) 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. The staff performed confirmatory calculations and concluded that the applicant's results are comparable; the staff therefore considers the applicant's response acceptable. Therefore, RAI 2.2.3-4 is resolved and closed. The staff also requested on March 9, 2009, additional information in RAI 2.2.3-6 (ADAMS Accession No. ML090680312), to provided rationale for screening sodium hydroxide on the basis of vapor pressure of 10 torr. The applicant in a letter dated May 27, 2009 (ADAMS Accession No. ML091490217), provided response and rationale by comparing United States Environmental Protection Agency (EPA) suggested threshold value of 10 torr to the NRC guidance value provided in RG 1.78, which the staff considers reasonable and acceptable as it satisfies the NRC guidance. This RAI 2.2.3-6 is resolved and closed.

In Enclosure 6 to a letter dated December 18, 2013 (ADAMS Accession No. ML14013A113), the applicant provided a response to RAI 2.2.3-8 and enclosed the list of onsite chemicals and the Control Room Toxic Gas concentrations, which are included in FSAR Table 2.2-205. In addition to these chemicals, potential releases from gasoline delivery trucks have been analyzed and included in the table. The applicant used immediate danger to life and health (IDLH) of 500 PPM for gasoline instead of 300 PPM that is based Time Weighted Average. Therefore, the staff requested the applicant in RAI 2.2.3-10 (ADAMS Accession No. ML14283A550), to revise the analysis using the IDLH of 300 ppm. The applicant performed the analysis and provided the results in a response letter (ADAMS Accession No. ML15051A288) dated February 16, 2015.

The staff considers that the applicant's response adequately addresses the control room concentration of gasoline, which is determined by the applicant to be lower than IDLH concentration of 300 ppm. The staff therefore finds the response acceptable. The applicant also provided proposed revisions to FSAR Section 2.2.3.3 and FSAR Table 2.2-205. The staff verified that the appropriate COLA revisions are incorporated into the FSAR, Revision 9, and, therefore, Confirmatory Item 2.2-02 from the staff's advanced SER for North Anna 3 is resolved and closed.

Each of the hazardous chemicals analyzed, with exception of nitrogen, oxygen, carbon dioxide, an 8,500 gallon gasoline delivery truck, and a 13,000 gallon liquid hydrogen delivery truck, had distances to their respective toxic or asphyxiating limit less than the distance to the control room. However, the control room concentrations for nitrogen, oxygen, carbon dioxide, gasoline, and liquid hydrogen were determined and reported to be below the asphyxiating or toxic limits for each hazardous chemical in FSAR Table 2.2-205. Since, the concentration of these chemicals exceeded their respective IDLH concentrations at the intake to the control room, these chemicals are further considered and evaluated in Section 6.4 of the SER in addressing for the control room habitability.

Airways

The staff evaluation for North Anna 3 airways is contained in the SER related to the ESP SSAR (NUREG-1835). Supplemental information contained in North Anna 3 FSAR Section 2.2.3.2.2 pertaining to effective plant areas for North Anna 3 was reviewed by the staff. However, the staff finds that this modification did not change any conclusions made by the staff in the ESP SER. Consequently, the staff finds that the modification in the COL FSAR, Revision 8, 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.

External Fires

The staff evaluation for North Anna 3 external fires is contained in the FSER related to the ESP SSAR (NUREG-1835). Supplemental information contained in North Anna 3 FSAR Section 2.2.3.4 included information regarding North Anna 3 external fires. The applicant performed an analysis of a wildfire near North Anna 3 using methodology discussed in the SER for the ESP, to determine the incident heat flux on North Anna 3. On the basis of a calculated heat flux with conservative assumptions to include wildfire at plant elevation, closest to the Unit 3 control building (CB) and fuel building (FB), the staff considers the applicant's analysis reasonable and the conclusion acceptable.

Collision with North Anna 3 Intake Structure

FSAR Section 2.2.3.5 states that the North Anna 3 intake structure is located on Lake Anna in a cove behind a cofferdam that is northeast of the North Anna 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 North Anna 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 North Anna 3 intake structure. Even if there is such a collision, the North Anna 3 intake structure is not a safety-related structure, and therefore the staff concluded that such a 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 North Anna 3. The staff finds the applicant's assessment that minor spills into the lake will not affect safe operation or shutdown of the proposed unit is reasonable and therefore acceptable.

2.2.3.5 Post Combined License Activities

There are no post COL activities related to this subsection.

2.2.3.6 Conclusion

The staff reviewed the application and checked the referenced ESP SSAR. 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 subsection.

As set forth above, the applicant identified potential accidents related to the presence of hazardous materials or activities in the site vicinity that could affect a nuclear power plant or plants of the specified type that might be constructed on the proposed site. The applicant also appropriately determined those events that should be considered as design-basis events and demonstrated that the plant is adequately protected and can be operated with an acceptable degree of safety, with regard to design-basis accidents. The staff reviewed the information in the ESP SSAR and supplemented in the FSAR and for the reasons given above, concluded that the applicant has provided information that identified potential hazards, and also has established that the construction and operation of North Anna 3 on the proposed site location is acceptable and meets the requirements of 10 CFR 52.79(a)(1)(iv) and 10 CFR 52.79(a)(1)(vi) for compliance with respect to determining the acceptability of the site. The information addresses COL Item 2.0.6-A and NAPS ESP COL Action Item 2.2-2. In conclusion, the applicant has provided sufficient information to satisfy 10 CFR Parts 50, 52, and 100.

2.3 Meteorology

To ensure that a nuclear power plant or plants can be designed, constructed, and operated on a COL applicant's proposed site in compliance with the NRC regulations, the 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 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 also reviews the applicant's onsite meteorological monitoring program and 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 Sections 2.0 and 2.3 of the North Anna 3 COL FSAR, Revision 8, which references ESBWR DCD, Revision 10, responses to staff RAIs, and applicable sections of NUREG-0800.

2.3.1 Regional Climatology

2.3.1.1 Introduction

North Anna 3 COL FSAR, Revision 9, Section 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

North Anna 3 COL FSAR, Revision 9, Section 2.3.1, "Regional Climatology," incorporates by reference Section 2.3.1 of the ESBWR DCD, Revision 10, "Regional Climatology," and Section 2.3.1 of the North Anna 3 ESP SSAR, Revision 9, "Regional Climatology".

In addition, the North Anna 3 COL FSAR Section 2.3.1, the COL applicant provided the following:

COL Item:

- NAPS COL 2.0-7-A

The COL applicant provided information in NAPS COL 2.0-7-A to address site-specific information relating to regional climatology, site-specific meteorology, and the onsite meteorological measurements program.

Early Site Permit Variance:

- NAPS ESP VAR 2.3-1

The COL applicant proposed variance NAPS ESP VAR 2.3-1 from the ESP SSAR. This variance recalculated North Anna 3 tornado site characteristic values to replace corresponding values presented in the ESP SSAR.

2.3.1.3 Regulatory Basis

The regulatory basis of the information incorporated by reference is addressed in the FSERs related to the ESBWR DCD and the North Anna 3 ESP.

In addition, the acceptance criteria associated with the relevant requirements of the NRC regulations for regional climatology are given in Section 2.3.1 of NUREG-0800.

The acceptance criteria for the additional regional climatic information presented in the FSAR beyond that presented in the ESP SSAR (i.e., NAPS COL 2.0-7-A and NAPS ESP VAR 2.3-1) are based on meeting the following relevant requirements of 10 CFR Part 52 and 10 CFR Part 100:

- 10 CFR 52.79(a)(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 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), as it relates to the consideration given to the regional meteorological characteristics of the site.

The climatological and meteorological information assembled in compliance with the above regulatory requirements are necessary to determine a proposed facility's compliance with the following requirements in Appendix A, "General Design Criteria for Nuclear Power Plants," of 10 CFR Part 50:

- General Design Criterion (GDC) 2, "Design Bases for Protection Against Natural Phenomena," which requires that SSCs important to safety be designed to withstand the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, floods, tsunami, and seiches without loss of capability to perform their safety functions.

- GDC 4, "Environmental and Dynamic Effects Design Bases," which requires that SSCs important to safety be designed to accommodate the effects of and to be compatible with the environmental conditions associated with normal operation, maintenance, testing, and postulated accidents, included loss-of-coolant accidents.

The related acceptance criteria from Section 2.3.1 of NUREG-0800 are as follows:

- The description of the general climate of the region should be based on standard climatic summaries compiled by the National Oceanic and Atmospheric Administration (NOAA).

- 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.

- The tornado parameters should be based on RG 1.76, "Design-Basis Tornado and Tornado Missiles for Nuclear Power Plants," Revision 1. Alternatively, a COL applicant may specify any tornado parameters that are appropriately justified, provided that a technical evaluation of site-specific data is conducted.

- The extreme (straight-line) 100-year return period 3-second gust wind speed site characteristics should be based on appropriate standards, with suitable corrections for local conditions.

- In accordance with RG 1.27, "Ultimate Heat Sink for Nuclear Power Plants," Revision 2, the ultimate heat sink (UHS) meteorological conditions resulting in maximum evaporation and drift losses should be the worst 30-day average combination of controlling parameters (e.g., dewpoint, depression, wind speed, and solar radiation). The meteorological conditions resulting in minimum water cooling should be the worst combination of controlling parameters, including diurnal variations, where appropriate, for the critical time period(s) unique to the specific design of the sink. (Not applicable to a passive containment system design [such as the Passive Containment Cooling System used by the ESBWR design] that does not utilize a cooling tower or cooling pond).

- The 100-year ground-level snowpack or snowfall, whichever is greater, should be based on data recorded at nearby representative climatic stations or obtained from appropriate standards with suitable corrections for local conditions. The weight of the 48-hour probably maximum winter precipitation (PMWP) should be determined in accordance with reports published by NOAA's Hydrometeorological Design Studies Center.

- 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.

- High air pollution potential information should be based on EPA studies.

- All other meteorological and air quality conditions identified by the COL applicant as design and operating bases should be documented and substantiated.

The information should be consistent with acceptable practices, data from NOAA, industry standards, and NRC RGs.

Interim Staff Guidance (ISG) document DC/COL-ISG-7, "Interim Staff Guidance on Assessment of Normal and Extreme Winter Precipitation Loads on the Roofs of Seismic Category I Structures" (74 FR 31470) (ADAMS Accession No. ML091490565), was issued subsequent to the publication of Section 2.3.1 in NUREG-0800. The ISG clarifies the Staff's position that the COL applicant should identify winter precipitation events as site characteristics and site parameters for determining normal and extreme winter precipitation loads on the roofs of seismic Category I structures.

To the extent that the data are applicable to the acceptance criteria outlined above, the applicant has applied the following NRC-endorsed meteorological information selection methodologies and techniques:

- RG 1.23, "Meteorological Monitoring Programs for Nuclear Power Plants," Revision 1, which provides criteria for an acceptable onsite meteorological measurements program, which can be used to monitor regional meteorology site characteristics.

- RG 1.76, Revision 1, which provides criteria for selecting the design-basis tornado parameters.

- RG 1.206, which describes the type of regional meteorological data that should be presented in FSAR Section 2.3.1.

- RG 1.221, "Design-Basis Hurricane and Hurricane Missiles for Nuclear Power Plants," which provides criteria for selecting the design basis hurricane parameters.

2.3.1.4 Technical Evaluation

The staff reviewed Section 2.3.1 of the North Anna 3 COL FSAR and checked the referenced North Anna 3 ESP SSAR, Revision 9. The staff's review confirmed that the information in the North Anna 3 COLA and incorporated by reference to Section 2.3.1 of the North Anna 3 ESP

SSAR, addresses the relevant information related to the regional meteorology. The staff's technical evaluation of the information incorporated by reference to the North Anna 3 ESP SSAR related to regional climatology is documented in the corresponding SER (i.e., NUREG-1835).

The staff reviewed the information in the North Anna 3 COL FSAR as follows:

COL Item:

- NAPS COL 2.0-7-A

The staff reviewed NAPS COL 2.0-7-A related to the provision of regional climatology. The staff found that the COL applicant had appropriately supplied site-specific regional climatological information by incorporating by reference Revision 9 to the North Anna 3 ESP SSAR Section 2.3.1, except as discussed below.

Early Site Permit Variance:

- NAPS ESP VAR 2.3-1

The staff reviewed NAPS ESP VAR 2.3-1 related to from the ESP SSAR. This variance recalculated North Anna 3 tornado site characteristic values as evaluated below by the staff under Section "Tornado Characteristics."

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, "Evaluation of Site/Design Parameters and Characteristics." Unless otherwise noted in North Anna 3 COL FSAR Table 2.0-201, the North Anna 3 site characteristic values are acceptable to the staff because NUREG-0800, Section 2.3.1, states that a COLA 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 COL applicant had appropriately compared the ESBWR DCD site parameter values with the North Anna 3 site characteristics, except as discussed below.

Design Basis Dry and Wet Bulb Temperatures

The ESBWR DCD site parameters for ambient air temperature are as follows:

- <u>Ambient Design Air Temperature (0 percent exceedance maximum dry bulb and mean coincident wet bulb)</u>: These site parameter values represent a maximum dry bulb temperature that exists for 2 hours or more, combined with the maximum wet bulb temperature that exists in that population of dry bulb temperatures.

- <u>Ambient Design Air Temperature (0 percent exceedance minimum dry bulb)</u>: This site parameter value represents a minimum dry bulb temperature that exists within a set of hourly data for duration of 2 hours or more.

- Ambient Design Air Temperature (0 percent exceedance maximum non-coincident wet bulb): This site parameter value represents a maximum wet bulb temperature that exists within a set of hourly data for duration of 2 hours or more.

- Ambient Design Air Temperature (1 percent annual exceedance maximum dry bulb and mean coincident wet bulb): These site parameter values represent a 1-percent annual exceedance dry bulb temperature combined with the corresponding wet bulb temperature that exists in that population of dry bulb temperatures.

- Ambient Design Air Temperature (1 percent annual exceedance minimum dry bulb): The minimum normal value is the 99-percent annual exceedance temperature.

- Ambient Design Air Temperature (1 percent annual exceedance maximum non-coincident wet bulb): The maximum normal value is the 1-percent annual exceedance non-coincident wet bulb temperature.

- Ambient Design Air Temperature (2 percent annual exceedance maximum dry bulb and mean coincident wet bulb): These site parameter values represent a 2-percent annual exceedance dry bulb temperature combined with the corresponding wet bulb temperature that exists in that population of dry bulb temperatures.

- Ambient Design Air Temperature (2 percent annual exceedance minimum dry bulb): The minimum normal value is the 98-percent annual exceedance temperature.

- Ambient Design Air Temperature (2 percent annual exceedance maximum non-coincident wet bulb): The maximum normal value is the 2-percent annual exceedance non-coincident wet bulb temperature.

North Anna 3 COL FSAR Table 2.0-201 compares the ESBWR ambient design temperature site parameters against the corresponding 100-year return period temperatures estimated near the North Anna 3 site. 10 CFR 52.79(a)(1)(iii) states that COLAs 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.

As shown in North Anna 3 COL FSAR Table 2.0-201, all of the COL applicant's site characteristics for ambient design air temperature are bounded by the ESBWR DCD site parameters. These temperatures include the 100-year return period dry bulb temperatures with the mean coincident wet bulb temperatures and the 100-year return period noncoincident wet bulb temperatures. The COL applicant derived a 100-year return period, maximum coincident wet bulb temperature value of 76 °F 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 °F. The staff performed an independent evaluation of the site characteristic temperatures that resulted in generally similar temperatures. Although the staff's calculation determined the 100-year return period coincident wet bulb temperature to be higher than the COL applicant's, both the staff's and COL applicant's dry bulb and coincident wet bulb temperatures are well within bounds of the ESBWR DCD site parameter value of 80.0 °F for the coincident wet bulb temperature. RAI 02.03.01-6 requested that the COL applicant provide a 100-year return period minimum dry bulb temperature for comparison against the US-APWR [Advanced Pressurized Water Reactor] site parameter temperature (in previous revisions of the North Anna 3 COL FSAR when the reference DCD was the US-APWR). The COL applicant responded by committing to include a justification for the use of a 0 percent exceedance minimum dry bulb temperature instead of the 100-year return period temperature. North Anna 3 COL FSAR Table 2.0-201 included a 0 percent annual exceedance minimum temperature of -21 °F for comparison against the US-APWR (now ESBWR) site characteristic 0 percent annual exceedance minimum temperature. The 0 percent annual exceedance temperature is used as the North Anna 3 site characteristic minimum dry bulb temperature because it bounds the calculated 100-year return period minimum dry bulb temperature of -19 °F. The -21 °F temperature was recorded at the Louisa Cooperative observation site, which is located about 10 miles WSW of the North Anna 3 site, whereas the 100-year return period temperature is an extrapolation of data from Richmond, VA. Both the 100-year return period temperature and 0 percent exceedance temperature presented by the COL applicant bound the Staff's independently calculated 100-year return period minimum dry bulb temperature, and are, therefore, acceptable to the staff. The staff reviewed the changes proposed in the response to RAI 02.03.01-6 and finds them to be acceptable. Therefore, the staff has determined that RAI 02.03.01-6 is resolved and closed.

Using a combination of National Climatic Data Center (Hourly data from Richmond, VA (1978-2009)), and climate data from the American Society of Heating, Refrigerating and Air-Conditioning Engineers, the staff was able to verify the COL applicant's site characteristic temperatures presented in North Anna 3 COL FSAR, Table 2.0-201. The staff, therefore, accepts them as correct.

Extreme Winds

Section 2.3.1.3.1 of the North Anna 3 FSAR includes a description of extreme wind, including estimates of 10^{-7} per year hurricane wind speeds. Using the guidance in RG 1.221, the applicant chose a 3-second gust hurricane wind speed value of 62 m/s (140 mph). This wind speed represents the maximum nominal 3-second gust wind speed at 10 m (33 ft) above ground over open terrain having a probability of exceedance of 10^{-7} per year. The staff, using the guidance provided in RG1.221, confirmed the hurricane wind speed value chosen by the applicant.

Section 2.3.1.3.1 of the North Anna 3 FSAR also presents a basic wind speed value of 40 m/s (90 mph) for Unit 3 nonsafety-related structures not included in the certified design. The applicant used the American Society of Civil Engineers/Structural Engineering Institute (ASCE/SEI) Standard 7-05, "Minimum Design Loads for Buildings and Other Structures," to determine the value. The value was confirmed by the staff through the use of ASCE/SEI Standard 7-05.

The applicant presents a 50-year wind speed site characteristic of 42.9 m/s (96 mph) in Table 2.0-201 for "Other Seismic NS Standard Plant Structures." This site characteristic value is the same as the ESP and Unit 3 site characteristic value for a 100-year wind speed. The 100-year wind speed site characteristic value is higher than a 50-year wind speed. This is a conservative assumption and is therefore acceptable to the staff.

The applicant specified exposure Category D in Table 2.0-201 for Unit 3 as part of the extreme wind site characteristics for Seismic Category I, II, and radwaste building structures. ASCE/SEI Standard 7-05 describes Exposure Category D as having flat, unobstructed area and water surfaces that prevail in the upwind direction for a distance greater than 5,000 ft (1,525 m) or 20 times the building height, whichever is greater. The use of Exposure Category D results in the most severe design wind pressures and is therefore a conservative assumption and is acceptable to the staff. Hurricane wind speed effect on safety systems and structures is evaluated in Chapter 3 Section 3.3 and Chapter 19 Appendix 19A of this SER.

Tornado Characteristics

Revision 3 of the North Anna 3 COL FSAR presented tornado site characteristics that differed from those presented in the North Anna 3 ESP. The tornado site characteristics approved in the North Anna 3 ESP were based on RG 1.76, Revision 0. The most recent guidance provided for determining tornado site characteristics is RG 1.76, Revision 1. This updated guidance effectively lowered the wind speeds based on the Enhanced Fujita scale. In RAI 02.03.01-5, the staff asked the COL applicant to include in the North Anna 3 COL FSAR either a request for a variance (NAPS ESP VAR 2.3-1) related to the ESP tornado site characteristic values, or request an amendment to the North Anna 3 ESP.

In response to RAI 02.03.01-5, the COL applicant proposed an update to Part 7, "Departures Report," of the North Anna 3 COL that includes a variance in accordance with 10 CFR 52.79(b)(2), CFR 52.93(b) and 10 CFR 52.39(d). The staff has determined that the COL applicant's updated tornado site characteristics are appropriate for the North Anna 3 site. Additional staff evaluation of this variance is below. The staff has confirmed that the COL applicant included this variance request in Part 7 of the COLA and therefore determines that RAI 02.03.01-5 is resolved.

The COL applicant chose tornado site characteristics based on RG 1.76, Revision 1. RG 1.76, Revision 1 provides design-basis tornado characteristics for three tornado intensity regions throughout the United States, each with a 10^{-7} per year probability of occurrence. The proposed COL site is located in Tornado Intensity Region II where severe tornadoes have been observed. The COL applicant proposed the following tornado site characteristics, which are listed in North Anna 3 COL FSAR Table 2.0-201 and North Anna 3 COL FSAR Table 2.3-225:

- Maximum wind speed 200 mph
- Maximum translational speed 40 mph
- Maximum rotational speed 160 mph
- Radius of maximum rotational speed 150 ft.
- Pressure drop 0.9 psi
- Rate of pressure drop 0.4 psi/sec

Because the COL applicant has identified design-basis tornado site characteristics based on RG 1.76, Revision 1, the staff concludes that the COL applicant's tornado site characteristics are acceptable. As shown in North Anna 3 COL FSAR Table 2.0-201, the North Anna 3 COL tornado site characteristics are bounded by the ESBWR DCD site parameter values.

Precipitation Extremes

The staff also reviewed the COL applicant's additional information related to winter precipitation roof loading provided in North Anna 3 COL FSAR Section 2.3.1.3.4. The staff issued DC/COL-ISG-7, which clarifies the Staff's position on identifying winter precipitation events as site characteristics and site parameters for determining normal and extreme winter precipitation loads on the roofs of seismic Category I structures. The ISG revises the previously issued staff guidance as discussed in Section 2.3.1 in NUREG-0800.

The ISG states that normal and extreme winter precipitation events should be identified in Section 2.3.1 of NUREG-0800, as COL site characteristics to compare against site parameters related to normal and extreme winter precipitation loads on the roofs of seismic Category I structures. The normal winter precipitation roof load is a function of the normal winter precipitation event; whereas, the extreme winter precipitation roof loads are based on the weight of the antecedent snowpack resulting from the normal winter precipitation event plus the larger resultant weight from either: (1) the extreme frozen winter precipitation event; or (2) the extreme liquid winter precipitation event. The extreme frozen winter precipitation event is assumed to accumulate on the roof on top of the antecedent normal winter precipitation event; whereas, the extreme liquid winter precipitation event may or may not accumulate on the roof, depending on the geometry of the roof and the type of drainage provided. The ISG further states:

- The normal winter precipitation event should be the highest ground-level weight (in pounds per square foot (lb/ft^2)) among: (1) the 100-year return period snowpack; (2) the historical maximum snowpack; (3) the 100-year return period two-day snowfall event; or (4) the historical maximum two-day snowfall event in the site region.

- The extreme frozen winter precipitation event should be the higher ground-level weight (in lb/ft^2) between: (1) the 100-year return period two-day snowfall event; and (2) the historical maximum two-day snowfall event in the site region.

- The extreme liquid winter precipitation event is defined as the theoretically greatest depth of precipitation (in inches of water) for a 48-hour period that is physically possible over a 25.9-square-kilometer (km) (10-square-mile (mi)) area at a particular geographical location during those months with the historically highest snowpack.

The COL applicant identified the maximum snowfall events for the area surrounding the North Anna 3 site to be 25.5 inches. This was measured at two different stations; Piedmont Research Station on January 8, 1996, and Fredericksburg on January 28, 1922. The COL applicant presented the normal winter precipitation roof load of 30.5 lb/ft^2. The staff notes that the normal winter precipitation roof load resulting from the 100-year return period snowpack (30.5 lb/ft^2) is less than the ESBWR design basis normal winter precipitation roof load site parameter value of 50 lb/ft^2. The COL applicant also presented its extreme winter precipitation ground load of 141.3 lb/ft^2. This value is based on the sum of the site characteristic normal winter precipitation event plus the liquid 48-hr PMWP. The staff notes that this extreme winter precipitation ground snow load is less than the ESBWR site parameter value of 162 lb/ft^2. The staff performed an independent evaluation following the methodology provided in DC/COL-ISG-7 and determined that the COL applicant’s snow load calculations are conservative and acceptable.

A comparison between the ESBWR site parameter and the North Anna 3 site characteristic for snow load is presented in North Anna 3 COL FSAR Table 2.0-201. The COL applicant’s site characteristic for snow load is conservatively bounded by the ESBWR DCD site parameter.

2.3.1.5 Post Combined License Activities

There are no post-COL activities to this section.

2.3.1.6 Conclusion

The staff reviewed the application and checked the referenced ESP SSAR. The staff finds that the COLA includes all the information relevant to this subsection and the staff confirmed that there is no outstanding information that remains to be addressed in the COL FSAR related to this section.

The staff concluded that the information pertaining to North Anna 3 COL FSAR Section 2.3.1 is within the scope of the ESP SSAR and adequately incorporates by reference Section 2.3.1 of the ESP SSAR. The information is therefore acceptable to the staff. The staff evaluated additional information related to NAPS ESP VAR 2.3-1 as discussed in “Tornado Characteristics,” above. The staff found this information to be correct and acceptable for the North Anna 3 site. In addition, the staff compared the additional COL information in the application to the relevant NRC regulations and acceptance criteria defined in Section 2.3.1of NUREG-0800. The staff concluded that the COL applicant is in compliance with the relevant requirements of 10 CFR Parts 52 and 100. The staff finds that COL 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

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

2.3.2.2 Summary of Application

Section 2.3.2, “Local Meteorology,” of the North Anna 3 COL FSAR, Revision 9, incorporates by reference Section 2.3.2 of the ESBWR DCD, Revision 10 and Section 2.3.2 of the North Anna 3 ESP SSAR.

In addition, in North Anna 3 COL FSAR Section 2.3, the COL applicant provided the following:

COL Items:

- NAPS COL 2.0-8-A

The COL applicant provided information in NAPS COL 2.0-8-A to address site-specific information relating to regional climatology, site-specific meteorology, and the onsite meteorological measurements program.

- NAPS ESP COL 2.3-1

The staff reviewed the resolution to NAPS ESP COL 2.3-1, related to 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 COL applicant responded to this COL item by providing supplemental information on the potential impact of the North Anna 3 cooling towers on North Anna 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 of the information incorporated by reference is addressed in the FSER related to the DCD.

In addition, the acceptance criteria associated with the relevant requirements of the Commission regulations for local meteorology are given in Section 2.3.2 of NUREG-0800.

The applicable regulatory requirements for identifying local meteorology are:

- 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 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) as it relates to the consideration given to the local meteorological characteristics of the site.

The related acceptance criteria from Section 2.3.2 of NUREG-0800 are as follows:

- Local summaries of meteorological data based on onsite measurements in accordance with RG 1.23, Revision 1, and NWS station summaries or other standard installation summaries from appropriate nearby locations (e.g., within 80 km (50 mi)) should be presented as specified in RG 1.206, Section 2.3.2.1.

- A complete topographical description of the site and environs out to a distance of 80 km (50 mi) from the plant, as described in RG 1.206, Section 2.3.2.2, should be provided.

- A discussion and evaluation of the influence of the plant and its facilities on the local meteorological and air quality conditions should be provided. COL applicants should also identify potential changes in the normal and extreme values, resulting from plant construction and operation. The acceptability of the information is determined through comparison with standard assessments.

- The description of local site airflow should include wind roses and annual joint frequency distributions (JDF) of wind speed and wind direction by atmospheric stability for all measurement levels using the criteria provided in RG 1.23, Revision 1.

2.3.2.4 Technical Evaluation

The staff reviewed Section 2.3.2 of the North Anna 3 COL FSAR and checked the referenced ESP SSAR, Revision 9. The staff's review confirmed that the information contained in the North Anna 3 COLA and incorporated by reference to Section 2.3.2 of the ESP SSAR 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 item NAPS COL 2.0-8-A, and (2) the resolution of COL Action Item NAPS ESP COL 2.3-1.

COL Items:

- NAPS COL 2.0-8-A

- NAPS ESP COL 2.3-1

The staff reviewed the resolution to NAPS COL 2.0-8-A and NAPS ESP COL 2.3-1 related to local meteorology. The staff found that the COL applicant had appropriately supplied site-specific local meteorological information by incorporating by reference Revision 9 to the North Anna ESP SSAR Section 2.3.2. The staff's review of the COL applicant's supplemental information regarding the North Anna 3 cooling tower impact on North Anna 3 plant design and operation is discussed below.

Potential Influence of the Plant and the Facilities on Local Meteorology

The COL applicant states that the cooling towers are positioned at a location that attempts to reduce or eliminate the potential for plume interference effects on the same-unit and adjacent-unit components and systems that are important to safety. The COL applicant provided a discussion of the effects of salt and moisture deposition on the North Anna 3 transformers, switchyard equipment, or transmission lines. The COL applicant provided an electronic copy of the input and output files from the Seasonal/Annual Cooling Tower Impact (SACTI) computer model. The staff reviewed the model input files to assure that the COL applicant made conservative assumptions. The SACTI results indicate that a highest deposition rate of salt accumulation would result in 0.00015 milligrams per cubic centimeter per month (mg/cm^2-month) near the North Anna 3 transformers during the winter months. This accumulation rate is below the lower end of the "Light Contamination Level" range of 0.03 – 0.08 mg/cm^2 defined by the Institute of Electrical and Electronic Engineers (IEEE) standard[2]. The staff has independently verified the source cited by the COL applicant. The staff agrees that total accumulation reaching amounts that require mitigation is highly unlikely due to local precipitation removing any salt deposits before it reaches a level of concern.

The COL applicant states that the plume from the CIRC hybrid cooling towers is unlikely to affect any heating, ventilation, and air conditioning systems due to the location of the CB being over 1600 ft away. This assures sufficient mixing between the exhaust plume and the surrounding air to minimize any significant increases in wet bulb or dry bulb temperature above local ambient values. The staff agrees with this assessment and finds that the COL applicant has given adequate consideration to whether cooling towers may adversely impact local temperatures, humidity, and other hazards posed by cooling towers.

2.3.2.5 Post Combined License Activities

There are no post COL activities associated with this subsection.

2.3.2.6 Conclusion

The staff reviewed the application and checked the referenced North Anna ESP SSAR. The staff finds that the COLA includes all the required information relevant to this section, and the staff confirmed that there is no outstanding information that remains to be addressed in the COL FSAR related to this Section.

The staff concluded that the information pertaining to North Anna 3 COL FSAR, Section 2.3.2 is within the scope of the ESP and adequately incorporates by reference Section 2.3.2 of the ESP SSAR. Therefore the information is acceptable to the staff. In addition, the staff compared the additional COL information in the application to the relevant NRC regulations and acceptance

[2] IEEE Guide for Application of Power Apparatus Bushings, IEEE Standard C.57.19.100-1995, Aug 1995.

criteria defined in Section 2.3.2 of NUREG-0800 and concluded that the COL applicant is in compliance with the relevant requirements of 10 CFR Parts 52 and 100. COL item NAPS COL 2.0-8-A and COL Action Item NAPS ESP COL 2.3-1 have been adequately addressed by the COL applicant and can be considered closed.

2.3.3 Onsite Meteorological Measurement Programs

2.3.3.1 Introduction

The North Anna 3 onsite meteorological measurement program addresses the need for onsite meteorological monitoring and the resulting data. The staff review covers the following specific areas: (1) meteorological instrumentation, including siting of sensors, sensor type and performance specifications, methods and equipment for recording sensor output, the quality assurance program for sensors and recorders, data acquisition and reduction procedures, and special considerations for complex terrain sites; and (2) the resulting onsite meteorological database, including consideration of the period of record and amenability of the data for use in characterizing atmospheric dispersion conditions.

2.3.3.2 Summary of Application

Section 2.3 of the North Anna 3 COL FSAR, Revision 9, incorporates by reference Section 2.3.3 of the ESBWR DCD, Revision10 and Section 2.3.3 of the North Anna 3 ESP SSAR, Revision 9.

COL Item:

- NAPS COL 2.0-9-A

The COL applicant provided information in NAPS COL 2.0-9-A to address site-specific information relating to regional climatology, site-specific meteorology, and 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 COLA 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 FSER 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. NUREG-0800, Section 2.3.3, states that guidance on a suitable onsite meteorological monitoring program is in RG 1.23, Revision 1.

2.3.3.4 Technical Evaluation

The staff reviewed Section 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

COLA and incorporated by reference to Section 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 Item NAPS COL 2.0-9-A. There are no site parameters or site characteristics associated with this FSAR subsection.

COL Item:

- NAPS COL 2.0-9-A

The staff reviewed the resolution to NAPS COL 2.0-9-A related to the onsite meteorological measurements program. The staff found that the COL applicant had appropriately supplied site-specific onsite meteorological measurements program information by incorporating by reference North Anna 3 ESP SSAR Section 2.3.3.

The staff also reviewed the information provided by the COL applicant in North Anna 3 COL FSAR Section 2.3.3.1.2, concerning the distance between the onsite meteorological towers and the North Anna 3 structures. The COL applicant stated that the highest building at the North Anna 3 site is the Turbine Building (TB) at 52 m (170.6 ft). The primary and backup meteorological towers are approximately 733.4 m (2,406 ft) and 744 m (2,440 ft), respectively, from the plant facility boundary. Because the primary and backup meteorological towers are more than 10 building heights away from the tallest building at the North Anna 3 site, the COL applicant concluded that the North Anna 3 TB does not influence the meteorological measurements. The staff concurred with this assessment because the COL applicant had met the RG 1.23, Revision 1 guidance. RG 1.23, Revision 1 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 tallest cooling tower is the CWS hybrid cooling tower, which, at 55 m (180 ft), is slightly taller than the TB, but is located further from the primary and backup meteorological towers. Therefore, the staff concluded that the building wake from the cooling tower structures would not influence the meteorological measurements.

2.3.3.5 Post Combined License Activities

Part 10 of the COLA describes proposed COL conditions, including ITAAC. Part 10, Table 2.3-1 of the COLA contains the emergency planning (EP) ITAAC. The following 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.

- EP Program Element 6.4: The means exist to acquire and evaluate meteorological information.

- The North Anna 3 EP, including EP ITAAC are addressed in SER Section 13.3, "Emergency Planning."

2.3.3.6 Conclusion

The staff reviewed the application and checked the referenced ESP SSAR. The staff finds that the COLA includes all the information relevant to this subsection, and the staff confirmed that there is no outstanding information that remains 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 2.3.3 is within the scope of the ESP SSAR and adequately incorporates by reference Section 2.3.3 of the North Anna 3 ESP SSAR. The information is therefore acceptable to the staff. 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 COL applicant is in compliance with the 10 CFR Parts 52 and 100 as described in RG 1.23 and SRP Section 2.3.3. Therefore, NAPS COL Item 2.0-9-A has been adequately addressed by the COL applicant and can be considered closed.

2.3.4 Short-Term Diffusion Estimates (Related to RG 1.206, Section C.III.1, Chapter 2, C.I.2.3.4, "Short-Term Atmospheric Dispersion Estimates for Accident Releases")

2.3.4.1 Introduction

The short-term diffusion estimates are used to determine the amount of airborne radioactive materials expected to reach a specific location during an accident situation. The diffusion estimates address the requirement for conservative atmospheric dispersion (relative concentration) factor (χ/Q value) estimates at the EAB, the outer boundary of the LPZ, and at the control room for postulated design-basis accidental radioactive airborne releases. The staff's review covers the following specific areas: (1) atmospheric dispersion models to calculate atmospheric dispersion factors for postulated accidental radioactive releases; (2) meteorological data and other assumptions used as input to atmospheric dispersion models; (3) derivation of diffusion parameters (e.g., σ_y and $o_{z.}$); (4) cumulative frequency distributions of χ/Q values; (5) determination of conservative χ/Q values used to assess the consequences of postulated design-basis atmospheric radioactive releases to the EAB, LPZ, and control room; and (6) any additional information requirements prescribed within the "Contents of Application" sections of the applicable subparts to 10 CFR Part 52.

2.3.4.2 Summary of Application

North Anna 3 COL FSAR, Revision 9, Section 2.3.4 addresses site-specific information on short-term atmospheric dispersion estimates for accident releases. The COL applicant addressed the information as follows:

<u>*COL Item:*</u>

- NAPS COL 2.0-10-A

This COL item states that the COL applicant should provide conservative factors as described in Section 2.3.4 of NUREG-0800.

- NAPS ESP COL 2.3-2

This COL action item states that the COL applicant should assess dispersion of airborne radioactive materials to the control room. The COL applicant responded to this COL action item by providing details regarding the source and receptor information needed to determine χ/Q values at the ESBWR control room. The χ/Q values calculated through the use of the ARCON96 computer program are provided in North Anna 3 COL FSAR Table 2.0-201. Tables 2.3-201 through 2.3-204, Table 2.3-206, and 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 COLA 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 FSER 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. The staff considered the following regulatory requirements in reviewing the COL applicant's discussion of control room atmospheric dispersion analyses:

- 10 CFR Part 50, Appendix A, GDC 19, "Control Room," as it relates 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, as it relates to providing an onsite technical support center (TSC) from which effective direction can be given and effective control can be exercised during an emergency.

The related acceptance criteria from Section 2.3.4 of NUREG-0800 are as follows:

- 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 $o_{z.}$) 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.

Section 15.0.3 of NUREG-0800 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.

The following RGs are applicable to this section:

- RG 1.78, Revision 1;

- RG 1.145, "Atmospheric Dispersion Models for Potential Accident Consequence Assessments at Nuclear Power Plants," Revision 1; and

- RG 1.194, "Atmospheric Relative Concentrations for Control Room Radiological Habitability Assessments at Nuclear Power Plants."

2.3.4.4 Technical Evaluation

The staff reviewed North Anna 3 COL FSAR Section 2.3.4 and checked the referenced ESP SSAR, Revision 9. The staff's review confirmed that the information contained in the North Anna 3 COLA and incorporated by reference to Section 2.3.4 of the ESP SSAR, addresses the relevant information related to short-term atmospheric diffusion estimates for accident 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 FSER (i.e., NUREG-1835).

The staff's technical evaluation of this subsection is limited to reviewing: (1) the resolution of COL item NAPS COL 2.0-10-A; (2) the resolution of COL Action Item NAPS ESP COL 2.3-2; and (3) whether the North Anna 3 short-term atmospheric diffusion site characteristics fall within the ESBWR DCD short-term atmospheric diffusion site parameter values.

EAB and LPZ χ/Q Values

The staff found the continued use of the North Anna 3 ESP SSAR accident EAB and LPZ χ/Q values acceptable for the following reasons:

- Section 2.3.4 of NUREG-0800, states that a COLA referencing an ESP need not include a re-investigation of the site characteristics that have been previously accepted in the referenced ESP.

- The North Anna 3 site layout shown in North Anna 3 COL FSAR Figure 2.0-205, "Unit 3 Power Block Building Locations Within the ESP Proposed Facility Boundary," is the same layout shown in North Anna 3 ESP Figure 1.2-4 and the definitions of the North Anna 3 COL FSAR EAB and LPZ are the same as the North Anna 3 ESP definitions. Consequently, the downwind distances used in the North Anna 3 ESP SSAR to calculate the EAB and LPZ χ/Q site characteristic values are applicable to the North Anna 3 COLA.

Other input assumptions used to derive the North Anna 3 ESP SSAR EAB and LPZ accident χ/Q site characteristic values remain bounding for North Anna 3. For example, all release points are as ground level releases and the COL applicant did not take credit for building wake effects. Ignoring building wake effects for a ground-level release decreases the amount of atmospheric turbulence assumed to be in the vicinity of the release point, resulting in higher (more conservative) χ/Q values.

The staff concluded that the input assumptions used to model the North Anna 3 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 accident release points is appropriate. Therefore, the staff finds that the COL applicant's use of the North Anna 3 ESP SSAR EAB and LPZ χ/Q values for North Anna 3 is appropriate.

Control Room and TSC χ/Q Values for North Anna 3 Releases

The COL applicant used the computer code ARCON96 (NUREG/CR-6331, "Atmospheric Relative Concentrations in Building Wakes") to estimate χ/Q values at the control room for potential accidental releases of radioactive material. The ARCON96 model implements the methodology outlined in RG 1.194.

The ARCON96 code estimates χ/Q values for various time-averaged 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 to the atmosphere will be normally distributed (Gaussian) about the plume centerline. 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.

The 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 and the relative concentrations that are exceeded no more than 5 percent of the time for each averaging period is determined.

The meteorological input to ARCON96 used by the COL applicant consisted of wind speed, wind direction, and atmospheric stability data based on hourly onsite data from a 3-year period from January 1, 1996 through December 31, 1998. The wind data were obtained from the 10-m and 48.4 m levels of the onsite meteorological tower, and the stability data were derived from the vertical temperature difference (delta-temperature) measurements taken between the 48.4-m and 10-m levels on the onsite meteorological tower.

The following sources were used as the necessary input to ARCON96:

Onsite Hourly Meteorological Data: ----------- January 1, 1996 – December 31, 1998
ESBWR DCD Figure 2A-1:-----------------------Site Plan with Release and Intake Locations
ESBWR DCD Table 2A-1 to 2A-4:------------- CR and TSC Source/Receptor Data
North Anna 3 COL FSAR Figure 2.1-201:----Plant Layout on the North Anna 3 Site

North Anna 3 COL FSAR Section 2.4.2.3 states that for North Anna 3 Units 3, the plant orientation is rotated 23.54 degrees clockwise from true north. ARCON96 modeling was conducted by the COL applicant to evaluate impacts at the Control Room emergency intakes.

North Anna 3 COL FSAR Table 2.3-201 through 2.3-207 lists the atmospheric dispersion estimates that the COL applicant derived from its ARCON96 modeling run results. In accordance with the ESBWR DCD, North Anna 3 COL FSAR Table 2.0-201 compared the site-specific control room χ/Q values to the corresponding site parameters provided in the DCD. This comparison showed that the ESBWR control room values conservatively bounded the site-specific values.

RAI 02.03.04-2 requested the COL applicant provide a copy of the ARCON96 input and output files used to determine the control room and TSC χ/Q values. As part of the response to RAI 02.03.04-2 dated January 10, 2011 (ADAMS Accession No. ML110140131), the COL applicant committed to updating the FSAR to include a comparison of the site χ/Q values against Revision 3 of the US-APWR DCD. The staff confirmed the COL applicant's atmospheric dispersion estimates for the 1996-1998 data by running the ARCON96 computer model and obtaining similar results (i.e., values on average within ± 2.5 percent). Both the staff and COL applicant used a ground-level release assumption for each of the release/receptor combinations as well as other conservative assumptions. In light of the foregoing, the staff accepts the control room χ/Q values presented by the COL applicant and determines that RAI 02.03.04-2 is resolved and closed. The licensee later submitted ARCON96 input and output files to support the control room and TSC χ/Q values for the ESBWR DCD.

2.3.4.5 Post Combined License Activities

There are no post COL activities associated with this subsection.

2.3.4.6 Conclusion

The staff reviewed the application and checked the referenced DCD and the North Anna 3 ESP SSAR. The staff finds that the COLA includes all the required information related to short-term diffusion estimates, and the staff confirmed that there is no outstanding information that remains to be addressed in the North Anna 3 COL FSAR related to this subsection. The staff's technical evaluation of the information incorporated by reference to the ESP SSAR related to local meteorology is documented in NUREG-1835.

In addition, the staff has compared the additional COL information in the application to the relevant regulations and acceptance criteria defined in NUREG-0800, Section 2.3.4. The staff concludes that the COL applicant is in compliance with the relevant requirements of 10 CFR Parts 50, 52, and 100.

2.3.5 Long-Term Diffusion Estimates (Related to RG 1.206, Section C.III.2, Chapter 2, C.I.2.3.5, "Long Term Atmospheric Dispersion Estimates for Routine Releases")

2.3.5.1 Introduction

The long-term diffusion estimates are used to determine the amount of airborne radioactive materials expected to reach a specific location during normal operations. The diffusion estimates address the requirement concerning atmospheric dispersion and dry deposition estimates for routine releases of radiological effluents to the atmosphere. The review covers the following specific areas: (1) atmospheric dispersion and deposition models used to calculate concentrations in air and amount of material deposited as a result of routine releases of radioactive material to the atmosphere; (2) meteorological data and other assumptions used as input to the atmospheric dispersion models; (3) derivation of diffusion parameters (e.g., σ_z); (4) atmospheric dispersion (relative concentration) factors (χ/Q values) and deposition factors (D/Q values) used for assessment of consequences of routine airborne radioactive releases; (5) points of routine release of radioactive material to the atmosphere, the characteristics of each release mode, and the location of potential receptors for dose computations; and (6) any additional information requirements prescribed in the "Contents of Application" sections of the applicable subparts to 10 CFR Part 52.

2.3.5.2 Summary of Application

North Anna 3 COL FSAR, Section 2.3.5 addresses site-specific information on long-term atmospheric dispersion estimates for routine releases. The COL applicant addressed the information as follows:

COL Items:

- NAPS COL 2.0-11-A

This COL information item states that the COL applicant should characterize the atmospheric transport and diffusion conditions necessary for estimating radiological consequences of the routine release of radioactive materials to the atmosphere, and provide realistic estimates of annual average χ/Q values and D/Q values as described in Section 2.3.5 of NUREG-0800.

- NAPS ESP COL 2.3-3

This COL 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 COL 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 North Anna 3 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 COL applicant recalculated long-term χ/Q and D/Q values at the site boundary; however, χ/Q and D/Q values from the ESP SSAR are used because the COL applicant had determined that the ESP SSAR values for the site boundary are bounding.

Early Site Permit Variances:

- NAPS ESP VAR 2.0-1a

The COL applicant proposed variance NAPS ESP VAR 2.0-1a from the ESP SSAR. This variance recalculated North Anna 3 maximum long-term (routine release) χ/Q and D/Q values for the RW ventilation stack to replace corresponding values presented 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 COLA 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 FSER 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 Section 2.3.5, beyond those presented in the ESP SSAR, are based on meeting the relevant requirements of 10 CFR Parts 20, "Standards for Protection Against Radiation," 50, and 100. The staff considered the following regulatory requirements in reviewing the COL applicant's discussion of long-term atmospheric dispersion and deposition estimates:

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

- 10 CFR 50.34a, "Design objectives for equipment to control releases of radioactive material in effluents – nuclear power reactors," and Sections II.B, II.C, and II.D of Appendix I, "Numerical Guides for Design Objectives and Limiting Conditions for Operation to Meet the Criterion 'As Low as is Reasonably Achievable' for Radioactive Material in Light-Water-Cooled Nuclear Power Reactor Effluents," of 10 CFR Part 50, as they relate to establishing atmospheric dispersion site characteristics 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), as it relates to establishing atmospheric dispersion site characteristics such that radiological effluent release limits associated with normal operation can be met for any individual located offsite.

The related acceptance criteria from Section 2.3.5 of NUREG-0800 are as follows:

- A detailed description of the atmospheric dispersion and deposition models used by the COL applicant to calculate annual average concentrations in air and amount of material deposited as a result of routine releases or radioactive materials to the atmosphere.

- A discussion of atmospheric diffusion parameters, such as vertical plume spread ($o_{z.}$) as a function of distance, topography, and atmospheric conditions.

- Meteorological data summaries (onsite and regional) used as input to the dispersion and deposition models.

- Points of routine release of radioactive material to the atmosphere, including the characteristics (e.g., location, 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-mi [8-km] 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 and 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 specified locations of potential receptors of interest utilizing appropriate meteorological data for each routine venting location; and (2) estimates of annual average χ/Q values and D/Q values for 16 radial sectors to a distance of 50 mi (80 km) from the plant using appropriate meteorological data.

The following RGs are applicable to this section:

- RG 1.23, Revision 1;

- RG 1.109, "Calculation of Annual Doses to Man from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10 CFR Part 50, Appendix I," Revision 1;

- RG 1.111, "Methods for Estimating Atmospheric Transport and Dispersion of Gaseous Effluents in Routine Releases from Light-Water-Cooled Reactors," Revision 1; and

- RG 1.112, "Calculation of Releases of Radioactive Materials in Gaseous and Liquid Effluents from Light-Water-Cooled Power Reactors," Revision 1.

2.3.5.4 Technical Evaluation

The staff reviewed North Anna 3 COL FSAR Section 2.3.5 and checked the referenced ESP SSAR, Revision 9. The staff's review confirmed that the information contained in the North Anna 3 COLA and incorporated by reference to Section 2.3.5 of the ESP SSAR, 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 FSER (i.e., NUREG-1835).

The staff's technical evaluation of this subsection is limited to reviewing: (1) the resolution of COL Item NAPS COL 2.3-3, (2) the resolution of COL Action Item NAPS ESP COL 2.3-3, (3) variance NAPS ESP VAR 2.0-1 (Long-Term Dispersion Value (D/Q) Estimate), 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.

Atmospheric Dispersion Model

The COL applicant used the NRC-sponsored computer code XOQDOQ (described in NUREG/CR-2919, "XOQDOQ Computer Program for the Meteorological Evaluation of Routine Effluent Releases at Nuclear Power Stations") to estimate χ/Q and D/Q values resulting from routine releases. The XOQDOQ model implements the constant mean wind direction model methodology outlined in RG 1.111, Revision 1.

The XOQDOQ model is a straight-line Gaussian plume model based on the theoretical assumption that material released to the atmosphere will be normally distributed (Gaussian) about the plume centerline. In predictions of χ/Q and D/Q values for long time periods (i.e., annual averages), the plume's horizontal distribution is assumed to be evenly distributed within the downwind direction sector (e.g., "sector averaging"). A straight-line trajectory is assumed between the release point and all receptors.

Release Characteristics and Receptors

The COL applicant modeled two ground-level release points and two mixed-mode release points. Releases from the TB and the RB assumed a minimum building cross-sectional area of 3,098 m^2, a building height of 46.1 m, and release heights of 71.3 m (TB) and 52.77 m (RB). Releases from the RW assume a building minimum building cross-sectional area of 3,098 m^2, a building height of 46.1 m, and a release height of 0.0 m. Releases from the CIRC Cooling Tower assume a height of 0.0 m for both building height and release height and a minimum cross-sectional area of 0.0 m^2. The COL applicant assumed a mixed-mode release for releases from the RB ventilation stack and the TB ventilation stack. Ground-level releases are used to model routine releases from the RW and the CIRC Cooling Tower.

The staff found that the ESBWR DCD assumed a ground-level release for releases from the RW, while mixed-mode releases were considered for releases from the RB/ FB stack and the TB stack based on the criteria set forth in RG 1.111. Revision 8 of the North Anna 3 FSAR stated that the vent stacks on the RB/FB, TB, and RW are all modeled as mixed-mode releases. On September 9, 2014, the staff issued RAI 02.03.05-5, which asked the applicant to update the FSAR to include a justification for modeling the RW vent stack (RW-VS) as a mixed-mode release or update the FSAR to implement the ground-level source configuration guidance provided in RG 1.111 for the RW-VS releases. The applicant submitted a response to RAI 02.03.05-5 on October 17, 2014 (ADAMS Accession No. ML14295A659), which updated the FSAR to reflect the RW-VS source as a ground-level release. The RAI response also updated FSAR Section 2.3.5.1, Table 2.3-16R, Tables 2.3-208 through 2.3-215, and Table 2.0-201. The staff confirmed the applicant's changes to the release point characteristics by comparing the release details against the ESBWR DCD. The staff performed an independent confirmatory analysis of the release sources using the XOQDOQ model and the provided onsite meteorological database. The staff has confirmed the assumptions and revised χ/Q and D/Q values provided in the RAI response. Therefore, the staff considers RAI 02.03.05-5 to be closed. The staff verified that the appropriate changes are incorporated into FSAR Section 2.3.5, Revision 9, and, therefore, Confirmatory Item 2.3.5-1 from the staff's advanced SER for North Anna 3 is resolved and closed. The use of mixed-mode releases and ground-level releases is acceptable to the staff because it follows the guidance provided in RG 1.111, Revision 1, and the methodology used in the ESBWR DCD.

The distance to the receptors of interest (i.e., the EAB, nearest residence, nearest vegetable garden, and nearest meat animal) were presented in North Anna 3 COL FSAR Table 2.3-15R. For the evaluation of each of the receptors (with the exception of the EAB), the COL applicant conservatively assumed that the location of the closest receptor is the distance to each of the receptors. The closest receptor was determined to be a residence in the NW direction at a distance of 1.2 km. Therefore, for the purposes of the atmospheric dispersion calculations, each receptor was assigned a distance of 1.2 km for each radial direction. For releases from the CIRC Cooling Tower, which lies outside of the plant facility boundary, distances from the CIRC Cooling Tower to the EAB in each sector were used to calculate separate χ/Q and D/Q values. Because the COL applicant chose to use the closest distance for each of the receptors, these assumptions are conservative and are therefore acceptable to the staff.

Meteorological Data Input

The meteorological input to XOQDOQ used by the COL applicant consisted of a JFD of wind speed, wind direction, and atmospheric stability based on hourly onsite data from a 3-year period from January 1, 1996 through December 31, 1998. The wind data were obtained from the 10-m level of the onsite meteorological tower, and the stability data were derived from the vertical temperature difference (delta-temperature) measurements taken between the 48.4-m and 10-m levels on the onsite meteorological tower. As discussed in SER Section 2.3.3, the staff considers the January 1, 1996 through December 31, 1998 onsite meteorological database suitable for input to the XOQDOQ model.

Diffusion Parameters

The COL applicant chose to implement the diffusion parameter assumptions outlined in RG 1.111, Revision 1 for the XOQDOQ model runs. The staff evaluated the applicability of the XOQDOQ diffusion parameters and concluded that no unique topographic features preclude the use of the XOQDOQ model for the North Anna 3 site. Therefore, the staff finds that the COL applicant's use of diffusion parameter assumptions, as outlined in RG 1.111, Revision 1 is acceptable.

Resulting Relative Concentration and Relative Deposition Factors

North Anna 3 COL FSAR Table 2.3-16R, "XOQDOQ Predicted Maximum χ/Q and D/Q Values at Specific Points of Interest," lists the maximum long-term atmospheric dispersion and deposition estimates for the special receptors of interest that the COL applicant derived from its XOQDOQ modeling results. North Anna 3 COL FSAR Table 2.3-208 through 2.3-223 lists the COL applicant's long-term atmospheric dispersion and deposition estimates for 16 radial sectors from the site boundary, to a distance of 50 mi from the proposed facility.

The χ/Q values presented in North Anna 3 COL FSAR Table 2.3-16R reflect several plume radioactive decay and deposition scenarios. Section C.3 of RG 1.111, Revision 1 states that radioactive decay and dry deposition should be considered in radiological impact evaluations of potential annual radiation doses to the public, resulting from routine releases of radioactive materials in gaseous effluents. Section C.3.a of RG 1.111, Revision 1 states that an overall half-life of 2.26 days is acceptable for evaluating the radioactive decay of short-lived noble gases and an overall half-life of 8 days is acceptable for evaluating the radioactive decay for all iodine's released to the atmosphere. Definitions for the χ/Q categories listed in the headings of North Anna 3 COL FSAR Table 2.3-16R are as follows:

- Undepleted/No Decay χ/Q values are χ/Q values used to evaluate ground-level concentrations of long-lived noble gases, tritium, and carbon-14. The plume is assumed to travel downwind, without undergoing dry deposition or radioactive decay.

- Undepleted/2.26-Day Decay χ/Q values are χ/Q values used to evaluate ground-level concentrations of short-lived noble gases. The plume is assumed to travel downwind, without undergoing dry deposition, but is decayed, assuming a half-life of 2.26 days, based on the half-life of xenon-133.

- Depleted/8.00-Day Decay χ/Q values are χ/Q values used to evaluate ground-level concentrations of radioiodine and particulates. The plume is assumed to travel downwind, with dry deposition, and is decayed, assuming a half-life of 8.00 days, based on the half-life of iodine-131.

Using the information provided by the COL applicant, including the 10-m level JFDs of wind speed, wind direction, and atmospheric stability presented received during the North Anna 3 ESP SSAR review, the staff confirmed the COL applicant's χ/Q and D/Q values by running the XOQDOQ computer code. Although the staff's χ/Q and D/Q values differed from the COL applicants, the values presented in the North Anna 3 COL FSAR were consistently more conservative than those calculated by the staff. The applicant provided information related to NAPS ESP VAR 2.0-1, which requests the use the North Anna 3 maximum long-term deposition value (D/Q) estimate provided in North Anna 3 FSAR Table 2.3-16R for the maximum annual average meat animal D/Q value in the South direction for releases from the RW ventilation stack rather than the corresponding ESP value in FSER Supplement 1, Appendix A and in ESP SSAR Table 2.3-16. Both the COL applicant and the staff calculated χ/Q and D/Q (including those provided as part of NAPS ESP VAR 2.0-1) values were within bounds of the ESBWR DCD χ/Q and D/Q site parameter values, and are, therefore, acceptable to the staff.

2.3.5.5 Post Combined License Activities

There are no post-COL activities related to this section.

2.3.5.6 Conclusion

The staff reviewed the application including NAPS COL 2.3-3 and checked the referenced DCD and the North Anna 3 ESP SSAR. The staff finds that the COLA includes all the required information relating to long-term diffusion estimates, and the staff confirmed that there is no outstanding information that remains to be addressed in the North Anna 3 COL FSAR related to this subsection. The staff evaluated additional information related to NAPS ESP VAR 2.0-1 as discussed in "Resulting Relative Concentration and Relative Deposition Factors," above. The staff found this information to be correct and acceptable for use in the FSAR. The staff's technical evaluation of the information incorporated by reference to the ESP SSAR related to local meteorology is documented in NUREG-1835.

ESBWR DCD, Section 2.3.6.5 states that a COL applicant shall characterize the atmospheric transport and diffusion conditions necessary for estimating radiological consequences of the routine release of radioactive materials to the atmosphere, and provide realistic estimates of annual average χ/Q values and D/Q values as described in Section 2.3.5 in NUREG-0800. Based on the meteorological data provided by the COL applicant and an atmospheric dispersion model that is appropriate for the characteristics of the site and release points, the staff concludes that representative atmospheric dispersion and deposition factors have been calculated for 16 radial sectors from the site boundary to a distance of 50 mi (80 km), as well as for specific locations of potential receptors of interest. The characterization of atmospheric dispersion and deposition conditions are acceptable to meet the criteria described in RG 1.111, Revision 1 and are appropriate for the evaluation to demonstrate compliance with the numerical guides for doses in Subpart D of 10 CFR Part 20 and Appendix I to 10 CFR Part 50. The staff finds that the COL applicant has provided sufficient information to meet the requirements of the ESBWR DCD.

2.4 Hydrology

This section of the SER addresses the North Anna 3 COL FSAR, Revision 9, site-specific hydrological site parameters and site characteristics identified in Chapter 5 of Tier 1 and Chapter 2 of Tier 2 of the ESBWR DCD, Revision 10.

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

North Anna 3 COL FSAR Section 2.4.1, "Hydrologic Description," describes the site from the standpoint of hydrologic considerations. This section also provides topographic and regional maps showing proposed changes to the site's natural drainage features and major hydrological features.

The COL applicant addressed the ESBWR DCD and ESP information as follows:

COL Item:

- NAPS COL Item 2.0-12-A — Hydraulic Description, COL Applicant to provide information in accordance with SRP 2.4.1

The COL applicant incorporated by reference ESP SSAR Section 2.4.1 to address COL Item 2.0-12-A.

The COL applicant provided updated site-specific information to supplement ESP SSAR, Section 2.4.1.1, "Site and Facilities," by stating that the design plant grade elevation is 88.39 m (290.0 ft) North American Vertical Datum 1988 (NAVD88) and that the layout will affect a few small wetlands and the upper portion of two small unnamed streams that flow into Lake Anna northwest of the powerblock. In these areas, drainage will be directed into drainage swales and a stormwater management system and then rejoined with the two small streams.

- NAPS ESP COL 2.4-1 Intake and Discharge Tunnels Layout

The NAPS ESP COL 2.4-1 item provides a site-specific layout of intake and discharge tunnels for plant service water (SW) and circulating water systems.

- NAPS ESP COL 2.4-2 Shut Down Water Level

The NAPS ESP COL 2.4-2 item describes the Lake Anna required shutdown water level.

- NAPS ESP COL 2.4-6 UHS Reservoir Design

The NAPS ESP COL 2.4-6 item provides the basis for emergency cooling capability.

- NAPS ESP COL 2.4-7 UHS Storage Basins Sufficient for 30-Day Emergency Cooling Water Needs

The NAPS ESP COL 2.4-7 item provides the North Anna 3 UHS for the passive ESBWR design.

- NAPS ESP COL 2.4-8 Use of Lake Anna or the Waste Heat Treatment Facility (WHTF) for Safety-Related Water Withdrawals

The NAPS ESP COL 2.4-8 item describes that the Isolation Condenser/Passive Containment Cooling System (IC/PCCS) pools have their own water in place during North Anna 3 operation for safety-related cooling in the event that use of the UHS is required.

Early Site Permit Condition:

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

Early Site Permit Variance:

The following variances from the ESP SSAR is discussed in Section 2, “Variances,” of Part 7 to the COLA:

- NAPS ESP VAR 2.4-4 Lake Level Increase

The COL applicant requested VAR 2.4-4 to the ESP SSAR to use a higher value for the normal elevation of Lake Anna. The COL applicant supplemented ESP SSAR Section 2.4.1.3, “Existing and Proposed Water Control Structures,” by stating that, with the addition of North Anna 3, the normal pool elevation will be increased by 7.6 cm (3 in) to a level of 76.01 m (249.39 ft) NAVD88.

In addition, the COL applicant supplemented North Anna 3 COL FSAR Section 2.4.1 with a statement that the flood surcharge capacity of Lake Anna is 4.50 m (14.75 ft) above the normal pool elevation and included information on Lake Anna storage allocations in North Anna 3 COL FSAR Table 2.4-1R.

- NAPS ESP VAR 2.0-7 Coordinates/Removal of abandoned mat foundations

This variance is discussed in the Variances Section of the Departures Report (Part 7) of the COLA and contains two parts as discussed below:

The COL applicant requested a variance from one of the coordinate systems that define the "ESP Plant Parameter Envelope" shown in the ESP, Appendix A, Figure 1 which lists the coordinates of the site in State NAD 83 South Zone, as well as in the North Anna 3 site Grid coordinates. In the variance, the COL applicant requested to use the values given in North Anna 3 COL FSAR Figure 2.0-205 as "COORDINATES (STATE PLANE NAD 83 VA SOUTH ZONE)," to replace those in the ESP given as "Coordinates (State NAD 83 South Zone)." The review of this part of the variance (site Grid coordinates) request is discussed below.

The COL applicant in addition requested a variance from ESP, Appendix A, Figure 1, Note 2, which states, "Abandoned Unit 3 and 4 Reactor Building Mat Foundations are to be removed." The applicant requests to not remove the abandoned mat foundations for the originally planned North Anna Units 3 and 4 unless a Unit 3 Seismic Category I or II structure would be located above an abandoned foundation. The review of this part of the variance request is discussed above in Section 2.0.

2.4.1.3 Regulatory Basis

The regulatory basis of the information incorporated by reference is addressed in NUREG-1966, the FSER related to ESBWR DCD, and in NUREG-1835 the FSER related to the North Anna 3 ESP. In addition, guidance relevant to the Commission's regulations for the hydrologic descriptions, and the associated acceptance criteria, with the relevant requirements of the NRC regulations for site hydrology are described in Section 2.4.1 of NUREG-0800 SRP.

The acceptance criteria for the North Anna 3 site hydrologic information presented in the FSAR, beyond that presented in the ESP SSAR (i.e., NAPS COL Item 2.0-12-A and NAPS ESP VAR 2.4-4), 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 margin for the limited accuracy, quantity, and time in which the historical data have been accumulated.

- 10 CFR 100.20(c), as it relates to the consideration given to the hydrological characteristics of the site.

The hydrological information assembled in compliance with the above regulatory requirements are necessary to determine a proposed facility's compliance with the following requirements in Appendix A of 10 CFR Part 50:

- GDC 2, which requires that SSCs important to safety be designed to withstand the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, floods, tsunami, and seiches without loss of capability to perform their safety functions.

The related acceptance criteria from Section 2.4.1 of NUREG-0800 SRP are as follows:

- Interface of the Plant with the Hydrosphere: The application should provide a description of hydrology in the vicinity of the site and site regions and of how the plant interfaces with the hydrosphere.

- Hydrological Causal Mechanisms: The application should provide a description of hydrological causal mechanisms that affect the safety of the plant.

- Surface and Ground Water Uses: The application should provide a description of surface and ground water uses in the vicinity of the site that affect the safety related water supply to the plant.

- Data: The application should provide a complete description of all spatial and temporal datasets used by the applicant in support of its conclusions regarding safety of the plant.

- Alternate Conceptual Models: The application should provide a description of alternate conceptual models of site hydrology.

- Consideration of Other Site-Related Evaluation Criteria: The application should demonstrate that the potential effects of site-related proximity and of seismic and non-seismic information as they relate to hydrologic description in the vicinity of the proposed plant site and site regions are appropriately taken into account.

The description of hydrologic characteristics should correspond to those of the United States Geological Survey (USGS), Natural Resources Conservation Service (NRCS), U.S. Army Corps of Engineers (USACE), or appropriate State and river basin agencies.

In addition, the hydrologic characteristics should be consistent with appropriate sections from: RG 1.27, RG 1.29, "Seismic Design Classification," RG 1.59, "Flood Design Basis for Nuclear Power Plants," as supplemented by best current practices, and RG 1.102, "Flood Protection for Nuclear Power Plants."

2.4.1.4 Technical Evaluation

As documented in Section 2.4.1 of NUREG-1966 and Section 2.4.1 of NUREG-1835, the staff reviewed and approved information related to hydrologic description for the certified ESBWR DCD, Revision 10, and Section 2.4.1 of the North Anna ESP SSAR, respectively. The staff reviewed Section 2.4.1 of the North Anna 3 COL FSAR, Revision 9, and checked the referenced ESBWR DCD and the North Anna ESP SSAR to ensure that the combination of the information in the North Anna 3 COL FSAR and the information in the ESBWR DCD and ESP SSAR represent the complete scope of information relating to this review topic. The staff's review confirms that the information in the application and the information incorporated by reference address the required information related to "Hydrologic Description."

The staff's review of the additional information and ESP variances contained in the North Anna 3 COL FSAR is as follows.

The staff's technical review of this application includes the supplemental information pertaining to NAPS COL 2.0-12-A and NAPS ESP VAR 2.4-4. This review also includes staff evaluation of additional items discussed in the ESP and the North Anna 3 COL FSAR, as described below.

COL Items:

- NAPS COL 2.0-12-A Hydraulic Description

The COL applicant's updated design plant grade elevation for North Anna 3 is 88.39 m (290.0 ft) NAVD88 which is 6.36 m (20.86 ft) above the flood elevation site characteristic (82.03 m [269.14 ft] NAVD88). The COL applicant provided North Anna 3 COL FSAR Figure 2.1-201 showing the layout of the external structures and components of North Anna 3.

The COL applicant stated that small changes to natural drainage features would be required to accommodate North Anna 3, including a few small wetlands and the upper ends of two intermittent streams that discharge to Lake Anna. Drainage from filled areas will be directed into swales before entering the streams. North Anna 3 COL FSAR Section 2.4.2.3 discusses drainage during the local probable maximum precipitation (PMP). The staff finds that the additional information is consistent with the information in the ESP SSAR, which has already been accepted by the staff as documented in the North Anna ESP FSER (NUREG-1835).

- NAPS ESP COL 2.4-1 Intake and Discharge Tunnels Layout

ESP COL Action Item 2.4-1 considers the layout of intake and discharge tunnels for plant SW and circulating water systems. North Anna 3 COL FSAR Section 1.12 discusses hazards to existing units from construction, and it is stated that piping plans for intake and discharge structures will be provided to NRC 60 days prior to construction of the piping.

Based on the description of the UHS in ESBWR DCD Section 9.2.5 and North Anna 3 COL FSAR Section 9.2.5, staff have determined that intake and discharge piping does not provide safety-related functions. The maximum flood and the maximum groundwater elevations are below the ESBWR DCD site parameters for hydrologic characteristics; therefore, ESP COL Action Item 2.4-1 is considered closed.

- 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 FSER Section 2.4.1, the COL applicant chose to discuss this item in North Anna 3 COL FSAR Section 2.4.14. This report follows the North Anna 3 COL FSAR convention, and staff's review of NAPS ESP COL 2.4-2 can be found in Section 2.4.14.

- NAPS ESP COL 2.4-6 UHS Reservoir Design
- NAPS ESP COL 2.4-7 UHS Storage Basins Sufficient for 30-Day Emergency Cooling Water Needs
- NAPS ESP COL 2.4-8 Use of Lake Anna or the Waste Heat Treatment Facility (WHTF) for Safety-Related Water Withdrawals

ESBWR DCD Section 9.2.5 and North Anna 3 COL FSAR Section 9.2.5 describe the UHS. The UHS is provided by the IC/PCCS pools, with makeup from the equipment storage pool and Reactor Well sufficient during the initial 72 hours of an accident. ESBWR DCD Section 9.2.5 states that a separate safety-related reservoir is not required. The Fire Protection System, described in ESBWR Section 9.5.1, provides onsite makeup to the UHS from 72 hours to 7 days through a connection to safety-related components of the Fuel and Auxiliary Pools Cooling System, described in ESBWR DCD Section 9.1.3. ESBWR DCD Section 9.2.5 states that the makeup water source beyond 7 days post-accident is not required to be safety-related.

The COL applicant supplemented North Anna 3 COL FSAR Section 2.4.8 to state that Lake Anna and the WHTF are not used for safety-related cooling.

Based on the description of the UHS, staff have determined that no underground reservoirs are included in the design of the ESBWR UHS and no external source of safety-related makeup water is required for the UHS. Accordingly, ESP COL Action Items 2.4-6, 2.4-7, and 2.4-8 are considered closed.

Early Site Permit Condition:

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

In North Anna 3 COL FSAR Table 1.10-202, the COL applicant states that Permit Condition 3 is not applicable to North Anna 3.

The North Anna 3 COL FSAR describes 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.

Early Site Permit Variance:

- NAPS ESP VAR 2.4-4 Lake Level Increase

With the addition of North Anna 3, the normal pool elevation is to be held at 76.01 m (249.39 ft) NAVD88, which is 0.08 m (0.25 ft) higher than prior to the addition of North Anna 3. The higher water level is to improve water availability to downstream users during drought conditions. The COL applicant analyzed the effect of the lake level increase on the maximum elevation from the probable maximum flood (PMF) in North Anna 3 COL FSAR Section 2.4.3 and the effect on water balance and minimum water level in North Anna 3 COL FSAR Section 2.4.11. The staff's review of NAPS ESP VAR 2.4-4 can be found in those sections.

- NAPS ESP VAR 2.0-7 Coordinates/Removal of abandoned mat foundations

The COL applicant requested a variance from one of the coordinate systems presented in the ESP, Appendix A, Figure 1 which lists the coordinates of the site in State NAD 83 South Zone as well as in the North Anna 3 Grid coordinates. In the variance, the COL applicant stated that there is an error associated with the coordinates of the proposed facility boundaries, which are coordinated of the eight points that define "ESP Plant Parameter Envelope." The applicant requested to use the values given in North Anna 3 COL FSAR Figure 2.0-205 as "COORDINATES (STATE PLANE NAD 83 VA SOUTH ZONE)," to replace those in the ESP given as "Coordinates (State NAD 83 South Zone)." The coordinates provided in the North Anna Grid coordinates in the ESP, Appendix A, Figure 1 remained unchanged; therefore, this variance request corrects an administrative error and is acceptable.

The COL applicant requested a variance from ESP, Appendix A, Figure 1, Note 2 that states, “Abandoned Unit 3 and 4 Reactor Building Mat Foundations are to be removed.” The applicant requests to not remove the abandoned mat foundations for the originally planned North Anna Units 3 and 4 unless a Unit 3 Seismic Category I or II structure would be located above on an abandoned foundations. The review of this part of the variance request is discussed above in Section 2.0.

2.4.1.5 Post Combined License Activities

There are no post COL activities related to this section.

2.4.1.6 Conclusion

The staff reviewed the application and checked the referenced ESP SSAR. The staff’s review confirmed that the COL applicant has addressed the relevant information and no outstanding information remains to be addressed in the North Anna 3 COL FSAR related to this section.

In addition, the staff compared the additional information in the COLA to the relevant NRC regulations, the guidance in Section 2.4.1 of NUREG–0800, and NRC RGs. The staff’s review concludes that the applicant has provided sufficient information to satisfy the requirements of NRC regulations. The staff has determined that the applicant has adequately addressed NAPS COL 2.0-12-A as it relates to the hydrologic description.

As set forth above, the COL 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 GDC 2, 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 COL 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 FSER. 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 section 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 described 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 section also determines the local intense precipitation on the site used to estimate localized flooding and sheet flow. Local intense precipitation is reported as a site characteristic used in site grading design.

2.4.2.2 Summary of Application

North Anna 3 COL FSAR, Revision 9, Section 2.4.2, “Floods,” describes the site from the standpoint of flooding considerations.

The COL applicant addressed the ESBWR DCD and ESP information as follows:

COL Items:

- NAPS COL Item 2.0-13-A — Floods, COL Applicant to provide information in accordance with SRP 2.4.2

The COL applicant incorporated by reference ESP SSAR Section 2.4.2 to address NAPS COL 2.0-13-A. The COL applicant also supplemented the site-specific information of ESP SSAR Section 2.4.2.2, “Flood Design Consideration,” indicating that the design plant grade elevation of 89.39 m (290 ft) NAVD88 for safety-related SSCs is below the localized sheet flow levels at specific locations of the site due to the local intense precipitation event. As indicated in the discussion in SER Section 2.4.2, the staff issued RAI 02.04.02-8 (ADAMS Accession Number No. ML110970719) dated April 07, 2011, and RAI 02.04.02-10 through 02.04.02-15 dated December 11, 2014 (ADAMS Accession No. ML14345B075), which asked for clarification of the design sheet flow levels due to the local precipitation event. The applicant’s response (ADAMS Accession Nos. ML11124A154, ML15022A199, and ML16229A451) dated May 03, 2011, January 19, 2015, and June 12, 2015, respectively, stated that the local PMP sheet flow flood elevation is above the plant grade elevation in three specific areas of the site. As detailed in SER Section 2.4.10, the applicant committed to providing flood protection features for the impacted site areas.

- 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 North Anna 3 COL FSAR Section 2.4.14, and NAPS ESP COL 2.4-4, which is discussed in North Anna 3 COL FSAR Section 2.4.2.

- NAPS ESP COL 2.4-4 and 2.4-5

The COL applicant provided updated site-specific information to supplement ESP SSAR Section 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 four figures, with the first (North Anna 3 COL FSAR Figure 2.4-201) showing the site layout and sub-basin drainage areas, the second (North Anna 3 COL FSAR Figure 2.4-202) showing the site's PMP duration-intensity curve, the third (North Anna 3 COL FSAR Figure 2.4-203) showing the location of ditch cross sections used for the HEC-RAS model analysis (ADAMS Accession No. ML16229A451), and the fourth (North Anna 3 COL FSAR Figure 2.4-221) showing the location of supercritical flow and hydraulic jumps from the HEC-RAS model analysis.

2.4.2.3 Regulatory Basis

The regulatory basis of the information incorporated by reference is addressed in NUREG-1966, the FSER related to ESBWR DCD, and in NUREG-1835, the FSER related to the North Anna ESP. In addition, guidance relevant to the Commission's regulations for flooding descriptions, and the associated acceptance criteria, with the relevant requirements of the NRC regulations are described in Section 2.4.2 of NUREG-0800 SRP.

The acceptance criteria for the North Anna 3 site floods information presented in the North Anna 3 COL FSAR, beyond that presented in the ESP SSAR (i.e., NAPS COL Items 2.0-13-A, and NAPS ESP COL 2.4-3, 2.4-4 and 2.4-5), 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 margin for the limited accuracy, quantity, and time in which the historical data have been accumulated.

- 10 CFR 100.20(c), as it relates to the consideration given to the hydrological characteristics of the site.

The following related acceptance criteria are summarized from SRP Section 2.4.2:

Local Flooding on the Site and Drainage Design: The application should include an estimate of local intense precipitation or local PMP and a determination of the capacity of site drainage facilities (including drainage from the roofs of buildings and site ponding).

- Stream Flooding: The application should include documentation of the potential sources of flood and flood response characteristics.

- Surges: The application should include the complete history of storm surges in the vicinity of the site.

- Seiches: The application should include the complete history of seiches in the vicinity of the site.

- Tsunami: The application should include the complete history of tsunami in the vicinity of the site.

- Seismically Induced Dam Failures (or Breaches): The application should include the flooding hazard at the plant site resulting from seismically induced dam failure upstream of the site location.

- Flooding Caused by Landslides: The application should include the flooding hazard at the plant site from flood waves induced by landslides and backwater effects due to stream blockage from landslides.

- Effects of Ice Formation in Water Bodies: The application should include information concerning potential flooding at the plant site due to flood waves resulting from the collapse of an ice dam or backwater effects due to stream blockage due to an ice dam or an ice jam downstream of the plant site.

- Combined Events Criteria: The application should include information concerning design basis flooding at the plant site, including consideration of appropriate combinations of individual flooding mechanisms in addition to the most severe effects from individual mechanisms themselves.

- Consideration of Other Site-Related Evaluation Criteria: The application should demonstrate that the potential effects of site-related proximity, seismic, and nonseismic information as they relate to hydrologic description in the vicinity of the proposed plant site and site regions are appropriately taken into account.

In addition, the hydrologic characteristics should be consistent with appropriate sections in RGs 1.27, 1.29, 1.59, as supplemented by best current practices and in RG 1.102.

2.4.2.4 Technical Evaluation

As documented in Section 2.4.2 of NUREG-1966 and Section 2.4.2 of NUREG-1835, the staff reviewed and approved information related to floods for the certified ESBWR DCD, Revision 10, and Section 2.4.2 of the North Anna ESP SSAR, respectively. The staff reviewed Section 2.4.2 of the North Anna 3 COL FSAR, Revision 9, and checked the referenced ESBWR DCD and the North Anna ESP SSAR to ensure that the combination of the information in the North Anna 3 COL FSAR and the information in the ESBWR DCD and ESP SSAR represent the complete scope of information relating to this review topic. The staff's review confirms that the information in the application and the information incorporated by reference address the required information related to "Floods."

In addition the staff reviewed Section 2.4.2 of the North Anna 3 COL FSAR, Revision 9, related to flood history, flood design, and the effects of the PMP as follows:

<u>*COL Items:*</u>

- NAPS COL 2.0-13-A Floods

The staff reviewed the resolution to NAPS COL 2.0-13-A, related to historical flooding at the proposed site or in the region of the site, and included in North Anna 3 COL FSAR Section 2.4.2. The staff's technical review of this application was limited to reviewing the supplemental information pertaining to NAPS COL 2.0-13-A and ESP COL Action Items 2.4-4 and 2.4-5, as addressed below:

The staff reviewed the North Anna 3 COL FSAR, Revision 9, the applicant's responses to RAI 02.04.02-10 through 02.04.02-15, and checked the referenced ESP SSAR. The staff's review confirmed that the information contained in the application and in the responses to RAIs, and incorporated by reference addresses the relevant information related to this section. Based on a review of the North Anna 3 site grading plan, the design plant grade elevation is 88.39 m (290.0 ft) NAVD88. As discussed in the ESP FSER, the flooding site characteristic is produced by the PMF in Lake Anna's watershed, the simultaneous failure of upstream storage reservoirs, and coincident wave action, which produces a water surface elevation of 82.03 m (269.14 ft) NAVD88. However, for the North Anna 3 COLA, the applicant provided supplemental information from the analysis of local intense precipitation that produces localized sheet flow levels that are above site grade. According to the COL applicant's analysis, the sheet flow level resulting from the local intense precipitation is a maximum of 0.15 m (0.5 ft) above the design plant grade.

The staff checked ESP FSER Section 2.4.2.3 and supplemented the ESP safety evaluation with an independent confirmation of the applicant's steady-state HEC-RAS numerical modeling analysis of site drainage during local intense precipitation. The ESBWR DCD site parameter Maximum Flood (or Tsunami) Level is 1 ft below plant grade. The design plant grade elevation is 88.39 m (290.0 ft) NAVD88. As stated above, the maximum sheet flow flood level at the site, during a local intense precipitation event, is 88.54 m (290.5 ft) NAVD88 which is (0.15 m) 0.5 ft above the design plant grade. By definition, sheet flow due to local intense precipitation will always be above plant grade; therefore, the ESBWR DCD site parameter Maximum Flood (or Tsunami) Level does not apply to localized sheet flow. However, local intense precipitation-generated sheet flow is included in determination of the design-basis event and any necessary flood protection as discussed below.

- NAPS ESP COL 2.4-4 and 2.4-5

The COL applicant provided to the staff the input files of the numerical model HEC-RAS that were used to analyze runoff from local intense precipitation for site drainage of North Anna 3 with the ESBWR reactor. HEC-RAS is a numerical model developed by the USACE, Hydrologic Engineering Center (USACE 2010a). The model is widely used within the engineering community and is accepted as a standard engineering-practice tool for the analysis of flooding. Figure 2.4.2-1 shows the site drainage plan provided by the COL applicant in the North Anna 3 COL FSAR and includes additional identifying information. The staff determined that the site drainage plan satisfies the requirements of ESP COL Action Item 2.4-4 and ESP COL Action Item 2.4-5. The staff also reviewed the supplemental information provided in North Anna 3 COL FSAR Section 2.4.2 and the HEC-RAS hydraulic model provided by the COL applicant, and also conducted sensitivity tests on the hydraulic model.

Information Submitted by Applicant:

In North Anna 3 COL FSAR Section 2.4.2.2 the COL applicant provides supplemental information on the local intense precipitation flooding which is reported as being a maximum of 0.15 m (0.5 ft) above the design plant grade of 88.39 m (290.0 ft) NAVD88. In addition to the design plant grade and elevations of safety-related buildings (corresponding to the floor and entrance elevations), the COL applicant stated that the ground level elevations outside the buildings is 88.24 m (289.5 ft) NAVD88.

The site drainage plan consists of three drainage channels (labeled east ditch, south ditch, and west ditch in Figure 2.4.2-1), a stormwater management pond, and an outfall channel. Figure 2.4.2-1 also shows the layout of drainage basins used in the estimation of local intense precipitation-generated runoff. For the analysis of local intense precipitation flooding, the culverts were assumed to be blocked where the ditches passed under the plant access roads. In the HEC-RAS model of the drainage system, the roads crossing the ditches were treated as broad-crested weirs. As noted in Figure 2.4.2-1, these weirs are located in the south and west ditches. The east ditch has no weirs. Figure 2.4.2-2 shows the layout of HEC-RAS cross sections with respect to the ditches, stormwater management pond, and outfall channel. Figure 2.4.2-2 also shows the locations of blocked culverts, which were simulated as inline weirs.

Because channel linings consist of rip-rap (stone used for erosion protection), the COL applicant set up the HEC-RAS hydraulic model using Manning's roughness values of 0.035 for all cross sections. The COL applicant generally used a contraction coefficient of 0.1 and an expansion coefficient of 0.3 for most cross sections, which assume a gradual transition between adjacent cross sections. However, for cross sections 900 in the east ditch, 500, 390, and 100 in the outfall, and 490 to 195 in the south ditch (Figure 2.4.2-2), the COL applicant used a contraction coefficient of 0.3 and an expansion coefficient of 0.5. The COL applicant did not explain how these values were determined. Therefore, in RAI 02.04.02-13, the staff requested that the COL applicant provide a description of the basis for selection of expansion and contraction coefficients. The COL applicant's response dated January 19, 2015 (ADAMS Accession No. ML15022A199), and the staff's independent confirmatory evaluation are described in the staff's technical evaluation section of this SER below.

The staff found in its examination of the HEC-RAS input files provided by the COL applicant that the downstream boundary condition assigned by the COL applicant to the HEC-RAS model was the water surface elevation of Lake Anna, which the COL applicant assigned a constant elevation of 80.77 m (265 ft) NAVD88.

The precipitation intensity used by the COL applicant for the local intense precipitation analysis was taken from ESP SSAR Table 2.4.3, which is shown in Table 2.4.2-1. The COL applicant divided the drainage area into subbasin areas (Table 2.4.2-2) for use in estimating precipitation runoff and distribution of runoff to the drainage channel system.

Table 2.4.2-1 Local intense precipitation depths for durations less than 6 hours and over a 2.59-km^2 (1-mi^2) area. (Derived from ESP SSAR Table 2.4-3)

Duration	Precipitation Depth (in)	Precipitation Depth (cm)
6-hr	27.9	70.9
1-hr	18.3	46.5
30-min	13.7	34.8
15-min	9.6	24.4
5-min	6.1	15.5

The COL applicant estimated discharge from local intense precipitation using the rational method, combined with the areas of the drainage basins and assumptions about the runoff coefficient (representing precipitation infiltration). The COL applicant's subbasin areas were provided in Table 2.4.2-2. The COL applicant assumed that vegetated areas have a runoff coefficient of 0.9 and that other areas have a runoff coefficient of 1.0, reflecting their imperviousness resulting in composite runoff coefficients ranging from 0.93 to 1.0. The COL applicant computed the time of concentration of a subbasin to determine the appropriate rainfall intensity for use in calculating subbasin discharges from local intense precipitation. The COL applicant estimated the time of concentration for each of the subbasins using the methods of the US Natural Resource Conservation Service (1986). To account for non-linear response to large storms, the COL applicant also included a 25 percent reduction of the times of concentration based on guidance from USACE (1994). Table 2.4.2-1 provided the duration-intensity data for local intense precipitation at the North Anna 3 site. Table 2.4.2-2 provided characteristics of the subbasins provided by the COL applicant including the cumulative drainage area along each reach, the runoff coefficients, the times of concentration, the precipitation intensities corresponding to the times of concentration, and the discharge estimates for cumulative drainage areas. Generally, the times of concentration and discharges increased with increasing cumulative drainage area. The COL applicant-provided information supplemental to the North Anna 3 COL FSAR provided detail of the methods used to calculate the time of concentration, precipitation intensity, and runoff. However, the staff determined that the North Anna 3 COL FSAR contained little discussion of the methods and results for computation of subbasin discharges. Therefore, in RAI 02.04.02-11, the staff requested that the COL applicant provide a description of the estimation of subbasin discharges including the estimation of flow type lengths, Manning's roughness coefficients, and times of concentration. The COL applicant's response dated January 19, 2015 (ADAMS Accession No. ML15022A199), and the staff's evaluation are described in the staff's technical evaluation section below.

Table 2.4.2-2. Subbasin characteristics used to estimate discharge during the local intense precipitation. (Derived from COL FSAR Tables 2.4-201, 2.4-202, and 2.4-203.)

Subbasin	Areas m^2 (ft^2)	Contributing Subbasins	Cumulative Area ha (ac)	Runoff Coefficient	Time of Concentration (min)	Precipitation Intensity cm/hr (in/hr)	Discharge m^3/s (cfs)
B	35,193 (378,813)	All	24.38 (60.24)	0.98	20.4	31.7	52.99 (1871.4)
W1	35,513 (382,258)	W1,W2,W3,S1,S2	13.59 (33.58)	0.98	20.4	31.7	29.54 (1043.2)
W2	27,129 (292,011)	W2,W3,S1,S2	10.04 (24.81)	0.97	19.8	32.0	21.81 (770.1)
W3	45,388 (488,556)	W3	4.54 (11.22)	0.93	11.2	48.0	14.18 (500.9)
S1	8,367 (90,065)	S1,S2	2.79 (6.89)	1.00	17.4	34.5	6.73 (237.7)
S2	19,524 (210,152)	S2	1.95 (4.82)	1.00	14.8	39.0	5.32 (188.0)
E1	23,820 (256,391)	E1,E2,E3	5.29 (13.08)	0.99	8.1	49.0	17.97 (634.5)
E2	16,261 (175,035)	E2,E3	2.91 (7.19)	1.00	7.2	65.5	13.33 (470.9)
E3	12,822 (138,011)	E3	1.28 (3.17)	1.00	6.2	68.5	6.15 (217.1)
U1&2	19,754 (212,630)	N/A	N/A	N/A	N/A	N/A	N/A

N/A – not available

According to the COL applicant's HEC-RAS model analysis, the highest predicted water surface elevation of 89.70 m (294.3 ft) NAVD88 occurred at the upstream end of the west ditch (ADAMS Accession No. ML16229A451). However, this portion of the west ditch is upstream of the powerblock, and it is tributary to the drainage system surrounding the powerblock (Figure 2.4.2-1). In the drainage channels surrounding the powerblock, the highest predicted water surface elevations occurred at the upstream ends of the south and east ditches. These computed water surface elevations were 87.92 m (288.45 ft) NAVD88 (south ditch) and 87.84 m (288.2 ft) NAVD88 (east ditch) and were on opposite sides of the Administration Building (Figure 2.4.2-1). Consequently, the maximum water surface elevation computed by the COL applicant in the site drainage ditches adjacent to the powerblock was in the south ditch. Note that in the North Anna 3 COL FSAR, the COL applicant rounded the water surface elevations to one-tenth of a foot and reported the maximum elevation as 87.90 m (288.4 ft) NAVD88, 0.18 m (0.6 ft) below the North Anna 3 ESBWR DCD's Maximum Flood (or Tsunami) Level site parameter value of 88.09 m (289.0 ft) NAVD88 (North Anna 3 COL FSAR Table 2.0-1).

The COL applicant assumed that the roads crossing the west and south ditches and the outfall from the stormwater management pond were completely blocked and functioned as weirs during the flooding from local intense precipitation (Figures 2.4.2-1 and 2.4.2-2). As found in the COL applicant's HEC-RAS input files, inline weirs were designated as broad-crested weirs with discharge coefficients specified as either 2.6 or 2.4. Because the COL applicant did not provide a justification for choosing the lower of these two discharge coefficient values, in RAI 02.04.02-14, the staff requested that the COL applicant provide a discussion of the basis for selecting weir discharge coefficients. The COL applicant's response dated January 19, 2015 (ADAMS Accession No. ML15022A199), and the staff's evaluation are described in the staff's technical evaluation section below in this SER.

According to North Anna 3 COL FSAR, Revision 9, Figures 2.4-201 and 2.4-203, the discharge from the west ditch was combined with the outflow from the stormwater management pond. However, according to the geometry of the HEC-RAS model provided by the COL applicant, the staff discovered that the discharge from the west ditch entered the stormwater management pond. Therefore, in RAI 02.04.02-12, the staff requested that the COL applicant provide an explanation for the disagreement between the North Anna 3 COL FSAR figures and the HEC-RAS input files and any necessary corrections. The COL applicant's response dated January 19, 2015 (ADAMS Accession No. ML15022A199), and the staff's evaluation are described in the staff's technical evaluation section below in this SER.

A drainage divide is located between the North Anna 3 stormwater management pond and the existing Unit 2 site at an elevation of 82.91 m (272.0 ft) NAVD88. As indicated in Figure 2.4.2-1, the stormwater management pond received flow from the east and west ditches. Discharge was routed from the stormwater management pond by overtopping the main access road, which was simulated in the HEC-RAS model as a broad-crested weir. The maximum water surface elevation computed by the COL applicant in the stormwater management pond was 82.84 m (271.8 ft) NAVD88 resulting in a freeboard of 0.06 m (0.2 ft). The COL applicant concluded that flows in North Anna 3 site would not affect the existing Units 1 and 2. Although the staff found references to Subbasin U1&2 in North Anna 3 COL FSAR Tables 2.4-201 and 2.4-202 (Table 2.4.2-2), the COL applicant did not adequately explain how Subbasin U1&2 derived flow from the existing Units 1 and 2 area. In RAI 02.04.02-10, the staff requested that the COL applicant provide additional details regarding how the rational method was applied to estimate peak discharges, particularly from Subbasin U1&2 (ML14345B075). The COL applicant's response dated January 19, 2015 (ADAMS Accession No. ML15022A199), and the staff's evaluation are described in the staff's technical evaluation section below in this SER.

Based on the staff's examination of the COL applicant's HEC-RAS analysis results, supercritical flow was found to occur in the east and west ditches during flooding from local intense precipitation. In these locations, the water velocities ranged from 2.1 m/s (7.0 fps) to 4.5 m/s (14.7 fps) with Figure 2.4.2-3 showing the locations of supercritical flow based on the HEC-RAS analysis. In North Anna 3 COL FSAR Section 2.4.2.3, the COL applicant stated that:

- The locations where supercritical flow regimes were predicted to occur would be protected against possible erosive forces arising from large velocities and potential hydraulic jumps using linings and hardened surface protections;

- Grading near safety-related SSCs will slope away from the structures so that ground and roof runoff during a local intense precipitation event will sheet flow towards drainage ditches;

- During the construction phase for North Anna 3, the construction and as-built drawings will be checked against site topography, surface type, and channel linings that were used for the for local intense precipitation analysis and the associated HEC-RAS modeling;

- During operation of North Anna 3 the drainage system will be monitored to ensure consistency with the assumptions used in the flood analysis for local intense precipitation and associated HEC-RAS modeling analysis;

- Drainage facilities will be inspected during construction at least once every two weeks; and

- Site inspections will be done quarterly to inspect areas with erosion potential.

During review of the COL applicant's local intense precipitation flood analysis, the staff noted that the COL applicant analyzed runoff from building roofs in the powerblock area as sheet flow. The staff located additional details of the analysis in the COL applicant's Calculation Package 25161-G-012. From the information provided by the COL applicant on the sheet flow analysis, the staff could not determine how the COL applicant partitioned roof runoff from adjacent roofs and direct precipitation in passageways between safety-related buildings. It was also unclear to the staff if the COL applicant's approach to sheet flow analysis was consistent with guidance provided in ANSI/ANS-2.8-1992, Section 11.4 (ANS 1992). Therefore, in RAI 02.04.02-15, the staff requested that the COL applicant provide: (1) a discussion of the effects of roof drainage and direct precipitation during local intense precipitation on flood water surface elevations along passageways between buildings and structures important for safety; (2) a comparison of these flood water surface elevations or depths to the elevations of any penetrations or openings housing safety-related SSCs; and, (3) an update to the FSAR to include this information. The COL applicant's responses dated January 19, 2015 and June 12, 2015 (ADAMS Accession Nos. ML15022A199 and ML16229A451, respectively), as well as the staff's evaluation are described in the staff's technical evaluation section below in this SER.

In response to staff's RAI 02.04.02-10 through 02.04.02-15, the COL applicant proposed updating the North Anna 3 COL FSAR in a future revision (ADAMS Accession Nos. ML15022A199 and ML16229A451). The staff verified that the appropriate updates are incorporated into the FSAR, Revision 9, and, therefore Confirmatory Items 2.4.2-1 to 2.4.2-6 from the staff's advanced SER for North Anna 3 are resolved and closed.

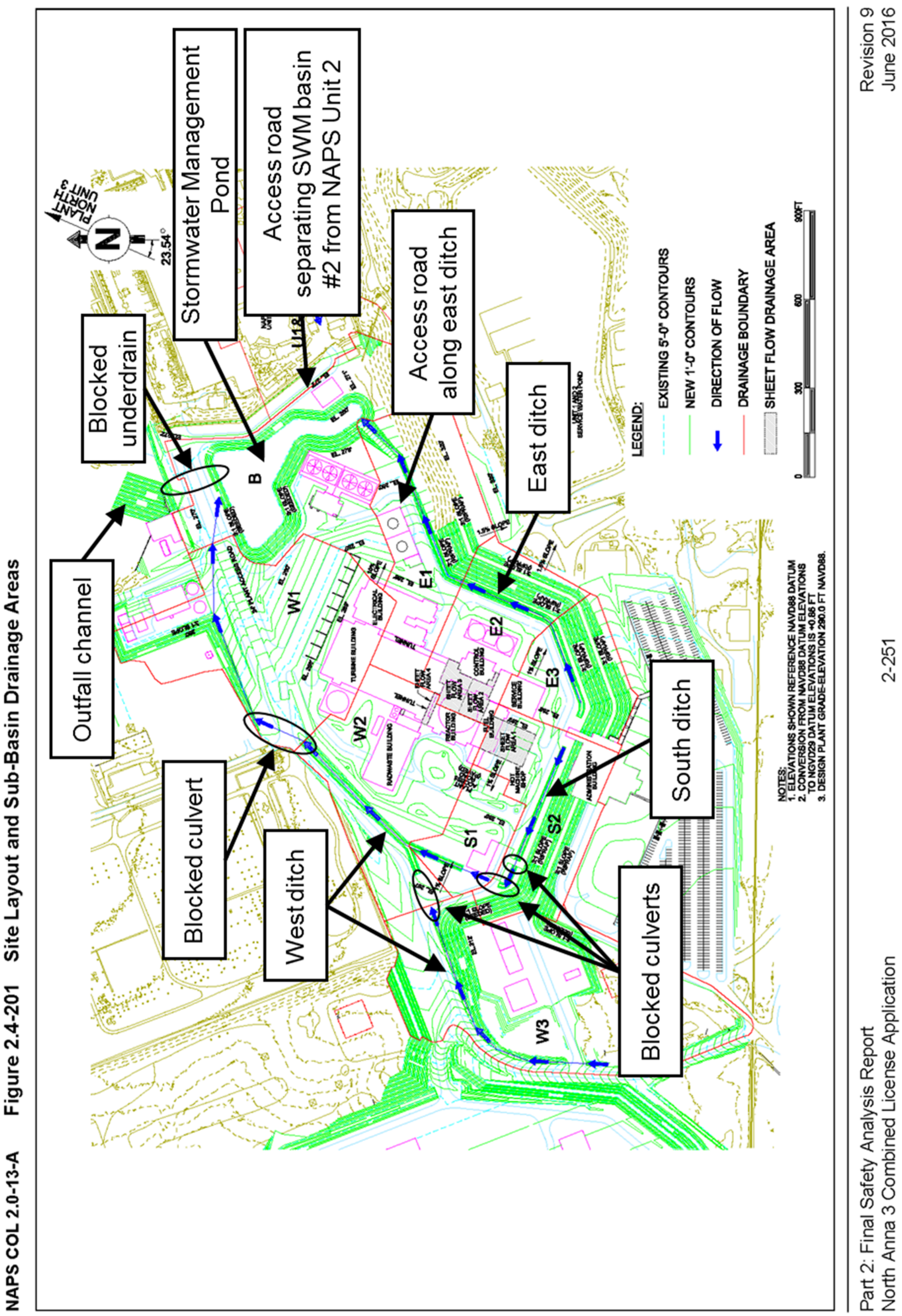


Figure 2.4.2-1. Site map with locations of drainage basins and primary hydraulic features of the drainage system flooding analysis from local intense precipitation (after North Anna 3 COL FSAR Figure 2.4-201)

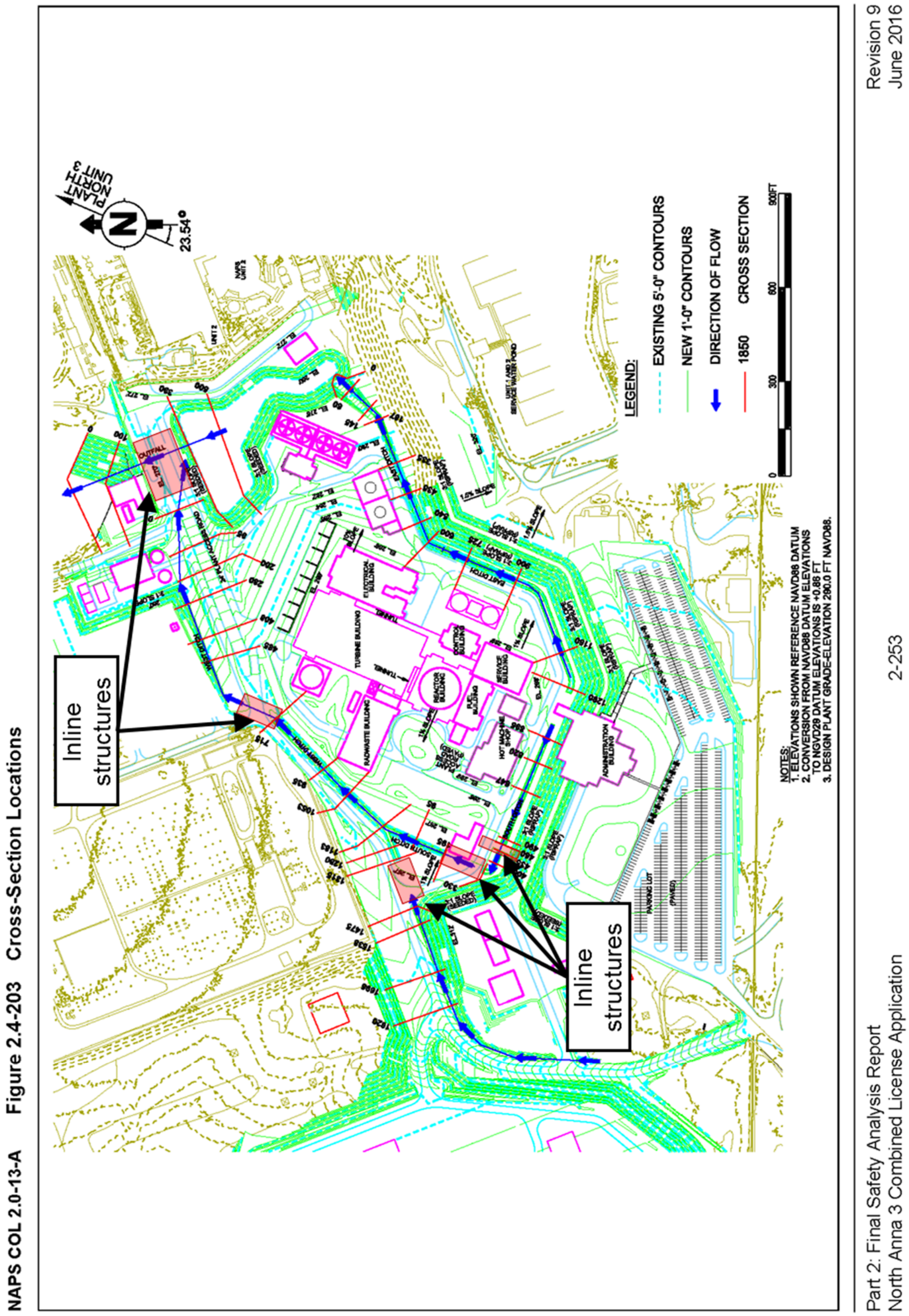


Figure 2.4.2-2. Site map with locations of the inline control structures that correspond to blocked culverts (after North Anna 3 COL FSAR Figure 2.4-203)

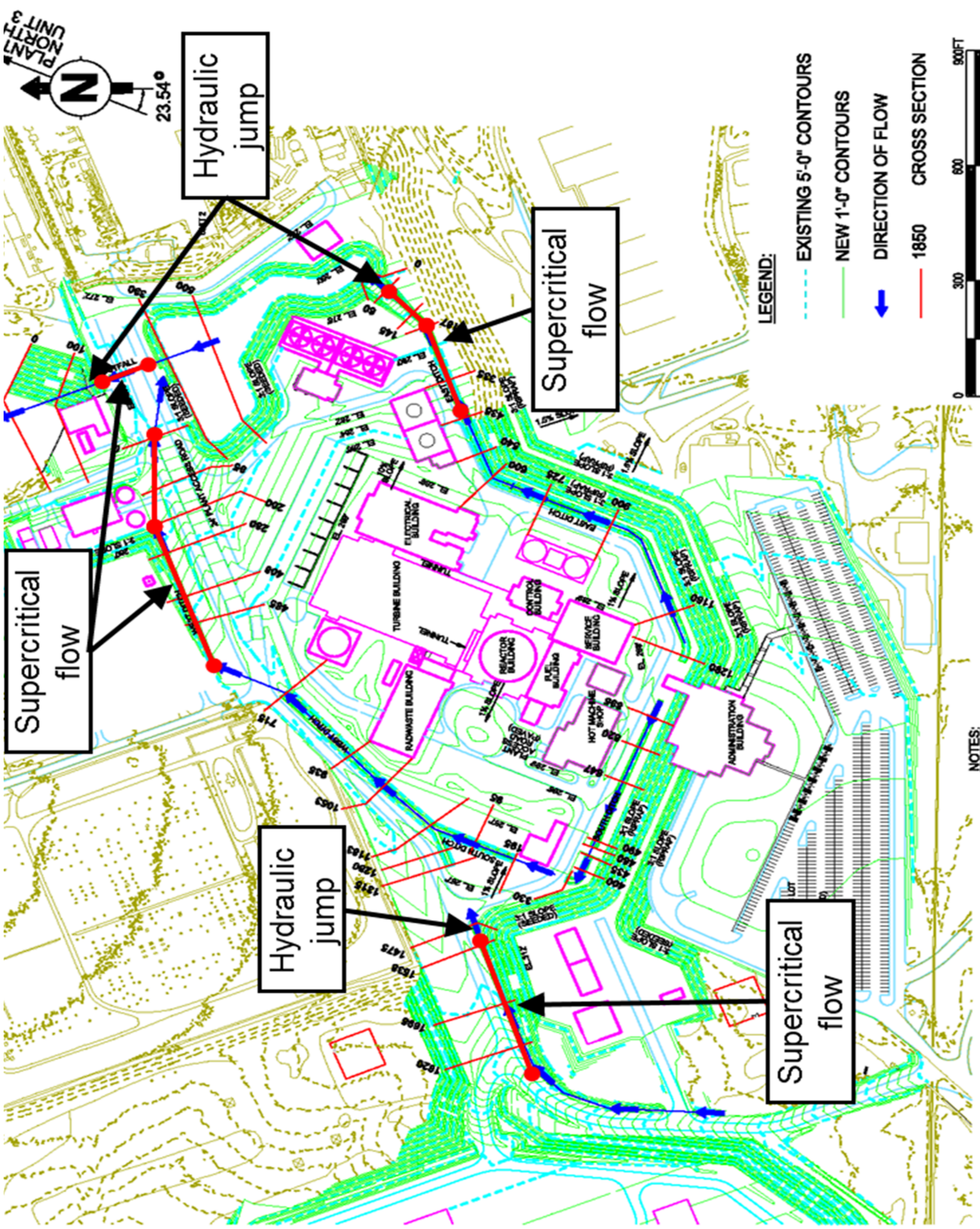


Figure 2.4.2-3. Site map with locations of supercritical flow and of hydraulic jumps from the applicant's HEC-RAS model and North Anna 3 COL FSAR Figure 2.4-221 (after North Anna 3 COL FSAR Figure 2.4-203)

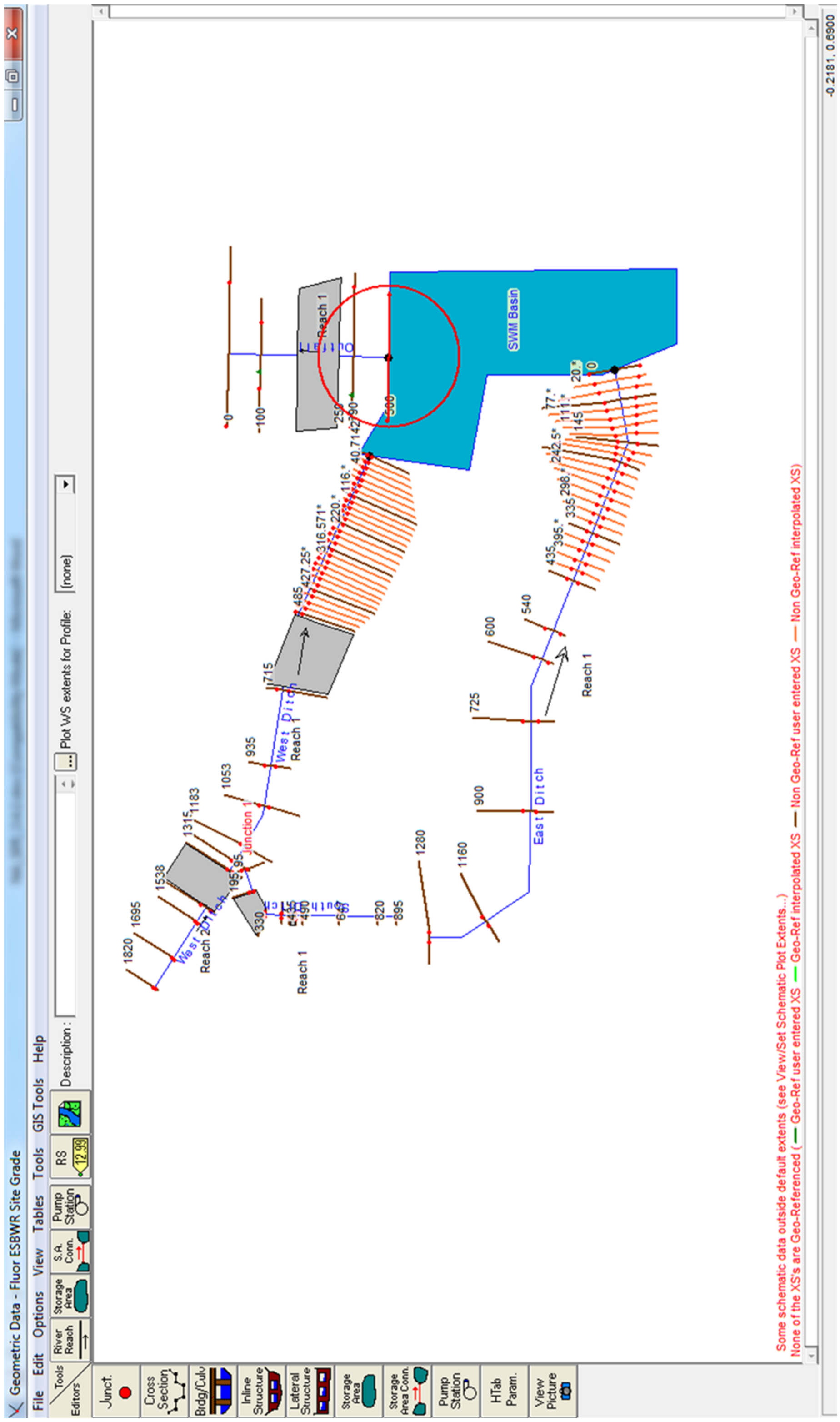


Figure 2.4.2-4. HEC-RAS schematic of the channel geometry derived from input files provided by the COL applicant

The Staff's Technical Evaluation

The staff reviewed the application and verified information discussed in this section.

The North Anna 3 COL FSAR states that the design plant grade for the safety-related SSCs for North Anna 3 is 88.39 m (290.0 ft) NAVD88. The maximum flood level reported in North Anna 3 COL FSAR from local intense precipitation sheet flow was 88.54 m (290.5 ft) NAVD88 which is 0.15 m (0.5 ft) above the design plant grade. The staff's examination of the HEC-RAS model provided by the applicant showed that the maximum flood level in the drainage ditches adjacent to the powerblock was 87.92 m (288.45 ft) NAVD88, reported in the North Anna 3 COL FSAR to the nearest tenth foot, or 87.90 m (288.4 ft) NAVD88.

In RAI 02.04.02-8, the staff requested that the COL applicant provide clarification as to why the reported design basis flood elevation was lower than the maximum flood elevation resulting from the local PMP. The COL applicant provided a response dated May 3, 2011 (ADAMS Accession No. ML11124A154), which clarified the issue. The staff noted that the information provided in the response is included in the current revision of the North Anna 3 COL FSAR. Accordingly, the staff considers RAI 02.04.02-8, resolved and closed.

The staff checked the COL applicant's precipitation depths and durations for the local intense precipitation (Table 2.4.2-1) and confirmed that they matched the values of the ESP (Dominion 2006). The staff also compared the 1-hour and 5-minute precipitation intensities (46.5 cm/hr [18.3 in/hr] and 15.5 cm/5 min [6.1 in/5 min], respectively) provided by the COL applicant against the ESBWR DCD and found that they were below the ESBWR DCD site parameter values of 49.3 cm/hr (19.4 in/hr) and 15.7 cm/5 min (6.2 in/5 min) for roof design. Therefore, the staff concluded that the ESBWR standard plant site parameters for precipitation bound the site-specific local intense precipitation.

The staff independently checked and confirmed the subbasin areas (Table 2.4.2-2) reported in the North Anna 3 COL FSAR. Although the staff did not obtain the exact subbasin areas as reported by the COL applicant, the staff's estimates were within 2 percent of the COL applicant's available area estimates. The staff considers this difference reasonable. The subbasin areas were used by the COL applicant to estimate runoff using the rational method. The COL applicant's use of the rational method to estimate runoff during the local intense precipitation is a conservative method because it assumes steady-state runoff using maximum precipitation depths over precipitation periods corresponding to the time of concentration. This approach results in the assumption that the whole subbasin was contributing runoff at the furthest downstream point. The staff determined that the rational method produced conservative estimates of discharge for use in steady-state analyses provided that the conservative times of concentration and precipitation data are used.

The staff noted that the North Anna 3 COL FSAR does not discuss North Anna 1 and 2 discharges, which was mentioned only in North Anna 3 COL FSAR Tables 2.4-201 and 2.4-202 (combined into Table 2.4.2-2). No value was provided in the FSAR for discharge from Subbasin U1&2 into the stormwater management pond; however, using the HEC-RAS input files provided by the applicant, the staff estimated that a discharge of 5.48 m^3/s (193.7 cfs) was used. In RAI 02.04.02-10, the staff requested that the COL applicant provide additional details regarding how the rational method was applied to estimate peak discharges, particularly from North Anna 1 and 2 Subbasin. In response to RAI 02.04.02-10 (ADAMS Accession No. ML15022A199), the COL applicant stated that a peak discharge specifically for Unit 1 and Unit 2 Subbasin was not calculated because it contributes flow to Subbasin B and was included in the calculation for Subbasin B (ADAMS Accession No. ML15022A199). The COL applicant provided proposed updated North Anna 3 COL FSAR text in the North Anna 3 COL FSAR, Revision 9, and the staff confirmed its inclusion. The staff reviewed the COL applicant's response and determined that the area of Subbasin B, including that of Subbasin U1&2 would be higher than that of North Anna 1 and 2 Subbasin itself and therefore the peak discharge estimated for Subbasin B would be slightly less than the peak discharge estimated for Subbasin U1&2 only. Therefore, it remained possible that the discharge for the outfall segment of the local drainage network could be slightly greater if North Anna 1 and 2 Subbasin were to be treated separately. However, the staff determined that the increase in discharge to be minor because the North Anna 1 and 2 Subbasin discharge occurs directly to the stormwater pond and would not significantly affect water-surface elevations in the powerblock area. Therefore, the staff determined that the COL applicant's response was adequate and RAI 02.04.02-10, was resolved and closed. The verified that all appropriate text changes are incorporated into the FSAR, Revision 9, and, therefore, Confirmatory Item 2.4.2-1 from the staff's advanced SER for North Anna 3 is resolved and closed.

The staff independently computed the times of concentration using Figure 2.4.2-1 for areas, distances, and slopes, and by using WinTR-55 software (SCS 1986, NRCS 2009). The TR-55 methodology includes three types of flow: overland (sheet) flow, concentrated flow, and channel flow. For sheet flow, the staff used Manning's roughness coefficients as provided in NRCS (2003). As indicated in the North Anna 3 COL FSAR, there are two land cover types: graveled areas and grass covered areas. For sheet flow over graveled areas, NRCS (2003) recommends a Manning's roughness of 0.02, while for sheet flow through dense-grass coverage a value of 0.24 is recommended. The WinTR-55 software provides drop-down lists for selection of surface type (as described by Manning's roughness values). For sheet flow, a 0.02 value for graveled areas is not provided in WinTR-55, so the staff used the next largest available value of 0.05. The staff assumed a 1 percent surface slope as indicated in Figure 2.4.2-1, though the staff expects that between buildings surface slopes would be smaller. Estimating the distance that sheet flow will occur is problematic without detailed information. The staff used a distance of 30.48 m (100 ft), which is the maximum distance that sheet flow could occur according to NRCS (2003). Comparing the staff-computed values with those provided by the applicant showed that for the east drainage areas the times of concentration are similar, though the staff's estimates are short by 1 to 2 minutes. However, the staff-computed times of concentration for the west and south drainage areas are shorter than those computed by the COL applicant, for example 10.4 min versus 20.4 min. Examination of additional information pertaining to the COL applicant's computation of times of concentration indicates the COL applicant used higher Manning's roughness coefficients for sheet flow and smaller slopes than used by the staff. The staff noted that in Subbasin S2, the applicant's estimated time of concentration for sheet flow accounts for over 60 percent of the subbasin's response time. Consequently, the COL applicant's basis for estimating sheet flow was needed.

The staff independently developed an exponential curve fit to estimate precipitation intensities for intermediate durations using the COL applicant's precipitation duration-depth data for 1-hr, 30-min, 15-min, and 5-min durations. The staff then used the independently estimated times of concentrations to compute precipitation intensities and discharges for the contributing areas. The staff used the same runoff coefficients for the Rational Method as those estimated by the COL applicant. The staff-computed discharges are higher than those estimated by the COL applicant because of higher estimated precipitation intensities. In RAI 02.04.02-11 (ADAMS Accession No. ML14345B075) dated December 11, 2014, the staff requested that the COL applicant provide a description of the assumptions made in estimation of subbasin discharges and include a discussion of the estimation of flow type lengths, Manning's roughness coefficients, times of concentration, and discharges.

In response to RAI 02.04.02-11 dated January 19, 2015 (ADAMS Accession No. ML15022A199), the COL applicant described the process used to estimate times of concentration for each subbasin. The COL applicant also described the basis for selection of Manning's roughness coefficients and the use of USACE guidance to reduce values of times of concentration for PMF events. The COL applicant provided proposed updated North Anna 3 COL FSAR text in the North Anna 3 COL FSAR, Revision 9, and the staff confirmed its inclusion. The staff reviewed the COL applicant's response and determined that the COL applicant appropriately followed current engineering practices and guidance applicable to PMF computations. The staff's higher estimates of discharges were related to differences in Manning's roughness coefficients and slopes. The staff determined that the COL applicant has appropriately used these parameters for the site-specific conditions. Therefore, the staff determined that the COL applicant's response was adequate and RAI 02.04.02-11 was resolved and closed. The staff verified that the appropriate text changes are incorporated into the FSAR, Revision 9, and, therefore, Confirmatory Item 2.4.2-2 from the staff's advanced SER for North Anna 3 is resolved and closed.

The staff received an updated set of HEC-RAS model input files from the COL applicant for the local intense precipitation flooding analysis (ADAMS Accession No. ML14013A113). The updated model files reflected the current North Anna 3 site design for the ESBWR.
The staff examined the COL applicant-provided HEC-RAS files and found the input consistent with the site plan shown in North Anna 3 COL FSAR Figure 2.4.2-203 (shown in Figure 2.4.2-1). In addition to the elevations computed by the HEC-RAS model, the staff examined the output from the COL applicant's analysis for supercritical flow. Locations with supercritical flow are noted in Figure 2.4.2-3. A transition from supercritical to subcritical flow regime is expected to produce a hydraulic jump. The staff examined the results from the COL applicant's HEC-RAS analysis for hydraulic jumps and found that the COL applicant correctly identified locations within the drainage ditches where supercritical to subcritical transitions would be predicted.

The staff noted that the downstream boundary condition in the HEC-RAS model is 80.77 m (265.0 ft) and noted that the boundary value was set 0.26 m (0.86 ft) higher than the maximum flood storage elevation in Lake Anna. The staff determined that the COL applicant used a conservative boundary condition which would result in conservative flood water surface elevations near safety-related SSCs during a local intense precipitation event.

The staff noted that the applicant's HEC-RAS input file geometry was inconsistent with the connectivity of the west ditch for the storm water management pond. In RAI 02.04.02-12, the staff requested that the COL applicant explain the apparent disagreement between the HEC-RAS input files and North Anna 3 COL FSAR Figures 2.4.201 and 2.4.203 which illustrate the connection of the west ditch to the stormwater management pond. In response to RAI 02.04.02-12 (ADAMS Accession No. ML15022A199), the COL applicant stated that as the west ditch approaches the stormwater management pond, water will flow in three directions: a portion will flow north into an area adjacent to the intake channel, another portion will flow south into the stormwater management pond, and a third portion will continue flowing along the west ditch towards the stormwater management pond outlet and into Lake Anna. The COL applicant chose to direct all flow from the west ditch into the stormwater management pond because the calculated water surface elevation would then be conservatively higher in Subbasin B. The COL applicant proposed updating North Anna 3 COL FSAR Figures 2.4-201 and 2.4-203 to correctly depict the discharge from the west ditch into the stormwater management pond, consistent with the HEC-RAS model setup. The staff determined that the COL applicant's response was adequate and verified that the appropriate updates to Figures 2.4-201 and 2.4-203 are incorporated into the FSAR, Revision 9, and, therefore, Confirmatory Item 2.4.2-3 from the staff's advanced SER for North Anna 3 is resolved and closed.

The HEC-RAS model requires specification of contraction and expansion coefficients. Typical contraction and expansion coefficient values are 0.1 and 0.3, respectively, for gradual transitions, 0.3 and 0.5 for typical bridge sections, respectively, and a maximum of 0.6 and 1.0 for abrupt transitions, respectively (USACE, 2010). The staff noted in the review of the COL applicant's HEC-RAS model that several cross sections were specified with contraction and expansion coefficients at the default value of 0.1 and 0.3, respectively, but others had values of 0.3 and 0.5, respectively. While staff acknowledged that these higher values are conservative, there was no discussion in the North Anna 3 COL FSAR concerning the selection of the higher values. In RAI 02.04.02-13, the staff requested that the COL applicant provide a discussion of the basis for selection of contraction and expansion coefficient values of 0.3 and 0.5, respectively. In response to RAI 02.04.02-13 (ADAMS Accession No. ML15022A199), the COL applicant explained that contraction and expansion coefficient values of 0.3 and 0.5, respectively, were specified at cross sections located upstream and downstream of inline weirs where flow transitioning was expected to be less gradual and act more similarly to flow transitions near bridges. The COL applicant provided proposed updated North Anna 3 COL FSAR text in the North Anna 3 COL FSAR, Revision 9, and the staff confirmed its inclusion. In the COL applicant's HEC-RAS model input geometry, the staff identified and confirmed the presence of inline weirs that were used in place of culverts and were used to represent fully blocked culverts. The staff reviewed the COL applicant's justification for using contraction and expansion coefficient values of 0.3 and 0.5, respectively, at these locations and determined the values and associated justification adequate. Therefore, the staff determined that the COL applicant's response was adequate and verified that the appropriate text changes are incorporated in the FSAR, Revision 9, and, therefore, Confirmatory Item 2.4.2-4 from the staff's advanced SER for North Anna 3 is resolved and closed.

During the review of the inline weirs used in the COL applicant's HEC-RAS model, the staff noted that weir coefficients in the model were set to either 2.6 or 2.4. The staff found no discussion of the basis for these values in the North Anna 3 COL FSAR. Therefore, in RAI 02.04.02-14, the staff requested that the COL applicant provide a discussion of the basis and the method used to specify the weir coefficients used in the HEC-RAS model. In response to RAI 02.04.02-14 (ADAMS Accession No. ML15022A199), the COL applicant described the basis for selection of the weir coefficients. The COL applicant stated that all inline weirs in the HEC-RAS model acted as broad-crested weirs and that the selected weir coefficient values of 2.4 and 2.6 were fairly low values for broad-crested weirs. These low values would produce higher water-surface elevations over the weirs, which would result in more conservative water-surface elevations in the ditches. The staff reviewed the typical weir coefficient values used in currently accepted engineering practice (Chow 1959) and determined that the COL applicant's conclusion was reasonable. The COL applicant stated that a weir coefficient of 2.4 was used for weirs at the outfall and at a south ditch cross section to account for additional hydraulic loss because of the presence of security barriers at these locations. The COL applicant used an iterative calculation to estimate the weir coefficient value of 2.4 at these locations. The COL applicant provided proposed updated North Anna 3 COL FSAR text in the North Anna 3 COL FSAR, Revision 9, and the staff confirmed its inclusion. The staff reviewed the COL applicant's method for estimating the weir coefficient at locations that have security barriers and concluded that the applicant has appropriately analyzed the flow at these locations. Therefore, the staff determined that the COL applicant's response was adequate and verified that appropriate text changes are incorporated in the FSAR, Revision 9, and, therefore, Confirmatory Item 2.4.2-5 from the staff's advanced SER for North Anna 3 is resolved and closed.

The staff checked the reference (Chow 1959) used by the applicant to select the Manning's roughness coefficient value. In the North Anna 3 COL FSAR, the applicant explained that the channel linings consist of riprap and used a Manning's roughness coefficient of 0.035 for all cross sections. According to Chow (1959), this value is for a channel with a gravel bottom with riprap sides. A slightly higher value might be expected if the channel was completely lined with riprap rather than just on its sides. The COL applicant set Manning's roughness coefficients for all cross sections in the HEC-RAS model input to 0.035, which represents a channel lined with riprap. To test the effect of a slightly higher Manning's roughness coefficient, the staff examined the effect on water surface elevations using a value of 0.040 for Manning's roughness coefficient. The staff determined that the water-surface elevation increased 0.06 m (0.2 ft) in the east ditch compared to that from the COL applicant's estimate, while for the south ditch the water surface elevation was the same as the COL applicant's estimate. Because these changes in water-surface elevations are minor and remained significantly below the design plant grade, the staff concluded that the COL applicant's use of a Manning's roughness coefficient value of 0.035 was acceptable.

The staff noted that the COL applicant's Calculation Package 25161-G-012 included an analysis of runoff and flood water depths between buildings during a local intense precipitation event. In this calculation, the COL applicant determined that a depth up to 12.7 cm (5 in) could be expected to occur in at least one location (between the Hot Machine Shop and Auxiliary Diesel Building). The staff also noted that the North Anna 3 COL FSAR did not include a discussion of drainage and flood discharge between buildings. The staff consider the guidance provided by ANSI/ANS-2.8-1992 Section 11.4 for consideration of roof drainage during local intense precipitation events an important aspect of the safety analysis. The North Anna 3 COL FSAR Revision 7 did not provide a description of this aspect of local intense precipitation flooding. Therefore, in RAI 02.04.02-15, the staff requested that the COL applicant provide the following:

- A discussion of the effects of roof drainage and direct precipitation on water-surface elevations or depths along passageways between buildings and structures important for safety;
- A comparison of these estimated water-surface elevations with the elevations of any penetrations or openings housing safety-related SSCs; and
- Appropriate updates to the North Anna 3 COL FSAR.

In response to RAI 02.04.02-15 (ADAMS Accession No. ML15022A199), the COL applicant provided details of the analysis in Calculation Package 25161-G-012.

The staff's review of the COL applicant's response revealed that some narrow alleyways between buildings in the powerblock area may not have been fully analyzed. In a revised response to RAI 02.04.02-15 (ADAMS Accession No. ML16229A451), the COL applicant provided an updated analysis of runoff between buildings during a local intense precipitation event. The COL applicant assumed that all roof drains will be clogged during a local intense precipitation event. The COL applicant also stated that scuppers in the parapets of the Reactor, Fuel, Control, Turbine, and Service Buildings will be sized to pass the peak discharge from the local intense precipitation and will be designed to prevent clogging. The COL applicant described its analysis (ADAMS Accession No. ML16229A451) of sheet flow within four key areas of relatively narrow passages within the powerblock:

- Area 1, the area located between the Hot Machine Shop and the Ancillary Diesel Building, south of the FB;

- Area 2, the area south of the CB, north of the Service Building, and east of the RB;
- Area 3, the area between the north end of the CB, the southeast corner or the TB, and east of the RB; and
- Area 4, the alleyway north of the RB and south of the TB.

The COL applicant estimated the drainage area that would contribute runoff to these four areas, including adjacent building roof areas. The COL applicant stated that building scuppers would be designed to direct roof drainage in specific directions. The COL applicant used the rational equation to estimate the peak sheet flow discharge for each of the four areas using a runoff coefficient of 1.0 and using a 5-minute time of concentration that results in a local intense precipitation intensity of 185.9 cm (73.2 in) /hr. The COL applicant estimated peak sheet flow discharges for Areas 1 through 4 as 0.83, 0.52, 0.60, and 0.10 m^3/s (29.3, 18.3, 21.2, and 3.7 cfs), respectively.

For Area 1, the COL applicant estimated a sheet-flow depth of 0.12 m (0.4 ft) using an estimated flow width of 9.14 m (30 ft), a channel slope of 0.4 percent, and a Manning's roughness coefficient of 0.02 to represent shallow flow over a paved surface. Therefore, the COL applicant estimated that the maximum flood water-surface elevation in this area to be 88.36 m (289.9 ft) NAVD88 (i.e., the site grade of 88.24 m [289.5 ft] NAVD88 plus a maximum sheet-flow depth of 0.12 m [0.4 ft]).

Similarly, for Area 2, the COL applicant estimated a maximum flow depth of 0.24 m (0.8 ft) that, when added to the site grade resulted in a maximum flood water-surface elevation of 88.48 m (290.3 ft) NAVD88. In addition, the COL applicant also estimated the sheet-flow water-surface elevation on top of the access tunnel roof because the access tunnel roof is 15.2 cm (6 in) above the site grade and therefore water will discharge as weir flow over the roof into the alleyway. The COL applicant determined that the weir would be submerged. However, because the depth of submergence would be small, the COL applicant used a free fall weir discharge equation to estimate a weir flow water depth of 0.15 m (0.5 ft) with a corresponding maximum sheet-flow elevation of 88.54 m (290.5 ft) NAVD88 in this area.

For Area 3, the COL applicant estimated a maximum flow depth of 0.12 m (0.4 ft) that, when added to the site grade outside the CB downstream of the access tunnel resulted in a maximum flood water-surface elevation of 88.36 m (289.9 ft) NAVD88. Similar to the second sheet-flow area analysis, the COL applicant estimated the weir flow water depth of 0.12 m (0.4 ft) with a corresponding maximum sheet-flow elevation of 88.51 m (290.4 ft) NAVD88 in this area.

For Area 4, the COL applicant estimated the weir flow depth passing over the tunnel to be 0.06 m (0.2 ft) with a corresponding maximum sheet-flow elevation of 88.45 m (290.2 ft) NAVD88.

Because of the revisions to the scupper design that would direct flow off building roofs in certain areas, the COL applicant stated that subbasin areas for the HEC-RAS analysis changed. The COL applicant updated the HEC-RAS analysis to reflect these changes. The staff's description in the *Information Submitted by Applicant* section above reflected these changes.

Comparing the safety-related floor and doorway elevations in Area 2 with estimated maximum sheet-flow elevations at the same locations, the COL applicant determined that the elevation of the CB south stairway landing adjacent to the emergency exit door, 88.39 m (290.0 ft) NAVD88, was below the estimated maximum sheet-flow elevation of 88.48 m (290.3 ft) NAVD88.

Therefore, the COL applicant stated that flood protection measures will be provided by installing a curb at the door entrance or by ensuring that the door threshold is above an elevation of 88.48 m (290.3 ft) NAVD88.

Comparing the safety-related floor and doorway elevations in Area 3 with estimated maximum sheet-flow elevations at the same locations, the COL applicant determined that the elevation of the CB north stairway landing adjacent to the emergency exit door, 88.39 m (290.0 ft) NAVD88, was below the estimated maximum sheet-flow elevation of 88.51 m (290.4 ft) NAVD88. Therefore, the COL applicant stated that flood protection measures will be provided by installing a curb at the door entrance or by ensuring that the door threshold is above an elevation of 88.51 m (290.4 ft) NAVD88.

Comparing the safety-related floor and doorway elevations in Area 4 with estimated maximum sheet-flow elevations at the same locations, the COL applicant determined that the elevation of the RB floor adjacent to the equipment access door on the north side of the RB, 88.39 m (290.0 ft) NAVD88, was below the estimated maximum sheet-flow elevation of 88.45 m (290.2 ft) NAVD88. Therefore, the COL applicant stated that flood protection measures will be provided by installing a curb at the door entrance or by ensuring that the door threshold is above an elevation of 88.45 m (290.2 ft) NAVD88.

The COL applicant proposed changes to North Anna 3 COL FSAR Section 2.4.2.3 to describe the effects of sheet flow including a comparison of estimated sheet-flow elevations to floor and door elevations of safety-related SSCs; updates to North Anna 3 COL FSAR Tables 2.4-201 through 2.4-204 to reflect revised subbasin drainage areas, peak discharges, and water-surface elevations; and, updates to North Anna 3 COL FSAR Figures 2.4-201 and 2.4-203 to reflect revised subbasin drainage areas and to show the locations of the access and radwaste tunnels. In addition, the COL applicant proposed revisions to North Anna 3 COL FSAR Section 2.4.10 to describe flood protection measures described above.

The staff reviewed the COL applicant's response to RAI 02.04.02-15 and determined that the COL applicant's sheet-flow analysis appropriately followed ANSI/ANS-2.8-1992 Section 11.4 guidance and used current engineering practice methods with conservative assumptions that maximize sheet-flow water-surface elevations adjacent to safety-related SSCs. The COL applicant proposed changes to the North Anna 3 COL FSAR that included a description of the design roof drainage directions, a description of the sheet flow analysis comparisons of safety-related floor and door elevations with maximum sheet-flow elevations, and locations of required flood protection measures. Therefore, the staff determined that the COL applicant's response was adequate and verified that the appropriate text revisions are incorporated into the FSAR, Revision 9, and, therefore, Confirmatory Item 2.4.2-6 from the staff's advanced SER for North Anna 3 is resolved and closed.

In evaluating the effects of local intense precipitation, the staff relied on the following statements on the part of the COL applicant:

- Locations where supercritical flow regimes are predicted to occur will be provided with linings and hardened surface protection;
- Grading in the vicinity of safety-related SSCs will slope away from the structures to provide sheet flow to drainage ditches;
- No storm drain inlets or depressed areas are located near safety-related buildings;

- During North Anna 3 construction, as-built drawings will be checked against site topography, surface conditions, and channel linings represented in the local intense precipitation flooding HEC-RAS analyses;

- During North Anna 3 construction, drainage facilities will be inspected at least once every two weeks;

- During North Anna 3 operation, the storm water drainage system will be monitored and maintained to ensure consistency with the design conditions represented in the HEC-RAS analyses;

- During North Anna 3 operation, the drainage system will be inspected quarterly for areas with potential for erosion; and

- The scuppers in the parapets of Reactor, Fuel, Control, Turbine, and Service Buildings will be sized to pass the peak discharge from a local intense precipitation and will be designed to prevent clogging.

<u>The Staff's Independent Review Related to the Previous COLA Reactor Design</u>

Preceding the RAIs discussed above and over the course of the staff's review, several RAIs were issued by the staff to resolve questions corresponding to earlier versions of the North Anna 3 COL FSAR referencing the APWR design. These earlier versions under the APWR reactor design used a different drainage system design; however, for completeness, these RAIs and their applicability and resolution are discussed below.

In RAI 02.04.02-1 dated August 21, 2008 (ADAMS Accession No. ML082340933), the staff requested additional information from the applicant regarding the local intense precipitation analysis. Specifically in RAI 02.04.02-1, the staff requested that the COL applicant provide the following items:

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

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

- A description of how runoff from each building and parking lot in North Anna 3 COL FSAR Figure 2.4-201 has been captured in the HEC-RAS model and hence, is correctly represented in the subbasin drainage boundaries in North Anna 3 COL FSAR Figure 2.4-201.

On September 16, 2008, the COL applicant responded to RAI 02.04.02-1 dated September 16, 2008 (ADAMS Accession No. ML082680033). Additionally, North Anna 3 COL FSAR Revision 3, Section 2.4.2 includes statements that address RAI 02.04.02-1.

Specifically concerning RAI 02.04.02-1(a), the applicant stated in North Anna 3 COL FSAR Section 2.4.2 that during construction of North Anna 3, construction and as-built drawings will be checked against site topography, surface type, and channel linings as provided for the local PMP flood analysis including the HEC-RAS modeling analysis.

Specifically concerning RAI 02.04.02-1(b), the applicant stated in North Anna 3 COL FSAR Section 2.4.2 that construction and as-built drawings will be checked against site topography, surface type, and channel linings as provided for the local PMP flood analysis including the HEC-RAS modeling analysis. The applicant also stated in North Anna 3 COL FSAR Section 2.4.2 that during operation of North Anna 3 the drainage system will be monitored so it continues to be consistent with the local PMP flood analysis including the HEC-RAS modeling analysis. Site inspections will be done quarterly to inspect areas with erosion potential.

Specifically concerning RAI 02.04.02-1(c), the applicant provided in North Anna 3 COL FSAR Section 2.4.2 a description of the site grading near the safety-related SSCs and described how ground and roof runoff reaches the drainage system. The applicant provided information on the imperviousness as included in the composite runoff coefficient. The staff addressed its concerns with the local intense precipitation analysis in RAI 02.04.02-10 through 02.04.02-15. As described previously herein, the staff described the resolution of these concerns.

In RAI 02.04.02-2 the staff requested information that was a follow-on to RAI 02.04.02-1 per the following items:

a. This item was a request for revised HEC-RAS model input files;

b. This item was a request that the COL applicant describe in the North Anna 3 COL FSAR a structure in the HEC-RAS model that results in overland flow from the ditch draining into the stormwater management pond;

c. This item requested a map be provided that identifies the locations where supercritical flows and hydraulic jumps are likely to occur in the drainage ditches. Additionally, the question requested the locations where flood events produce velocities higher than the design velocity for the channel bed material. A portion of the item concerned overland flow from the ditch draining into the stormwater management pond. This included the request for a description of how a potential failure of these drainage features could degrade any safety-related SSCs, or structures that satisfy RTNSS criteria; and,

d. This item requested controls and requirements needed to ensure the ditches and outfall canal would remain clear of obstructions, the side-slopes would remain stable, and the site drainage system would function as described in the North Anna 3 COL FSAR Section 2.4.2 for the length of the North Anna 3 licensing period. The item also requested that the COL applicant provide additional detail regarding Administrative Controls or surveillance requirements including the frequencies at which surveys will be conducted.

Specifically concerning RAI 02.04.02-2(a) dated March 06, 2009 (ADAMS Accession No. ML090680312), the applicant provided HEC-RAS files based on the current site storm water management system for the ESBWR reactor design. Therefore, this question item was resolved and closed.

Specifically concerning RAI 02.04.02-2(b), because the storm water management system was modified, the current design and HEC-RAS analysis does not include the referenced structure. Therefore, this question item no longer applied.

Specifically concerning RAI 02.04.02-2(c), because the storm water management system was modified, the current design and HEC-RAS analysis does not include overland flow and the erosion potential that would result from overflows from the ditch draining. Therefore, this portion of the RAI (item c) no longer applied. For the applicable remaining portion of the RAI (item d), the applicant had not provided a map of the potential locations of supercritical velocity and hydraulic jumps for the current storm water management system design. Therefore, in RAI 02.04.02-9, the staff requested that the COL applicant provide a map identifying locations with supercritical velocities and hydraulic jumps. The COL applicant provided a map in the current revision of the North Anna 3 COL FSAR with the locations of supercritical velocities and hydraulic jumps identified from HEC-RAS analyses (Figure 2.4.2-3). Therefore, the staff considered RAI 02.04.02-9, resolved and closed.

Specifically concerning RAI 02.04.02-2(d), the COL applicant committed to implementation of administrative controls and a quarterly monitoring program to inspect locations with erosion potential, as summarized above in this SER section titled "Information Submitted by Applicant." Additionally, the COL applicant committed to corrective action if erosion were to occur. Therefore, the staff considered RAI 02.04.02-2(d) resolved and closed.

In RAI 02.04.02-3, the staff requested that the COL applicant provide information concerning the hydraulic characteristics created by an access road crossing a ditch with a drop culvert used for floodwater conveyance. This design produced flood elevations capable of affecting the Units 1 and 2 site. This road crossing was not included in the current design for the ESBWR North Anna 3 site. Therefore, RAI 02.04.02-3 no longer applied.

In RAI 02.04.02-4 dated July 28, 2009 (ADAMS Accession No. ML092090567), the staff requested that the COL applicant provide information concerning the construction and maintenance of the storm water drainage system, specifically asking for this information to be added to the North Anna 3 COL FSAR. The requested information included (1) that channels and overbanks be checked prior to use and (2) that channels and overbanks be maintained over the licensing period in the same condition as represented in the updated HEC-RAS model. As summarized above in the SER section titled "Information Submitted by Applicant," this information has been included in the North Anna 3 COL FSAR. Therefore, the staff considered RAI 02.04.02-4 resolved and closed.

In RAI 02.04.02-5 dated July 28, 2009 (ADAMS Accession No. ML092090567), the staff requested that the COL applicant provide information concerning the construction and maintenance of the storm water drainage system, specifically asking for this information to be added to the North Anna 3 COL FSAR. Noting that the ditch identities below correspond to a previous version of the storm water drainage system, the previously requested information included the following items:

a. All drainage ditches, overflow area and embankments at North Anna 3 will be protected to withstand the predicted flood flow velocities resulting from the local PMP event for the North Anna 3 site;

b. The lining for the south drainage ditch at the location of the hydraulic jump will be designed to withstand the erosive forces generated by the hydraulic jump during the local PMP event;

c. The lining of the north ditch and storm water management basin side slopes in the vicinity of the north ditch will be designed to withstand the erosive forces of the hydraulic jump at the inlet to the storm water management basin; and,

d. The embankment for the outfall channel will be provided with hardened surface protection designed to withstand the erosive forces associated with the supercritical flow and the potential occurrence of a hydraulic jump at the embankment section.

As stated, the current North Anna 3 COL FSAR has different identities for the drainage ditches than was used in this early RAI above. As summarized above in the SER section titled "Information Submitted by Applicant," this information has been incorporated in the North Anna 3 COL FSAR. Therefore, the staff considered RAI 02.04.02-5 resolved and closed.

In RAI 02.04.02-6 dated July 28, 2009 (ADAMS Accession No. ML092090567), the staff requested that the COL applicant provide information concerning the construction and maintenance of the storm water drainage system, specifically asking for this information to be added to the North Anna 3 COL FSAR. The requested information included surveillance and monitoring requirements, with the frequencies at which the surveys will be conducted. In addition, staff requested that this information not be tied to permits issued by the Commonwealth of Virginia. As summarized above in the staff SER section titled "Information Submitted by Applicant," this information was included in the North Anna 3 COL FSAR. Additionally, the North Anna 3 COL FSAR does not include text that would tie this information to state issued permits. Therefore, the staff considered RAI 02.04.02-6 resolved and closed.

In RAI 02.04.02-7 dated July 28, 2009 (ADAMS Accession No. ML092090567), the staff requested that the COL applicant provide information concerning the hydraulic characteristics created by an access road crossing a ditch with a drop culvert used for floodwater conveyance. This design produced flood elevations capable of affecting the Units 1 and 2 site. This road crossing was not included in the current design for the ESBWR North Anna 3 site. Therefore, RAI 02.04.02-7 no longer applied.

2.4.2.5 Post Combined License Activities

There are no post COL activities related to this section.

2.4.2.6 Conclusion

The staff reviewed the application and checked the referenced ESP SSAR and staff's ESP FSER (NUREG-1835). The staff's review confirmed that the COL applicant has addressed the required information, and no outstanding information remains to be addressed in the North Anna 3 COL FSAR related to this section.

In addition, the staff compared the additional information in the COLA to the relevant NRC regulations, the guidance in Section 2.4.2 of NUREG–0800, and NRC RGs. The staff's review concluded that the COL applicant has provided sufficient information to satisfy the requirements of NRC regulations. The staff has determined that the COL applicant has adequately addressed NAPS COL Item 2.0-13-A as it relates to floods.

As set forth above, the COL applicant has presented and substantiated information relative to the floods important to the design and siting of this plant. The staff reviewed the available information provided. For the reasons given above, the staff concludes that the identification and consideration of the floods at the site and in the surrounding area are acceptable and meet the requirements of 10 CFR 52.79(a)(31) and 100.20(c), with respect to determining the acceptability of the site for the ESBWR design.

The staff finds that the COL applicant has considered the appropriate site phenomena in establishing the design bases for SSCs important to safety. The staff accepts the methodologies used to determine the locally intense precipitation flood event. 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 100.20(c) with respect to establishing the design basis for SSCs important to safety.

2.4.3 Probable Maximum Flood on Streams and Rivers

2.4.3.1 Introduction

The PMF 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

North Anna 3 COL FSAR Section 2.4.3, “Probable Maximum Flood on Streams and Rivers,” addresses the need for information on site-specific PMF on streams and rivers.

The COL applicant addressed the ESBWR DCD and ESP information as follows:

COL Item:

- NAPS COL 2.0-14-A — Probable Maximum Flood on Streams and Rivers, COL Applicant to supply site-specific information in accordance with SRP 2.4.3

The COL applicant incorporated by reference ESP SSAR Section 2.4.3 to address ESBWR DCD COL Item 2.0-14-A and provided updated site-specific information to supplement ESP SSAR Sections 2.4.3.

Early Site Permit Variance:

The following variance from the ESP SSAR are discussed in Section 2, “Variances,” of Part 7 to the COLA:

- NAPS ESP VAR 2.4-4

As described in Section 2.4.1, the COL applicant stated that, to improve water availability to downstream users during drought conditions, the normal pool elevation of Lake Anna is to be raised 0.08 m (0.25 ft) to 76.01 m (249.39 ft) NAVD88.

- NAPS ESP VAR 2.4-5

The COL applicant supplemented the ESP SSAR Section 2.4.3 with a revised PMF analysis for Lake Anna using the increased normal pool elevation, and also updated the model to use the USACE HEC-HMS code (USACE, 2010b) and USACE guidance on the use of peaked hydrographs to account for a nonlinear response to large storms. The COL applicant stated that the PMF for streams and rivers is at an elevation of 81.25 m (266.56 ft) NAVD88, which is 7.14 m (23.44 ft) below the design plant grade for safety-related components and structures.

2.4.3.3 Regulatory Basis

The regulatory basis of the information incorporated by reference is addressed in NUREG-1966, the FSER related to ESBWR DCD, and in NUREG-1835, the FSER related to the North Anna ESP. In addition, the guidance relevant to the Commission's regulations for the PMF on streams and rivers, and the associated acceptance criteria, are contained in Section 2.4.3 of NUREG-0800 SRP.

The acceptance criteria for the North Anna 3 PMF on streams and rivers presented in the North Anna 3 COL FSAR, beyond that presented in the ESP SSAR (i.e., NAPS COL Item NAPS COL 2.0-14-A, and NAPS COL VARs 2.4-4 and 2.4-5), are based on meeting the following relevant requirements of 10 CFR Part 52 and 10 CFR Part 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 margin for the limited accuracy, quantity, and time in which the historical data have been accumulated.

- 10 CFR 100.20(c), as it relates to the consideration given to the hydrological characteristics of the site.

- 10 CFR 100.23(d), sets forth the criteria to determine the citing factors for plant design bases with respect to seismically induced floods and water waves at the site.

The following related acceptance criteria are summarized from SRP Section 2.4.3:

- Design Bases for Flooding in Streams and Rivers: To meet the requirements of 10 CFR Part 100, estimates of the following characteristics are needed, and should be based on conservative assumptions of hydrometeorologic characteristics in the drainage area: (a) the area of the watershed used to estimate flooding in streams and rivers, (b) the total depth of PMP and the PMP hyetograph, (c) the maximum PMF water surface elevation in streams and rivers with coincident wind-waves, and (d) hydraulic characteristics that describe dynamic effects of PMF on SSC important to safety. If a potential hazard to SSC important to safety exists, the applicant should document and justify the design bases of affected facilities.

- Design Bases for Site Drainage: To meet the requirements of 10 CFR Part 100, estimates of the following characteristics are needed: the runoff from the immediate site area and the drainage from areas adjacent to the site, including the roofs of safety-related structures. Flood response characteristics should be identified to estimate flooding adjacent to and on the plant site. The effects of erosion and sedimentation during the flooding should be identified and their effects on SSC important to safety should be determined. If a potential hazard to SSC important to safety exists, the applicant should document and justify the design bases of affected facilities.

- Consideration of Other Site-Related Evaluation Criteria: To meet the requirements of 10 CFR Part 100 information about the potential effects of site related proximity, seismic, and non-seismic information as they relate to flooding in streams and rivers and local flooding adjacent to and on the plant site is needed.

In addition, the hydrologic characteristics should be consistent with appropriate sections from RGs:

- RG 1.27, describes the applicable UHS capabilities.

- RG 1.29, identifies seismic design bases for SSC important to safety.

- RG 1.59, as supplemented by current best practices provides guidance for developing the hydrometeorological design bases.

- RG 1.102, describes acceptable flood protection to prevent the safety-related facilities from being adversely affected.

2.4.3.4 Technical Evaluation

As documented in Section 2.4.3 of NUREG-1966 and Section 2.4.3 of NUREG-1835, the staff reviewed and approved information related to PMF for the certified ESBWR DCD, Revision 10, and Section 2.4.3 of the North Anna ESP, respectively. The staff reviewed Section 2.4.3 of the North Anna 3 COL FSAR, Revision 9, and checked the referenced ESBWR DCD and the North Anna ESP SSAR to ensure that the combination of the information in the North Anna 3 COL FSAR and the information in the ESBWR DCD and ESP SSAR represent the complete scope of information relating to this review topic. The staff's review confirms that the information in the application and the information incorporated by reference address the required information related to "Probable Maximum Flood on Streams and Rivers."

The staff's technical review in this section is limited to reviewing the supplemental information pertaining to NAPS COL 2.0-14-A, NAPS ESP VAR 2.4-4, and NAPS ESP VAR 2.4-5 as addressed below.

Information Submitted by COL Applicant:

The current design for the site calls for an increase in the normal pool elevation of Lake Anna by 7.62 cm (3 inches) from 75.94 m (249.14 ft) NAVD88 to 76.01 m (249.39 ft) NAVD88 to increase water availability downstream of Lake Anna during drought conditions when North Anna 3 is operational. With the change in normal pool elevation, the COL applicant updated the PMF analysis, which included an update to the model to use the USACE HEC-HMS code, rather than the HEC-1 code used for the ESP SSAR.

The initial HEC-HMS simulation used the lower normal pool elevation and the same input data used in the ESP SSAR HEC-1 analysis. However, the input parameters for the Coefficient Ratio (CR) and the Recession Ratio (RC) were adjusted so that the HEC-HMS analysis matched the stillwater PMF elevation of 80.23 m (263.21 ft) NAVD88 as developed in the ESP SSAR.

For the North Anna 3 COL FSAR, the COL applicant revised the initial Lake Anna elevation and the stage-discharge relationship to reflect the 0.08 m (0.25 ft) increase in the normal pool elevation. The COL applicant also applied the peaked unit hydrograph. The COL applicant stated that the revised PMF at Lake Anna dam was increased by 0.01 m (0.03 ft) compared to the ESP SSAR PMF elevation. The COL applicant stated that, because the increase in the PMF elevation at the dam was so small, backwater and wind-wave activity effects on the maximum flood elevation were not reanalyzed, but were kept at 1.01 m (3.32 ft) (i.e., 0.03 m [0.09 ft] for wave set-up, 0.92 m [3.03 ft] for wave run-up, and 0.06 m [0.20 ft] for backwater). The COL applicant stated that the PMF elevation for the North Anna 3 site is 81.25 m (266.56 ft) NAVD88 including these associated effects. Additionally, the COL applicant stated that the PMF elevation is 7.14 m (23.44 ft) below the North Anna 3 design plant grade and that all UHS SSCs and the Fire Water Service Complex (FWSC) (which provides makeup water to the UHS from 72 hr. to 7 days post-accident) are above the PMF elevation.

The Staff's Technical Evaluation:

The staff reviewed the North Anna 3 COL FSAR and the COL applicant-provided HEC-HMS files. The staff checked the ESP SSAR and compared the results with the current analysis. The COL applicant updated the method of analysis using HEC-HMS, while the analysis in the ESP SSAR used HEC-1, which was a predecessor to HEC-HMS. The staff finds it acceptable to update the analyses using standard modeling tools, especially because the USACE no long supports HEC-1.

The COL applicant set up a HEC-HMS model to reproduce the maximum water surface as obtained in the ESP SSAR HEC-1 analysis. The COL applicant adjusted two parameters of the HEC-HMS model, the CR used in precipitation loss and the RC. Otherwise, all other inputs were the same as used for the HEC-1 analysis. The COL applicant adjusted the value of CR to match the basin runoff found in the ESP SSAR analysis using HEC-1. The COL applicant computed the value of RC using a conversion formula from the HEC-HMS documentation (USACE, 2010b).

The staff checked the applicant-provided HEC-HMS model run used for conversion from HEC-1 to HEC-RAS and confirmed the stillwater PMF elevation of 80.23 m (263.21 ft) NAVD88 at Lake Anna Dam reported in the North Anna 3 COL FSAR. The staff found the stillwater PMF elevation to be consistent with the value reported in the ESP SSAR. The staff also checked the model run with an initial 7.62 cm (3 in or 0.25 ft) rise of the Lake Anna normal pool elevation and found that the HEC-HMS model produced a stillwater PMF elevation of 80.24 m (263.24 ft) NAVD88 at Lake Anna Dam, the same as reported in North Anna 3 COL FSAR Section 2.4.3.

The COL applicant set the CR and RC parameters to 11.055 and 0.72482, respectively. The staff conducted sensitivity analyses of the adjusted parameters. CR values ranging from 1.0 to 100 produced an elevation change from 80.00 m (262.47 ft) NAVD88 to 80.30 m (263.45 ft) NAVD88. RC values ranging from 0.1 to 1.0 produced an elevation range from 79.92 m (262.19 ft) NAVD88 to 80.24 m (263.27 ft) NAVD88. The staff finds that the model sensitivity to these parameters is at most ±0.15 m (±0.5 ft) which is small in comparison to the 7.14 m (23.44 ft) difference between the PMF elevation and the design plant grade elevation.

The ESP SSAR reports a backwater effect at the North Anna 3 site of 0.06 m (0.2 ft). The ESP SSAR also reports the effect of wind wave activity as 0.03 m (0.09 ft) for wind set-up and 0.92 m (3.03 ft) for wave run-up. Because the increase in the stillwater PMF elevation from the ESP SSAR was only 0.01 m (0.03 ft), the staff finds acceptable for the North Anna 3 COL FSAR the backwater and wind wave effects used in the ESP SSAR. The staff computed a final PMF elevation for the North Anna 3 site of 81.25 m (266.56 ft) NAVD88, which agrees with the PMF elevation reported in the North Anna 3 COL FSAR. Accordingly, the staff accepted NAPS ESP VAR 2.4-4 and NAPS ESP VAR 2.4-5.

2.4.3.5 Post Combined License Activities

There are no post COL activities related to this section.

2.4.3.6 Conclusion

The staff reviewed the application and checked the referenced ESP SSAR and staff's ESP FSER. The staff's review confirmed that the applicant has addressed the relevant information, and no outstanding information remains to be addressed in the North Anna 3 COL FSAR related to this section.

In addition, the staff compared the additional information in the COLA to the relevant NRC regulations, the guidance in Section 2.4.3 of NUREG–0800, and NRC RGs. The staff's review concludes that the COL applicant has provided sufficient information to satisfy the requirements of NRC regulations. The staff has determined that the applicant has adequately addressed COL Item NAPS 2.0-14-A as it relates to the PMF on streams and rivers.

As set forth above, the applicant has presented and substantiated information relative to the PMF 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 concluded that the identification and consideration of the PMF 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 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 PMF on streams and rivers. 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 concludes 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 PMF, 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

North Anna 3 COL FSAR Section 2.4.4,"Potential Dam Failures," addresses the need for site-specific information on potential dam failures. The COL applicant addressed the information as follows:

COL Items:

- NAPS COL 2.0-15-A — Potential Dam Failures, COL Applicant to supply site-specific information in accordance with SRP 2.4.4. COL Applicant to demonstrate that failure of existing and potential upstream or downstream water control structures will not cause flooding to exceed 0.3 m (1 ft) below plant grade.

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

- NAPS ESP COL 2.4-6

- NAPS ESP COL 2.4-7

The COL applicant provided updated site-specific information to supplement ESP SSAR Section 2.4.4 to address ESP COL Action Items 2.4-6 and 2.4-7, indicating that the UHS described in ESBWR DCD Section 9.2.5 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 NUREG-1966, the FSER related to ESBWR DCD, and in NUREG-1835, 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 contained in Section 2.4.4 of NUREG-0800 SRP.

The acceptance criteria for the North Anna 3 description of potential dam failures presented in the North Anna 3 COL FSAR, beyond that presented in the ESP SSAR (i.e., NAPS COL Item NAPS COL 2.0-15-A, and NAPS ESP COL Items 2.4-6 and 2.4-7), are based on meeting the following relevant requirements of 10 CFR Part 52 and 10 CFR Part 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 margin for the limited accuracy, quantity, and time in which the historical data have been accumulated.

- 10 CFR 100.20(c), as it relates to the consideration given to the hydrological characteristics of the site.

- 10 CFR 100.23(d), sets forth the criteria to determine the citing factors for plant design bases with respect to seismically induced floods and water waves at the site.

The related acceptance criteria from SRP Section 2.4.4 are as follows:

- Flood Waves from Severe Breaching of an Upstream Dam: To meet the requirements of 10 CFR Part 100 and 10 CFR 100.23(d), estimates of the following characteristics are needed, and should be based on conservative assumptions of hydrometeorological, geological, and seismic characteristics in the drainage area: (a) modes of assumed dam breaches or failures, (b) consideration of flood control reservoirs at full pool level, and (c) conservatism of coincident flow rates and water surface elevations.

- Domino-Type or Cascading Dam Failures: To meet the requirements of 10 CFR Part 100 and 10 CFR 100.23(d), an appropriate configuration of the cascade of dam failures and its potential to produce the largest flood adjacent to the plant site is needed.

- Dynamic Effects on Structures: To meet the requirements of 10 CFR Part 100, an estimate of dynamic effects of flood waves, such as velocities and momentum fluxes, on SSC important to safety is needed.

- Loss of Water Supply Due to Failure of a Downstream Dam: To meet the requirements of 10 CFR Part 100 and 10 CFR 100.23(d), an assessment regarding loss of safety-related water supply to the plant caused by failure of a downstream dam is needed.

- Effects of Sediment Deposition and Erosion: To meet the requirements of 10 CFR Part 100 and 10 CFR 100.23(d), an assessment is needed regarding loss of functionality of safety-related water supply to the plant caused by blockages due to sediment deposition or erosion during the dam failure-induced flood event.

- Failure of Onsite Water Control or Storage Structures: To meet the requirements of 10 CFR Part 100, an assessment is needed regarding the failure of any onsite water control or storage structures that may cause flooding of SSC important to safety.

- Consideration of Other Site-Related Evaluation Criteria: The potential effects of site-related proximity, seismic, and non-seismic information as they relate to flooding due to upstream dam failures and loss of safety-related water supply due to blockages and failures of downstream dam failures adjacent to and on the plant site and site regions are needed to meet the requirements of 10 CFR Part 100.

In addition, the hydrologic characteristics should be consistent with appropriate sections from: RGs 1.27, 1.29, 1.59, as supplemented by best current practices, and RG 1.102.

2.4.4.4 Technical Evaluation

As documented in Section 2.4.4 of NUREG-1966 and Section 2.4.4 of NUREG-1835, the staff reviewed and approved information related to potential dam failures for the certified ESBWR DCD, Revision 10, and Section 2.4.4 of the North Anna ESP SSAR, respectively. The staff reviewed Section 2.4.4 of the North Anna 3 COL FSAR, Revision 9, and checked the referenced ESBWR DCD and the North Anna ESP SSAR to ensure that the combination of the information in the North Anna 3 COL FSAR and the information in the ESBWR DCD and ESP SSAR represent the complete scope of information relating to this review topic.

The staff's review confirms that the information in the application and the information incorporated by reference address the required information related to "Potential Dam Failures."

The elevation of the design plant grade is 88.39 m (290.0 ft) NAVD88, which is 20.86 ft above the maximum flood level at the site resulting from a PMF in Lake Anna's watershed, the simultaneous failure of upstream storage reservoirs, and coincident wave action, as described in the ESP FSER.

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

The 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 in North Anna 3 COL FSAR Section 2.4.4. The staff finds that the additional information was consistent with the information in the ESP SSAR, which has already been accepted in the ESP FSER.

As described in Section 2.4.1 of this SER, the staff determined that no underground reservoirs are included in the design of the ESBWR UHS and no external source of safety-related makeup water is required for the UHS. Because the predicted flood elevation from dam failure was well below the design plant grade for North Anna 3 and the UHS does not depend on Lake Anna, the staff concludes that dam failure would not affect the North Anna 3 UHS.

2.4.4.5 Post Combined License Activities

There are no post COL activities related to this section.

2.4.4.6 Conclusion

The staff reviewed the COLA and checked the referenced ESP SSAR and staff's ESP FSER. The staff's review confirmed that the COL applicant has addressed the relevant information and no outstanding information remains to be addressed in the North Anna 3 COL FSAR related to this section.

In addition, the staff compared the additional information in the COLA to the relevant NRC regulations, the guidance in Section 2.4.4 of NUREG–0800, and NRC RGs. The staff's review concludes that the COL applicant has provided sufficient information to satisfy the requirements of NRC regulations. The staff has determined that the applicant has adequately addressed COL Item NAPS 2.0-15-A as it relates to potential dam failure.

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 characteristics 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; and, (7) any additional information requirements prescribed in the “Contents of Application” sections of the applicable subparts to 10 CFR Part 52.

The COL applicant incorporated by reference ESP SSAR Section 2.4.5 to address DCD COL Item 2.0-16-A, related to probable maximum surge and seiche flooding. The staff reviewed the COLA and checked the referenced ESP SSAR and the staff’s ESP FSER. The staff confirmed that no outstanding information remains to be addressed in the North Anna 3 COL FSAR related to this section.

2.4.6 Probable Maximum Tsunami Hazards

The probable maximum tsunami (PMT) 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) 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; and, (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.

The COL applicant incorporated by reference ESP SSAR Section 2.4.6 to address DCD COL Item 2.0-17-A related to PMT flooding. The staff reviewed the COLA and checked the referenced ESP SSAR and the staff’s ESP FSER. The staff confirmed that no outstanding information remains to be addressed in the North Anna 3 COL FSAR related to this section.

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; and, (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

The North Anna 3 COL FSAR, Revision 9, Section 2.4.7, “Ice Effects,” addresses site-specific ice effects. The COL applicant addressed the information as follows:

COL Item:

- NAPS COL 2.0-18-A — Ice Effects, COL Applicant to supply site-specific information in accordance with SRP 2.4.7

The COL applicant incorporated by reference ESP SSAR Section 2.4.7 to address DCD COL Item 2.0-18-A and provided updated site-specific information to supplement ESP SSAR Section 2.4.7. The COL applicant described the potential for ice formation at the North Anna 3 station water intake building and at the intake trash racks or intake screens. The COL applicant stated that the emergency cooling water for North Anna 3 is provided from the UHS, which is not affected by ice conditions, and that the normal cooling systems for North Anna 3 are not safety-related systems. The COL applicant further clarified that the water intake and associated pumps for North Anna 3 do not perform safety-related functions and that the makeup water supply from the North Anna 3 intake is not safety-related.

2.4.7.3 Regulatory Basis

The regulatory basis of the information incorporated by reference is addressed in NUREG-1966, the FSER related to ESBWR DCD, and in NUREG-1835, 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 contained in Section 2.4.7 of NUREG-0800 SRP.

The acceptance criteria for the North Anna 3 ice effects presented in the North Anna 3 COL FSAR, beyond that presented in the ESP SSAR (i.e., NAPS COL Item 2.0-18-A), are based on meeting the following relevant requirements of 10 CFR Part 52 and 10 CFR Part 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 margin for the limited accuracy, quantity, and time in which the historical data have been accumulated.

- 10 CFR 100.20(c), as it relates to the consideration given to the hydrological characteristics of the site.

The related acceptance criteria from SRP Section 2.4.7 are as follows:

- Historical Ice Accumulation: The application should include a complete history of ice formation at and in the vicinity of the site.

- High and Low Water Levels: The application should include estimates of water levels resulting from potential ice flooding or low flows.

- Ice Sheet Formation: The application should include estimates of the most severe ice sheet formation in water storage reservoirs.

- Ice-induced Forces and Blockages: The application should provide estimates of the most severe ice-induced forces on safety-related SSC.

- Consideration of Other Site-Related Evaluation Criteria: The application should demonstrate that the potential effects of site-related proximity, seismic, and nonseismic information as they relate to worst-case icing scenarios adjacent to and on the plant site and site regions are appropriately take into account.

In addition, the hydrologic characteristics should be consistent with appropriate sections from: RGs 1.27, 1.29, 1.59, as supplemented by best current practices, and RG 1.102.

2.4.7.4 Technical Evaluation

As documented in Section 2.4.7 of NUREG-1966 and Section 2.4.7 of NUREG-1835, the staff reviewed and approved information related to ice effects for the certified ESBWR DCD, Revision 10, and Section 2.4.7 of the North Anna ESP SSAR, respectively. The staff reviewed Section 2.4.7 of the North Anna 3 COL FSAR, Revision 9, and checked the referenced ESBWR DCD and the North Anna ESP SSAR to ensure that the combination of the information in the North Anna 3 COL FSAR and the information in the ESBWR DCD and ESP SSAR represent the complete scope of information relating to this review topic.

The staff's review confirms that the information in the application and the information incorporated by reference address the required information related to "Ice Effects."

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

The applicant incorporated by reference ESP SSAR Section 2.4.7 to address DCD COL Item 2.0-18-A and provided updated site-specific information to supplement ESP SSAR Section 2.4.7, related to ice effects. As stated in Section 2.4.1 of this SER, the staff confirmed that neither Lake Anna nor the WHTF will be used for safety-related withdrawals, and that the

UHS does not require an external source of safety-related makeup water. Therefore, the staff concludes that no safety-related systems or water supplies are affected by ice.

The staff also reviewed the additional information concerning surface ice and roof loads provided in the North Anna 3 COL FSAR, which states that the snow depths and winter PMP was discussed in North Anna 3 COL FSAR Section 2.3.1.3.4. The staff determined that the additional information was consistent with the information in the ESP SSAR, which has already been accepted in the ESP FSER (NUREG-1835).

2.4.7.5 Post Combined License Activities

There are no post COL activities related to this section.

2.4.7.6 Conclusion

The staff reviewed the application and checked the referenced North Anna ESP SSAR and staff's ESP FSER (NUREG-1835). 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 North Anna 3 COL FSAR related to this section.

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 FSER. 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 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

North Anna 3 COL FSAR Section 2.4.8, "Cooling Water Canals and Reservoirs," addresses the need for site-specific information on the use of cooling water canals and reservoirs. The COL applicant addressed the information as follows:

COL Items:

- NAPS COL 2.0-19-A — Cooling Water Canals and Reservoirs, COL Applicant to supply site-specific information in accordance with SRP 2.4.8

The COL applicant incorporated by reference ESP SSAR Section 2.4.8 to address ESBWR DCD COL Item 2.0-19-A.

- NAPS ESP COL 2.4-8

The COL applicant provided updated site-specific information to supplement ESP SSAR Section 2.4.8 to confirm that the North Anna Reservoir and WHTF, which comprise Lake Anna, are not used for safety-related water withdrawals for North Anna 3. The emergency cooling water for North Anna 3 comes from the UHS, as described in ESBWR DCD Section 9.2.5 and North Anna 3 COL FSAR Section 9.2.5.

2.4.8.3 Regulatory Basis

The regulatory basis of the information incorporated by reference is addressed in NUREG-1966, the FSER related to ESBWR DCD, and in NUREG-1835, the FSER related to the North Anna ESP. In addition, the guidance relevant to the Commission's regulations related to cooling water canals and reservoirs, and the associated acceptance criteria, are contained in Section 2.4.8 of NUREG-0800 SRP.

The acceptance criteria for the North Anna 3 cooling water canals and reservoirs presented in the North Anna 3 COL FSAR, beyond that presented in the ESP SSAR (i.e., NAPS COL Item 2.0-19-A and NAPS ESP COL Item 2.4-8), 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 margin for the limited accuracy, quantity, and time in which the historical data have been accumulated.

- 10 CFR 100.20(c), as it relates to the consideration given to the hydrological characteristics of the site.

- 10 CFR 100.23(d) sets forth the criteria to determine the citing factors for plant design bases with respect to seismically induced floods and water waves the site.

The related acceptance criteria from SRP Section 2.4.8 are as follows:

- Hydraulic Design Bases for Protection of Structures: To meet the requirements of 10 CFR Part 100, a complete description of the hydraulic design bases for protection of structures is needed.

- Hydraulic Design Bases of Canals: To meet the requirements of 10 CFR Part 100, a complete description of the hydraulic design bases related to the capacity, protection against wind waves, erosion, sedimentation, and freeboard, and the ability to withstand a PMF, surges, etc., is needed.

- Hydraulic Design Bases of Reservoirs: To meet the requirements of 10 CFR Part 100, a complete description of the design bases of safety-related reservoirs related to their 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 is needed.

- Consideration of Other Site-Related Evaluation Criteria: To meet the requirements of 10 CFR Part 100, a complete description of the potential effects of site-related proximity, seismic, and non-seismic information on the postulated design bases of safety-related canals and reservoirs is needed.

In addition, the hydrologic characteristics should be consistent with appropriate sections from RGs 1.27, 1.29, 1.59, as supplemented by best current practices, RG 1.102, and RG 1.125, "Physical Models for Design and Operation of Hydraulic Structures and Systems for Nuclear Power Plants."

2.4.8.4 Technical Evaluation

As documented in Section 2.4.8 of NUREG-1966 and Section 2.4.8 of NUREG-1835, the staff reviewed and approved information related to cooling water canals and reservoirs for the certified ESBWR DCD, Revision 10, and Section 2.4.8 of the North Anna ESP SSAR, respectively. The staff reviewed Section 2.4.8 of the North Anna 3 COL FSAR, Revision 9, and checked the referenced ESBWR DCD and the North Anna ESP SSAR to ensure that the combination of the information in the North Anna 3 COL FSAR and the information in the ESBWR DCD and ESP SSAR that represent the complete scope of information relating to this review topic.

The staff's review confirms that the information in the application and the information incorporated by reference address the required information related to "Cooling Water Canals and Reservoirs."

The staff's technical review of this application was limited to reviewing the supplemental information pertaining to NAPS COL 2.0-19-A and ESP COL Action Item 2.4-8, as addressed below:

The COL applicant incorporated by reference ESP SSAR Section 2.4.8 to address ESBWR DCD COL Item 2.0-19-A, related to cooling water canals and reservoirs. The staff determined that the additional information is consistent with the information provided in the ESP SSAR, which has already been accepted in the ESP FSER (NUREG-1835).

As described in Section 2.4.1 of this SER, the staff confirmed that the North Anna Reservoir and WHTF are not used for safety-related water withdrawals for North Anna 3.

2.4.8.5 Post Combined License Activities

There are no post COL activities related to this section.

2.4.8.6 Conclusion

The staff reviewed the COLA and checked the referenced ESP SSAR and the staff's ESP FSER. The staff's review confirmed that the COL applicant has addressed the required information and no outstanding information remains to be addressed in the COL FSAR related to this section.

In addition, the staff compared the additional information in the COLA to the relevant NRC regulations, the guidance in Section 2.4.8 of NUREG–0800, and NRC RGs. The staff's review concludes that the COL applicant has provided sufficient information to satisfy the requirements of NRC regulations. The staff has determined that the COL applicant has adequately addressed COL Item NAPS 2.0-19-A as it relates to cooling water canals and reservoirs.

As set forth above, the COL applicant has presented and substantiated information relative to the design bases of canals and reservoirs important to the design and citing of this plant. The staff has reviewed the available information provided and for the reasons given above, concludes that the identification and consideration of the design bases of canals and reservoirs is acceptable and meets the requirements of 10 CFR 52.79(a)(1)(iii), 10 CFR 100.20(c), and 10 CFR 100.23(d), with respect to determining the acceptability of the site.

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; and, (8) any additional information requirement prescribed in the "Contents of Application" sections of the applicable subparts to 10 CFR Part 52.

The COL applicant incorporated by reference ESP SSAR Section 2.4.9 with no supplement or departure to address DCD COL Item 2.0-20-A, related to channel diversions. The staff reviewed the COLA and checked the referenced ESP SSAR and the staff's ESP FSER. The staff confirmed that no outstanding information remains to be addressed in the North Anna 3 COL FSAR related to this section.

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

The North Anna 3 COL FSAR Section 2.4.10, "Flooding Protection Requirements," address the needs for site-specific information on flooding protection. The COL applicant addressed the information as follows:

<u>*COL Items:*</u>

• NAPS COL 2.0-21-A	Flooding Protection Requirements, COL Applicant to supply site-specific information in accordance with SRP 2.4.10

The COL applicant incorporated by reference ESP SSAR Section 2.4.10 to address ESBWR DCD COL Item 2.0-21-A and provided updated site-specific information to supplement ESP SSAR Section 2.4.10. The COL applicant described the results of the local PMP drainage analysis presented in North Anna 3 COL FSAR Section 2.4.2.3. The COL applicant stated that the maximum water-surface elevation within drainage ditches in the powerblock area would be 87.90 m (288.4 ft) NAVD88 or 0.49 m (1.6 ft) below the plant grade of 88.39 m (290.0 ft) NAVD88. In response to staff's RAI 02.04.02-15 (ADAMS Accession Nos. ML15022A199 and ML16229A451), the COL applicant stated that an analysis of sheet flow resulting from local intense precipitation between buildings in the powerblock area indicated that water levels would exceed the floor elevations of safety-related SSCs at three entrance locations. To prevent sheet flow from entering the RB and CB, the COL applicant committed to installing curbs at the entrances or to ensure that the door thresholds would be above the maximum sheet-flow elevations. The COL applicant proposed revisions to North Anna 3 COL FSAR Section 2.4.10 to describe flood protection measures. The staff verified that the appropriate text changes are incorporated in the FSAR, Revision 9, and, therefore, Confirmatory Item 2.4.10-1 from the staff's advanced SER for North Anna 3 is resolved and closed.

- NAPS ESP COL 2.4-9 Slope Embankment Protection

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

2.4.10.3 Regulatory Basis

The regulatory basis of the information incorporated by reference is addressed in NUREG-1966, the FSER related to ESBWR DCD, and in NUREG-1835 the FSER related to the North Anna 3 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 SRP.

The acceptance criteria for the North Anna 3 flooding protection requirements presented in the North Anna 3 COL FSAR, beyond that presented in the ESP SSAR (i.e., NAPS COL Item NAPS COL 2.0-21-A and NAPS ESP COL Item 2.4-9), are based on meeting the following relevant requirements of 10 CFR Part 52 and 10 CFR Part 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 margin for the limited accuracy, quantity, and time in which the historical data have been accumulated.

- 10 CFR 100.20(c), as it relates to the consideration given to the hydrological characteristics of the site.

- 10 CFR 100.23(d) sets forth the criteria to determine the citing factors for plant design bases with respect to seismically induced floods and water waves the site.

The related acceptance criteria from SRP Section 2.4.10 are as follows:

- Safety-related Facilities Exposed to Flooding: To meet the requirements of 10 CFR Part 100, identification of all SSC exposed to flooding is needed.

- Type of Flood Protection: To meet the requirements of 10 CFR Part 100, an evaluation of the applicant's proposed flood protection measures is needed.

- Emergency Procedures: To meet the requirements of 10 CFR Part 100, a listing of proposed emergency procedures is needed.

- Consideration of Other Site-Related Evaluation Criteria: To meet the requirements of 10 CFR Part 100, an assessment regarding the potential effects of site-related proximity, seismic, and non-seismic information on the postulated flooding protection is needed.

In addition, the hydrologic characteristics should be consistent with appropriate sections from: RGs 1.29, 1.59, as supplemented by best current practices, and RG 1.102.

2.4.10.4 Technical Evaluation

As documented in Section 2.4.10 of NUREG-1966 and Section 2.4.10 of NUREG-1835, the staff reviewed and approved information related to flooding protection requirements for the certified ESBWR DCD, Revision 10, and Section 2.4.10 of the North Anna ESP SSAR, respectively. The staff reviewed Section 2.4.10 of the North Anna 3 COL FSAR, Revision 9, and checked the referenced ESBWR DCD and the North Anna ESP SSAR to ensure that the combination of the information in the North Anna 3 COL FSAR and the information in the ESBWR DCD and ESP SSAR represent the complete scope of information relating to this review topic. The staff's review confirms that the information in the application and the information incorporated by reference address the required information related to "Flooding Protection Requirements."

The elevation of the design plant grade for North Anna 3 is 88.39 m (290.0 ft) NAVD88. This elevation is approximately 6.10 m (20 ft) above the maximum flood level at the site resulting from a PMF in Lake Anna's watershed, the simultaneous failure of upstream storage reservoirs, and coincident wave action (82.30 m [270 ft] NAVD88).

The staff's technical review in this section was limited to the supplemental information pertaining to ESBWR DCD COL Item 2.0-21-A and ESP COL Action Item 2.4-9, and to the flooding protection described in the response to RAI 02.04.02-15, as addressed below.

The staff reviewed the resolution to the ESBWR 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 North Anna 3 COL FSAR Section 2.4.10. As described in Section 2.4.2 of this SER, the COL applicant stated in the response to RAI 02.04.02-15 (ADAMS Accession Nos. ML15022A199 and ML16229A451), that the maximum flood elevation resulting from local intense precipitation exceeds the entrance elevations to some safety-related structures. The COL applicant will take action to provide flood protection measures at the following locations (the floor elevation at all three locations is 88.39 m [290.0 ft] NAVD88):

- CB south stairway emergency exit, maximum water surface elevation of 88.48 m (290.3 ft) NAVD88 (Area 2);

- CB north stairway emergency exit, maximum water surface elevation of 88.51 m (290.4 ft) NAVD88 (Area 3); and

- RB north wall equipment access door, maximum water surface elevation of 88.45 m (290.2 ft) NAVD88 (Area 4).

The COL applicant stated that the flood protection would be provided by installing curbs at the door entrances or by ensuring that door thresholds are above the maximum water surface elevations. The staff reviewed the COL applicant's response to RAI 02.04.02-15 (ADAMS Accession Nos. ML15022A199 and ML16229A451), and concluded that the proposed measures provide the required flood protection. The staff verified that the appropriate text changes are incorporated into the FSAR, Revision 9, and, therefore, Confirmatory Item 2.4.10-1 from the staff's advanced SER for North Anna 3 is resolved and closed.

As described in Section 2.4.1 of this SER, the UHS design for the ESBWR relies on an internal makeup water supply during the initial 7 days following an accident and the makeup water source beyond 7 days is not required to be safety-related. In addition, the staff confirmed that

Lake Anna will not be used for safety-related UHS withdrawals. Accordingly, the staff determined that the intake structure is not a safety-related structure and is not credited for safety-related functions. However, the structure has protection features that the applicant addressed in ESP COL Action Item 2.4-9 as applicable.

2.4.10.5 Post Combined License Activities

There are no post COL activities related to this section.

2.4.10.6 Conclusion

The staff reviewed the COLA and checked the referenced North Anna ESP SSAR and staff's ESP FSER. The staff's review confirmed that the COL applicant has addressed the required information and no outstanding information remains to be addressed in the North Anna 3 COL FSAR related to this section.

In addition, the staff compared the additional information in the COLA to the relevant NRC regulations, the guidance in Section 2.4.10 of NUREG–0800, and NRC RGs. The staff's review concludes that the applicant has provided sufficient information to satisfy the requirements of NRC regulations. The staff has determined that the applicant has adequately addressed COL Item NAPS 2.0-21-A as it relates to flooding protection requirements.

As set forth above, the applicant has presented and substantiated information relative to the flood protection measures important to the design and siting of this plant. The staff has reviewed the available information provided and for the reasons given above, concludes that the identification and consideration of the flood protection measures is acceptable and meets the requirements of 10 CFR 52.79(a)(1)(iii), 100.20(c), and 100.23(d), with respect to determining the acceptability of the site.

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 North Anna 3 COL FSAR 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

The North Anna 3 COL FSAR Section 2.4.11, "Low Water Considerations," addresses the impacts of low water on site water supply. The COL applicant addressed the information as follows:

<u>COL Items:</u>

- NAPS COL 2.0-22-A — Cooling Water Supply, COL Applicant to supply site-specific information in accordance with SRP 2.4.11.

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

- NAPS ESP COL 2.4-10

The COL applicant provided updated site-specific information to supplement ESP SSAR Sections 2.4.11.5, "Plant Requirements," and 2.4.11.6, "Heat Sink Dependability Requirements," to address ESP COL Action Item 2.4-10.

<u>Early Site Permit Variances:</u>

- NAPS ESP VAR 2.4-4

The COL applicant provided updated site-specific information to supplement ESP SSAR Sections 2.4.11.1, "Low Flow in Streams," which states that the operating level of Lake Anna will be 76.01 m (249.39 ft) NAVD88 with the addition of Unit 3. In addition, ESP SSAR Section 2.4.11.4, "Future Controls," provides supplemental information on the water budget and low water levels with the operation of North Anna 3.

2.4.11.3 Regulatory Basis

The regulatory basis of the information incorporated by reference is addressed in NUREG-1966, the FSER related to ESBWR DCD, and in NUREG-1835, 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 contained in Section 2.4.11 of NUREG-0800 SRP.

The acceptance criteria for the North Anna 3 low water consideration requirements is presented in the North Anna 3 COL FSAR, beyond that presented in the ESP SSAR (i.e., NAPS COL Item NAPS COL 2.0-22-A, NAPS ESP VAR 2.4-4 and NAPS ESP COL Item 2.4-10), are based on meeting the following relevant requirements of 10 CFR Part 52 and 10 CFR Part 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 margin for the limited accuracy, quantity, and time in which the historical data have been accumulated.

- 10 CFR 100.20(c), as it relates to the consideration given to the hydrological characteristics of the site.

- 10 CFR 100.23(d) sets forth the criteria to determine the citing factors for plant design bases with respect to seismically induced floods and water waves the site.

The related acceptance criteria from SRP Section 2.4.11 are as follows:

- Low Water from Drought: To meet the requirements of 10 CFR Part 100, a complete history of low water conditions at and in the vicinity of the site is needed.

- Low Water from Other Phenomena: To meet the requirements of 10 CFR Part 100, a complete history of low water conditions, caused by phenomena other than a drought, at and in the vicinity of the site is needed.

- Effect of Low Water on Safety-Related Water Supply: To meet the requirements of 10 CFR Part 100, a thorough description of all safety-related water supply requirements and the effects of the most severe low water event reasonably possible at or in the vicinity of the site is needed.

- Water Use Limits: To meet the requirements of 10 CFR Part 100, a thorough description of water use and discharge limitations (both physical and legal), already in effect or under discussion by responsible Federal, regional, State, or local authorities, that may affect water supply at the plant that have been considered and are substantiated by reference to reports of the appropriate agencies is needed.

- Consideration of Other Site-Related Evaluation Criteria: To meet the requirements of 10 CFR Part 100, the applicant should provide an assessment of the potential effects of site-related proximity, seismic, and non-seismic information on the postulated worst-case low-flow scenario for the proposed plant site

2.4.11.4 Technical Evaluation

As documented in Section 2.4.11 of NUREG-1966 and Section 2.4.11 of NUREG-1835, the staff reviewed and approved information related to low water considerations for the certified ESBWR DCD, Revision 10, and Section 2.4.11 of the North Anna ESP SSAR, respectively. The staff reviewed Section 2.4.11 of the North Anna 3 COL FSAR, Revision 9, and checked the referenced ESBWR DCD and the North Anna ESP SSAR to ensure that the combination of the information in the North Anna 3 COL FSAR and the information in the ESBWR DCD and ESP SSAR represent the complete scope of information relating to this review topic.

The staff's review confirms that the information in the application and the information incorporated by reference address the required information related to "Low Water Considerations."

The staff's technical review of this application is limited to the supplemental information pertaining to DCD COL 2.0-22-A, NAPS ESP COL Action Item 2.4-10, and NAPS ESP VAR 2.4-4 as addressed below.

<u>*COL Items:*</u>

- NAPS COL 2.0-22-A — Cooling Water Supply, COL Applicant to supply site-specific information in accordance with SRP 2.4.11.

The staff reviewed the resolution to ESBWR 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 North Anna 3 COL FSAR Section 2.4.11. The applicant provided supplemental information in North Anna 3 COL FSAR Section 2.4.11.4, in which the water budget for Lake Anna was updated using the ESBWR operational cooling requirements. The staff finds that the additional information is consistent with the information in the ESP SSAR as accepted in the ESP FSER.

- NAPS ESP COL 2.4-10

The COL applicant indicated that the North Anna 3 CWS has two modes of operation: energy conservation (when Lake Anna water level is at or above an elevation of 75.94 m (249.14 ft) NAVD88 at the North Anna Dam), and maximum water conservation (when the water level is below an elevation of 75.94 m (249.14 ft) NAVD88 and is not restored within a reasonable period of time). The COL applicant stated that North Anna 3 will be required to shut down when the Lake Anna water elevation decreases below 73.50 m (241.14 ft) NAVD88. The COL applicant stated that the North Anna 3 UHS does not rely on Lake Anna as a safety-related water source and staff determined that ESP COL Action Item 2.4-10 was addressed by the applicant as required.

Early Site Permit Variances:

- NAPS ESP VAR 2.4-4

As described in Section 2.4.1 of this SER, the staff confirmed that neither Lake Anna nor the WHTF will be used for safety-related withdrawals, and that the UHS does not require an external source of safety-related makeup water. Based on the UHS cooling system design specified in North Anna 3 COL FSAR Section 9.2.5, the staff accepted NAP ESP VAR 2.4-4.

2.4.11.5 Post Combined License Activities

There are no post COL activities related to this section.

2.4.11.6 Conclusion

The staff reviewed the application and checked the referenced ESP SSAR and staff's ESP FSER (NUREG-1835). The staff's review confirmed that the applicant has addressed the required information, and no outstanding information remains to be addressed in the North Anna 3 COL FSAR related to this section.

In addition, the staff compared the additional information in the COLA to the relevant NRC regulations, the guidance in Section 2.4.11 of NUREG–0800, and NRC RGs. The staff's review concludes that the COL applicant has provided sufficient information to satisfy the requirements of NRC regulations. The staff has determined that the applicant has adequately addressed COL Item NAPS 2.0-22-A as it relates to low water considerations.

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 and for the reasons given above, concludes that the identification and consideration of the potential for low water conditions are acceptable and meet the requirements of 10 CFR 52.79(a)(1)(iii), 10 CFR 100.20(c), and 10 CFR 100.23(d), with respect to determining the acceptability of the site.

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 characteristics documented in the ESP FSER. 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. One of the key objectives of groundwater investigations and monitoring at this site is to evaluate the maximum groundwater-surface elevation at the site, which is used in Section 2.5 of this report to determine the effects of groundwater on the stability of plant foundations and slopes. The evaluation is performed to ensure that the maximum groundwater-surface elevation remains less than the ESBWR DCD site parameter value of 0.61 m (2 ft) below plant grade. Other significant objectives are to examine whether groundwater provides any safety-related water supply, to determine whether dewatering systems are required to maintain groundwater-surface elevations below the required elevation, and to describe subsurface pathways for potential groundwater contaminants.

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-surface elevations beneath the site, seasonal and climatic fluctuations, monitoring and protection requirements, and man-made changes that have the potential to cause long-term changes in local groundwater regime; (2) effects of groundwater-surface elevations and other hydrodynamic effects of groundwater on design bases of plant foundations and those of 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

The North Anna 3 COL FSAR Section 2.4.12, "Groundwater," incorporates by reference ESBWR DCD Tier 2 Chapter 2, "Site Characteristics." This section of the North Anna 3 COL FSAR addresses the groundwater in terms of effects on structures and water supply. All elevations in this SER here and elsewhere are referenced to the NAVD88.

In addition, in North Anna 3 COL FSAR Section 2.4.12, the COL applicant addressed the following COL items:

COL Item:

- COL Item 2.0-12-A — Hydraulic Description Maximum Ground Water Level, per ESBWR DCD Tier 2, Table 2.0-1, 0.61 m (2 ft) below plant grade.

- COL Item 2.0-23-A — Groundwater, COL applicant to supply site-specific information in accordance with SRP 2.4.12.

To address these COL Items, the COL applicant incorporated by reference ESP SSAR Section 2.4.12. The COL applicant provided updated site-specific information to supplement or replace ESP SSAR sections as follows:

- The COL applicant described the local hydrogeology of the site, including the saprolite and bedrock hydrogeologic units, groundwater level measurements, hydraulic gradients, groundwater flow directions, hydraulic conductivity data, porosity data, and groundwater velocity. The COL applicant stated that the saprolite and bedrock are hydrologically connected. The COL applicant estimated a groundwater velocity of 0.11 m/d (0.35 ft/d) and a groundwater travel time to the Lake Anna shoreline of 7.8 yr. from the radwaste building and 6 yr. from the condensate storage tank (CST);

- The COL applicant stated that groundwater from six wells is currently used to supply water for North Anna Units 1 and 2, the North Anna Nuclear Information Center (NANIC), the security training building, and the Meteorology/Environmental Laboratory. The COL applicant provided well capacities and monthly usage data for the wells serving Units 1 and 2, and stated that groundwater will not be used for safety-related purposes for North Anna 3;

- The COL applicant described the groundwater monitoring for the ESP and COL subsurface investigations, and stated that groundwater levels will be monitored monthly during any dewatering activities, quarterly for two years after completion of construction, and semi-annually or annually during operation; and

- The COL applicant described the site characteristics, including the maximum operational groundwater-surface elevation, for groundwater-induced hydrostatic loadings on subsurface portions of safety-related SSCs. The COL applicant developed and applied a groundwater model of the North Anna 3 site and the surrounding area to evaluate post-construction groundwater-surface elevations. The COL applicant stated that the maximum groundwater elevation around seismic Category 1 structures was 86.1 m (282.6 ft), or 2.3 m (7.4 ft) below the North Anna 3 plant grade of 88.39 m (290 ft). The COL applicant stated that, based on the groundwater design bases described in ESBWR DCD Section 3.4 and comparison with the ESBWR DCD site parameter value for maximum groundwater level, a permanent dewatering system is not required.

Early Site Permit Variances

The following variances from the ESP SSAR are discussed in Section 2, “Variances,” of Part 7 to the COLA:

- NAPS ESP VAR 2.0-2 Hydraulic Conductivity

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

- NAPS ESP VAR 2.0-3 Hydraulic Gradient

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

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

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

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

The COL 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.

- NAPS ESP VAR 2.4-3 Well Reference Point Elevation

The COL applicant requested VAR 2.4-3 to use revised information for the reference point elevation of observation well WP-3 and provided FSAR Table 2.4-15R to correct groundwater level information for this well originally appearing in ESP SSAR Table 2.4-15.

2.4.12.3 Regulatory Basis

The regulatory basis of the information incorporated by reference is addressed in NUREG-1966, the FSER related to ESBWR DCD, and in NUREG-1835 the FSER related to the North Anna ESP. In addition, the guidance relevant to the Commission's regulations related to ground water considerations, and the associated acceptance criteria, are contained in Section 2.4.12 of NUREG-0800 SRP.

The acceptance criteria for the North Anna 3 ground water consideration requirements presented in the North Anna 3 COL FSAR, beyond that presented in the ESP SSAR (i.e., NAPS COL Item NAPS COL 2.0-12-A, 2.0-23-A, NAPS ESP VAR 2.0-2, 2.0-3, 2.4-1, 2.4-2, and 2.4-3), are based on meeting the following relevant requirements of 10 CFR) Part 52 and 10 CFR Part 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 margin for the limited accuracy, quantity, and time in which the historical data have been accumulated.

- 10 CFR 100.20(c), as it relates to the consideration given to the hydrological characteristics of the site.

- 10 CFR 100.23(d) sets forth the criteria to determine the citing factors for plant design bases with respect to seismically induced floods and water waves the site.

The related acceptance criteria from SRP Section 2.4.12 are as follows:

- Local and Regional Groundwater Characteristics and Use: To meet the requirements of 10 CFR 50.55a, "Codes and Standards," 10 CFR 100.20(c)(3), 10 CFR 100.23(d), and 10 CFR 100.20(c), a complete description of regional and local groundwater aquifers, sources, and sinks, local and regional groundwater use, present and known and likely future withdrawals, regional flow rates, travel time, gradients, and velocities, subsurface properties that affect movement of contaminants in the groundwater, groundwater levels including their seasonal and climatic fluctuations, groundwater monitoring and protection requirements, and any manmade changes with a potential to affect regional groundwater characteristics over a long period of time is needed.

- Effects on Plant Foundations and other Safety-Related SSCs: To meet the requirements of 10 CFR 50.55a, 100.20(c)(3), 100.23(d), and 100.20(c), a complete description of the effects of groundwater levels and other hydrodynamic effects on the design bases of plant foundations and other SSC important to safety is needed.

- Reliability of Groundwater Resources and Systems Used for Safety-Related Purposes: To meet the requirements of 10 CFR 50.55a, 100.20(c)(3), 100.23(d), and 100.20(c), a complete description of all SSC important to safety that depend on groundwater is needed.

- Reliability of Dewatering Systems: To meet the requirements of 10 CFR 50.55a, 100.20(c)(3), 100.23(d), and 100.20(c), a complete description of the site dewatering system, including its reliability to maintain the groundwater conditions within the groundwater design bases of SSC important to safety is needed.

2.4.12.4 Technical Evaluation

As documented in Section 2.4.12 of NUREG-1966 and Section 2.4.12 of NUREG-1835, the staff reviewed and approved information related to groundwater for the certified ESBWR DCD, Revision 10, and Section 2.4.12 of the North Anna ESP SSAR, respectively. The staff reviewed Section 2.4.12 of the North Anna 3 COL FSAR, Revision 9, and checked the referenced ESBWR DCD and the North Anna ESP SSAR to ensure that the combination of the information in the North Anna 3 COL FSAR and the information in the ESBWR DCD and ESP SSAR represent the complete scope of information relating to this review topic.

The staff's review confirms that the information in the application and the information incorporated by reference address the required information related to "Groundwater."

The staff's technical review of this application was limited to reviewing the supplemental information pertaining to COL Items 2.0-12-A and 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, NAPS ESP VAR 2.4-2, and NAPS ESP VAR 2.4-3 as addressed below.

The staff's discussion of groundwater characteristics is organized into technical areas as described below. Variances are described where appropriate within these areas.

General Hydrogeological Characteristics of the Site

Information Submitted by COL Applicant:

The COL applicant's description of the regional hydrogeology and groundwater conditions was described in ESP SSAR Section 2.4.12 and is incorporated by reference into the North Anna 3 COL FSAR with no supplements or variances.

The COL applicant's description of the site hydrogeology and groundwater conditions was supplemented based on the results of a North Anna 3 subsurface field investigation conducted from August to November of 2006 and two supplemental investigations conducted from September to October of 2009, as described in North Anna 3 COL FSAR Section 2.5.4.2.3. This investigation included 93 exploratory borings and the installation of seven observation wells.

The North Anna 3 COL FSAR used the same classification of subsurface materials as in the ESP SSAR. The COL applicant classified subsurface materials 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. The COL applicant stated that the borings described in the ESP SSAR and the North Anna 3 COL FSAR penetrated saprolite with a maximum thickness of 34.7 m (114 ft) and a median thickness of 11.3 m (37 ft). The COL applicant stated that groundwater at the site occurs in the saprolite and in the fractures of the bedrock. Of the seven wells installed as part of the North Anna 3 subsurface field investigation, the COL applicant stated that four were completed in rock and three were completed in soil/weathered rock. The COL applicant stated that the bedrock and saprolite are hydraulically connected, that groundwater heads observed in well pairs completed at different elevations were nearly equal, that the water table at the site reflects the ground surface topography, and that the groundwater flow at the site is toward areas of lower ground surface elevation.

The Staff's Technical Evaluation:

The staff reviewed the supplemental information provided in the North Anna 3 COL 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.

The staff evaluated the site groundwater head measurements provided in North Anna 3 COL FSAR Table 2.4-15R and illustrated in North Anna 3 COL FSAR Figure 2.4-205 and North Anna 3 COL FSAR Figures 2.4-207 through 2.4-214. The staff determined that the data obtained in 2006 and 2007 were consistent with earlier measurements. Groundwater flow direction from the North Anna 3 reactor area is generally to the northeast toward Lake Anna. Three of the wells installed as part of the North Anna 3 subsurface field investigation were located adjacent to and deeper than existing wells, providing a total of four well pairs that the staff used to evaluate vertical groundwater head gradients at the site. The staff determined that vertical groundwater head gradients were small and upward for three of the well pairs, but were higher and downward for the well pair located near the North Anna 3 intake (observation wells OW-848 and OW-950). Based on the observed vertical gradients in the well pairs, the staff concluded that the shallow bedrock and saprolite units are hydraulically connected, with vertical gradients between the units generally small, but significant at some locations.

Plant Groundwater Use

Information Submitted by COL Applicant:

The COL applicant stated that any groundwater required will not be used for safety-related functions at North Anna 3 (North Anna 3 COL FSAR Section 2.4.12.1.3, "Plant Groundwater Use").

The Staff's Technical Evaluation:

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 North Anna 3 COL FSAR.

Hydraulic Conductivity (NAPS ESP VAR 2.0-2)

Information Submitted by COL Applicant:

The COL applicant conducted slug tests in four of the seven wells installed as part of the North Anna 3 subsurface field investigation (three soil/weathered rock wells and one bedrock well) to supplement the existing data used to estimate hydraulic conductivities in the saprolite and the shallow bedrock. The COL applicant conducted packer tests in a borehole adjacent to one of the bedrock wells to estimate the hydraulic conductivity of the shallow bedrock. Using these supplemental data, the COL applicant estimated hydraulic conductivity for the saprolite of 0.076 to 3.017 m/d (0.25 to 9.9 ft/d) with a geometric mean of 0.53 m/d (1.74 ft/d) (as compared to a range of 0.06 to 1.04 m/d and a geometric mean of 0.40 m/d from the ESP SSAR). The COL applicant estimated hydraulic conductivity for the shallow bedrock of 0.152 to 1.920 m/d (0.5 to 6.3 ft/d) with a geometric mean of 0.625 m/d (2.05 ft/d) (compared to a range of 0.61 to 0.91 m/d from the ESP SSAR).

The maximum hydraulic conductivity of 3.0 m/d in North Anna 3 COL 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 site characteristic hydraulic conductivity of 1.0 m/d was based on the data obtained during the ESP subsurface field investigation. The additional hydraulic conductivity data obtained during the North Anna 3 field investigation resulted in a higher estimate of the maximum hydraulic conductivity.

In the COL Application Departures Report, the COL applicant identified the hydraulic conductivity variance (NAPS ESP VAR 2.0-2) and requested to use the North Anna 3 COL FSAR value of 3.0 m/d instead of the 1.04 m/d value in the ESP SSAR. The COL applicant provided the following two justifications for the request:

1) The COL applicant used a hydraulic conductivity value of 3.0 m/d in the groundwater transport analysis of North Anna 3 COL FSAR Section 2.4.13 and demonstrated compliance with the requirements of 10 CFR Part 20. The COL applicant stated that the radionuclide concentrations and associated doses calculated in North Anna 3 COL FSAR 2.4.13 are conservative because the hydraulic conductivity 3.0 m/d is the maximum observed at the North Anna 3 site; and

2) The groundwater flow model used in COL FSAR Section 2.4.12 to evaluate the maximum post-construction groundwater-surface elevation incorporated the data from the North Anna 3 subsurface field investigation, and the resulting maximum

groundwater-surface elevation satisfied the ESBWR DCD site characteristic on maximum groundwater level.

The Staff's Technical Evaluation:

The staff reviewed the supplemental slug test and packer test data in North Anna 3 COL FSAR Appendix 2.5.4AA and the resulting saturated hydraulic conductivities in North Anna 3 COL 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 higher maximum hydraulic conductivity estimates than were provided in the ESP SSAR: 3.0 m/d for the saprolite and 1.9 m/d for the shallow bedrock. Because a saturated hydraulic conductivity value of 3.0 m/d 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.

Hydraulic Gradient (NAPS ESP VAR 2.0-3)

Information Submitted by COL Applicant:

The maximum hydraulic gradient of 0.05 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 North Anna 3 field investigation resulted in higher estimates of the maximum groundwater hydraulic gradient.

In the COL Application Departures Report, the COL applicant identified the hydraulic gradient variance (NAPS ESP VAR 2.0-3) and requested to use the North Anna 3 COL FSAR value of 0.05 instead of the value of 0.03 in the ESP SSAR. The COL applicant justified the use of the higher hydraulic gradient by demonstrating compliance with the 10 CFR Part 20, Appendix B, Table 2 concentration limits using the North Anna 3 COL FSAR hydraulic gradient value of 0.05 in the groundwater transport analysis of North Anna 3 COL FSAR Section 2.4.13.

The Staff's Technical Evaluation:

The staff evaluated horizontal groundwater head gradients at the North Anna 3 site using the groundwater head measurements provided in North Anna 3 COL FSAR Table 2.4-15R. The COL applicant used the maximum head at observation well OW-901 and the minimum head at well OW-950 to estimate the horizontal groundwater gradient between the RB and Lake Anna. Based on the observed heads, the staff concluded that although the local gradient at the RB is likely to be higher, 0.05 is a conservative estimate of the average gradient between the RB 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-950 used to compute the gradient. Because a groundwater hydraulic gradient of 0.05 is based on site-specific observations and is conservative, the staff concluded that this value was an appropriate site characteristic and accepts NAPS ESP VAR 2.0-3.

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

Information Submitted by COL Applicant:

The COL applicant used samples from the North Anna 3 field investigation boreholes 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 COL applicant determined that the median moisture content was 17 percent and the median specific gravity was 2.65. Using these values, the COL applicant estimated a void ratio of 0.45 with a resulting total porosity of 0.31. (The ESP SSAR estimated values of 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 COL applicant assumed the effective porosity was 80 percent of the total porosity, or 0.25. (This assumption was also made in determining the ESP SSAR effective porosity of 0.33.)

The COL applicant used the geometric mean saprolite hydraulic conductivity (0.53 m/d), the site characteristic hydraulic gradient of 0.05, and the effective porosity (0.25) to compute a groundwater seepage velocity of 0.11 m/d (0.35 ft/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 between the radwaste building and Lake Anna, the COL applicant estimated a groundwater travel time of 7.8 yr. (as compared to the travel time of 40 yr. in the ESP SSAR for a distance of 549 m). Using a distance of 234.7 m (770 ft) from CST to Lake Anna, the COL applicant estimated a groundwater travel time of 6 yr.

In the COL Application Departures Report, the COL applicant identified the void ratio, porosity, and seepage velocity variance (NAPS ESP VAR 2.4-1) and requested to use the North Anna 3 COL FSAR values instead of the values in the ESP SSAR. The COL applicant justified the use of the North Anna 3 COL FSAR values by demonstrating compliance with the 10 CFR Part 20, Appendix B, Table 2 concentration limits in the groundwater transport analysis of North Anna 3 COL FSAR Section 2.4.13.

The Staff's Technical Evaluation:

The staff reviewed the data on gravimetric water content described in North Anna 3 COL FSAR Section 2.5.4 and the COL 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 North Anna 3 COL FSAR Appendix 2.5.4AA. Using a specific gravity of 2.65 as in North Anna 3 COL 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 North Anna 3 COL FSAR Section 2.4.12.1.2). The staff determined that the large number of samples provides confidence in the median porosity value used by the COL applicant, and that the samples with lower average porosity (i.e., those 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. Therefore the staff concluded that a total porosity estimate of 0.31 is appropriate for the groundwater transport analysis at the North Anna 3 site.

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 staff reviewed the computation of groundwater velocity using the COL applicant's site characteristic values of hydraulic gradient and effective porosity and the geometric mean saturated hydraulic conductivity for saprolite. The staff confirmed the COL applicant's groundwater velocity of 0.11 m/d provided in North Anna 3 COL FSAR Section 2.4.12.1.2. The staff also computed a more conservative groundwater velocity of 0.6 m/d using the COL applicant's maximum observed hydraulic conductivity (3.0 m/d). The staff determined that the higher groundwater velocity (3.0 m/d) was used by the COL applicant in the groundwater transport analysis of North Anna 3 COL FSAR Section 2.4.13. Although the staff determined that the available data do not provide evidence for a high permeability pathway between either the RW or the CST and Lake Anna, the staff concluded that the COL applicant's use of the maximum observed hydraulic conductivity in the transport analysis provided conservative estimates of accidental release concentrations and doses. Therefore, the staff accepts NAPS ESP VAR 2.4-1.

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

Information Submitted by COL Applicant:

Corrected and supplemental information was provided on the location and pumping rates for existing onsite groundwater supply wells in North Anna 3 COL FSAR Tables 2.4-17R and 2.4-205. The applicant stated that any groundwater used for North Anna 3 will not be safety-related. In the COL Application Departures Report, the applicant identified a variance in the plant water supply well information (NAPS ESP VAR 2.4-2). The variance arose from the use of incorrect information in the ESP SSAR and new information obtained on plant water supply wells. The COL applicant justified the North Anna 3 COL FSAR water supply well information (see North Anna 3 COL FSAR Table 2.4-17R) because it better reflected current plant water supply well conditions, and because it supported the ESP SSAR conclusion 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.

The Staff's Technical Evaluation:

The staff reviewed the corrected information provided in the North Anna 3 COL FSAR describing the existing groundwater supply wells and groundwater use and accepted NAPS ESP VAR 2.4-2. The staff also evaluated the potential for a groundwater transport pathway to the well located at the NANIC, which supplies potable water. The staff reviewed the maps of groundwater head and the information provided on the NANIC well construction and operation. The staff determined that the NANIC well is located approximately 0.9 kilometers (0.4 miles) up gradient of the radionuclide source used in the North Anna 3 COL FSAR Section 2.4.13 accidental release analysis, the groundwater head at the NANIC well is approximately 12.2 m (40 ft) higher than at the source location, the NANIC well is finished in bedrock at a depth of 79.2 m (260 ft) (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. Therefore, the staff concluded that an accidental release pathway to the NANIC water supply well is implausible.

Well Reference Point Elevation (NAPS ESP VAR 2.4-3)

Information Submitted by COL Applicant:

Supplemental information was provided in the North Anna 3 COL FSAR on the groundwater monitoring programs required during and following plant construction. The COL applicant stated that seven new observation wells were installed during subsurface investigations for North Anna 3, and that these have been monitored in addition to continued monitoring of wells installed previously. The COL applicant stated that some observation wells may need to be closed prior to site earthwork activities and that 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 COL applicant stated 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. In the COL Application Departure Report, the applicant identified a variance in the reference point elevation for observation well WP-3 (NAPS ESP VAR 2.4-3). The variance arose from using an un-surveyed vertical coordinate originating from a label attached to the well casing as the basis for the well reference elevation in the ESP SSAR. The COL applicant completed a field survey in 2009 to provide a corrected well reference elevation. The COL applicant justified the North Anna 3 COL FSAR well reference elevation because it was a corrected value and did not materially change the estimates of groundwater flow, post-construction groundwater head, or the analysis of accidental release of liquid effluents to groundwater. The COL applicant provided the corrected well reference elevation and corrected groundwater level measurements in North Anna 3 COL FSAR Table 2.4-15R and updated the groundwater head contour maps in North Anna 3 COL FSAR Figures 2.4-207 to 2.4-214.

The Staff's Technical Evaluation:

The staff reviewed the supplemental information provided in the North Anna 3 COL FSAR regarding groundwater monitoring programs. The staff recognizes that groundwater monitoring would be an ongoing activity, and that existing monitoring wells may need to be abandoned 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-surface levels will be adequately monitored as site conditions change. The staff determined that the frequency of monitoring proposed by the COL applicant was reasonable for monitoring the effects of construction on, and natural variation of, groundwater-surface levels.

The staff reviewed the groundwater head observations and associated contour maps based on the corrected well reference elevation for observation well WP-3 and verified that the corrected data was used by the COL applicant in the groundwater flow modeling carried out to support the post-construction estimate of maximum groundwater head.

Design Bases for Subsurface Hydrostatic Loading

Information Submitted by COL Applicant:

The design plant grade elevation is specified in the North Anna 3 COL FSAR as 88.39 m (290 ft) NAVD88. The COL applicant stated that construction of North Anna 3 will require cut and fill on the site, which will modify the existing groundwater elevations in the power block area. The ESBWR DCD site parameter for the maximum groundwater level is 0.61 m (2 ft) below plant grade (North Anna 3 COL FSAR Table 2.0-201), which corresponds to a maximum groundwater-surface elevation of 87.78 m (288 ft) NAVD88 at the North Anna 3 site. ESBWR DCD Table 2.0-1 (Note 1) indicates that the maximum groundwater level site parameter applies at seismic Category I, II, and Radwaste Building structures. The COL applicant developed and applied a groundwater flow model of the North Anna 3 site to evaluate post-construction groundwater-surface levels. The COL applicant revised the groundwater flow model in response to RAI 02.04.12-1 dated August 08, 2008 (ADAMS Accession No. ML082210547), and RAI 02.04.12-2 dated March 25, 2009 (ADAMS Accession No. ML090840271). In Enclosure 7 of a letter dated December 18, 2013 (ADAMS Accession No. ML14013A113), the COL applicant provided a response to these RAIs that superseded all prior responses. Enclosure 7 of the COL applicant's letter documented the development and application of a groundwater model of the NAPS site. The COL applicant used results from this model as the basis for the discussion of site characteristics for subsurface hydrostatic loading and dewatering in North Anna 3 COL FSAR, Section 2.4.12.4. The COL applicant provided the groundwater model input and output files in a letter dated August 19, 2014 (ML14238A018).

Based on the results of the groundwater modeling, the COL applicant concluded that the maximum post-construction groundwater-surface elevation in the power block area ranges from 82.30 to 86.56 m (270 to 284 ft) NAVD88 with a maximum of 86.14 m (282.6 ft) NAVD88 at Seismic Category 1 structures. Because the maximum groundwater elevation is less than the DCD site parameter value of 0.61 m (2 ft) below plant grade (87.78 m or 288 ft NAVD88), the COL applicant concluded that a permanent dewatering system is not needed for safe operation of North Anna 3.

The maximum post-construction groundwater elevation provided in North Anna 3 COL 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. In the response to RAI 02.04.12-3 dated October 23, 2012 (ADAMS Accession No. ML12307A196), the COL applicant stated that the ESP site characteristic was relative to the site grade. The ESP maximum groundwater elevation of 82.03 m (269.14 ft) NAVD88 was based on a proposed site grade of 82.34 m (270.14 ft) NAVD88 and a prior estimate of maximum groundwater elevation for the existing units. Because the North Anna 3 COL FSAR design plant grade is higher than the ESP proposed site grade, the North Anna 3 COL FSAR maximum groundwater elevation is also higher than the ESP value, but still less than the ESBWR DCD site parameter for maximum groundwater level.

<u>The Staff's Technical Evaluation:</u>

In RAI 02.04.12-1 the staff requested: (1) a description of the technical basis for the assumptions, parameter values, and boundary conditions used by the COL applicant in the groundwater flow model; (2) a discussion of the discrepancy between the observed and model-simulated groundwater heads at the location of the North Anna 3 RB; and, (3) the technical basis for confidence in model predictions of post-construction groundwater heads. The COL applicant's response to RAI 02.04.12-1 dated December 18, 2013 (ADAMS Accession No. ML14013A113), contained the technical basis for the assumptions, parameter values, and boundary conditions of the groundwater flow model. The COL applicant developed a steady-state, two-layer model, with the upper layer representing the saprolite and the lower layer representing the shallow bedrock. The upper layer reflected the ground-surface topography. The COL applicant based the elevation of the contact between the layers on data from the ESP and COL site investigations geotechnical borings. The COL applicant placed the lower, no-flow boundary at a depth of 38.10 m (125 ft) below the ground surface, reflecting the conceptual model in which the occurrence of water-bearing fractures decreases with depth. The COL applicant placed lateral and internal boundaries to represent the locations of drainages, ponds, and Lake Anna, including the WHTF. The COL applicant treated intermittent streams as drain boundaries and Lake Anna and the WHTF as constant head boundaries. The COL applicant assumed recharge was zero at the location of buildings and paved surfaces, relatively large at the Units 1 and 2 SW reservoir, and uniform over the remainder of the model domain (this latter assumption was tested by the COL applicant via simulation). The COL applicant used two saturated hydraulic conductivity zones defined by differences in the observed values of conductivity from slug tests and by the location of a fault identified in ESP SSAR, Figure 2.5-18. The COL applicant assumed hydraulic conductivities were the same in the two model layers and were isotropic everywhere. These assumptions were tested by the applicant via simulation. The staff reviewed the model assumptions and boundary conditions and concluded that they were appropriate and consistent with the site data and conceptual model presented by the COL applicant.

The COL applicant adjusted the recharge and saturated hydraulic conductivity to fit groundwater heads observed during May 2007. The COL applicant's calibrated recharge values were 28 cm/yr. (11.0 in/yr) over the majority of the domain and 37 cm/yr. (14.5 in/yr) over the SW reservoir. Calibrated hydraulic conductivity values were 0.35 m/d (1.14 ft/d) in the northern zone and 0.13 m/d (0.43 ft/d) in the southern zone. The COL applicant stated that all calibration criteria were met. In RAI 02.04.12-1, the staff noted that the observed head at well OW-901, located at the position of the North Anna 3 RB, was about 4 ft higher than the model simulation. This concerned the staff because of the potential for errors of similar magnitude in the post-construction maximum groundwater head in the reactor area estimated from the model. In response to RAI 02.04.12-1 (ADAMS Accession No. ML14013A113), the COL applicant stated that the model was unable to reproduce the steep gradient in groundwater head observed in the power block area, and that the model calibration therefore underestimated the highest heads and overestimated the lowest heads observed in the power block wells. The COL applicant also completed an alternative calibration in which the general recharge rate was increased to 32.3 cm/yr. (12.7 in/yr) in order to fit the observed head at OW-901. However, the COL applicant stated that the increased recharge resulted in unacceptable errors in the simulated groundwater levels at other wells.

The COL applicant conducted predictive simulations of post-construction groundwater heads using the calibrated model described above. In these simulations, the COL applicant modified the ground surface topography of the model to reflect the final site grading, made model cells inactive where deep building foundations will occur, and increased the constant head boundary conditions for Lake Anna and the WHTF to reflect an 8 cm (3 in) increase in the normal operating lake level. In addition, the COL applicant used a backfill zone with a hydraulic conductivity of 0.86 m/d (2.83 ft/d) in the area around the power block, applied a recharge rate of zero where buildings and paved areas will be located, and included model drain cells to represent the surface drainage ditches planned for controlling surface runoff around the power block and the cooling tower. The COL applicant assumed the May 2007 groundwater observations were close to historic maximum levels and presented data on precipitation and regional water conditions to support this assumption. The COL applicant completed a base case simulation with the model and presented results for this analysis in North Anna 3 COL FSAR Figure 2.4-216. The COL applicant compared the model-simulated heads at a set of 16 points around the power block buildings to the ESBWR DCD maximum groundwater elevation. The maximum groundwater head of 86.53 m (283.9 ft) NAVD88 occurred at the Ancillary Diesel Building and was 1.86 m (6.1 ft) below the design plant grade.

Input files for all the simulations described in the groundwater modeling report were used in the staff's review and confirmatory simulations. The staff concluded that the groundwater model developed by the COL applicant appropriately represented the site characterization data and the conceptual understanding of site groundwater flow. However, the staff was concerned with errors in the model's representation of observed groundwater heads in the power block area and the potential that these errors could be carried through to the model predictions of post-construction groundwater conditions.

The 88.39 m (290 ft) NAVD88 grade for the North Anna 3 power block will be created by excavating the existing soil and rock materials at the site. A significant cut-slope will be created on the southwest and southeast sides of the power block area, as shown on North Anna 3 COL FSAR Figure 2.4-201. As a result of groundwater flow from the upland areas towards the lake, the groundwater heads will be higher than plant grade above the cut-slope. Surface drainage ditches around the power block will be depended upon to also drain groundwater, increasing the groundwater head gradients around the power block and lowering the groundwater heads throughout the power block area. This effect can be seen in the model simulation results of North Anna 3 COL FSAR Figure 2.4-216, where the drainage ditches are shown in yellow.

Based on a set of confirmatory simulations, the staff determined that the groundwater elevations predicted by the COL applicant's groundwater model were strongly dependent on the characteristics of the model drain cells that represent the site surface water drainage system surrounding the power block. For the groundwater model used by the COL applicant, groundwater discharge to a model drain cell is proportional to the conductance parameter, the value of which is unknown, but is related to the effective hydraulic conductivity over the drainage pathway, the geometry of the drain, and the dimensions of the model grid cell. The COL applicant assigned a drain conductance value of 2.32 m^2/day (25 ft^2/day) based on a hydraulic conductivity of 0.35 m/day (1.14 ft/day). The hydraulic conductivity of the model cells within which the drains are located is about one-third of this value along eastern portions of the drainage ditches. Based on this observation, and on geometric considerations, the staff concluded that values of drain conductance less than 2.32 m^2/day (25 ft^2/d) were plausible. The staff requested additional information to resolve this issue in RAI 02.04.12-2.

In response to RAI 02.04.12-2 dated December 18, 2013 (ADAMS Accession No. ML14013A113), the COL applicant provided results of model simulations to evaluate the effect of the drain cell conductance on the groundwater heads in the power block area. In particular, the COL applicant evaluated groundwater heads in the power block area using a smaller drain conductance value of 0.23 m^2/day (2.5 ft^2/d) and reported that this increased the maximum groundwater head to 87.66 m (287.6 ft) NAVD88. Using groundwater model input files provided by the COL applicant, the staff evaluated groundwater heads in the power block area using a drain conductance value of 0.093 m^2/day (1.0 ft^2/d) and found that the simulated maximum groundwater head could exceed 87.78 m (288 ft) at this low conductance value. In RAI 02.04.12-4 dated November 21, 2014 (ADAMS Accession No. ML14325A831), the staff requested documentation in the North Anna 3 COL FSAR of the drainage ditch design, construction methods, and materials, and the function of the drainage ditches in maintaining groundwater levels. In the response to RAI 02.04.12-4 dated January 08, 2015 (ADAMS Accession No. ML15009A237), the COL applicant provided proposed updated North Anna 3 COL FSAR text in the North Anna 3 COL FSAR, Revision 9, and the staff confirmed its inclusion. Based on the description of the ditches provided by the COL applicant the staff determined that drainage ditch materials and construction would not impede the discharge of groundwater into the ditches. Therefore, the staff concluded that drain conductance values of 0.23 m^2/day (2.5 ft^2/d) and lower are unlikely and that a drain conductance value of 2.32 m^2/day (25 ft^2/day) is appropriate and conservative. The staff verified that the appropriate revisions are incorporated into the FSAR, Revision 9, and, therefore, Confirmatory Item 2.4.12-1 from the staff's advanced SER for North Anna 3 is resolved and closed.

Evaluation of the maximum groundwater elevation using the groundwater model depends on the ability of the model to accurately represent the groundwater system. Examination of the simulation results showed that the model predicted flooding (i.e., steady-state groundwater heads above the surface elevations) at a number of locations across the site, for both the pre-construction and post-construction models. The staff used groundwater head observations to evaluate whether the predicted flooding indicated a model bias.

The COL applicant used groundwater head observations from May 30, 2007 to develop and evaluate the pre-construction groundwater model. The staff plotted these observations as a function of the ground surface elevation at the observation well locations, as shown in Figure 2.4.122-1[3]. As described above, the observations from well pairs at different depths indicated that generally minor vertical gradients exist at the site. The groundwater heads in this shallow unconfined system were therefore interpreted as water table elevations. The staff determined that observed groundwater levels were related to ground surface topography; the envelope of maximum observed groundwater levels was well-represented as a linear function of the ground surface elevation (with a slope of 0.75), as shown in Figure 2.4.12-1. Based on this relationship, maximum observed groundwater levels were close to ground surface at lower elevations (e.g., at the Lake Anna elevation of 76.20 m [250 ft] NAVD88), and progressively deeper as the ground surface elevation increased (e.g., maximum groundwater level was 6.10 m [20 ft] deep at a ground surface elevation of 100.58 m [330 ft] NAVD88).

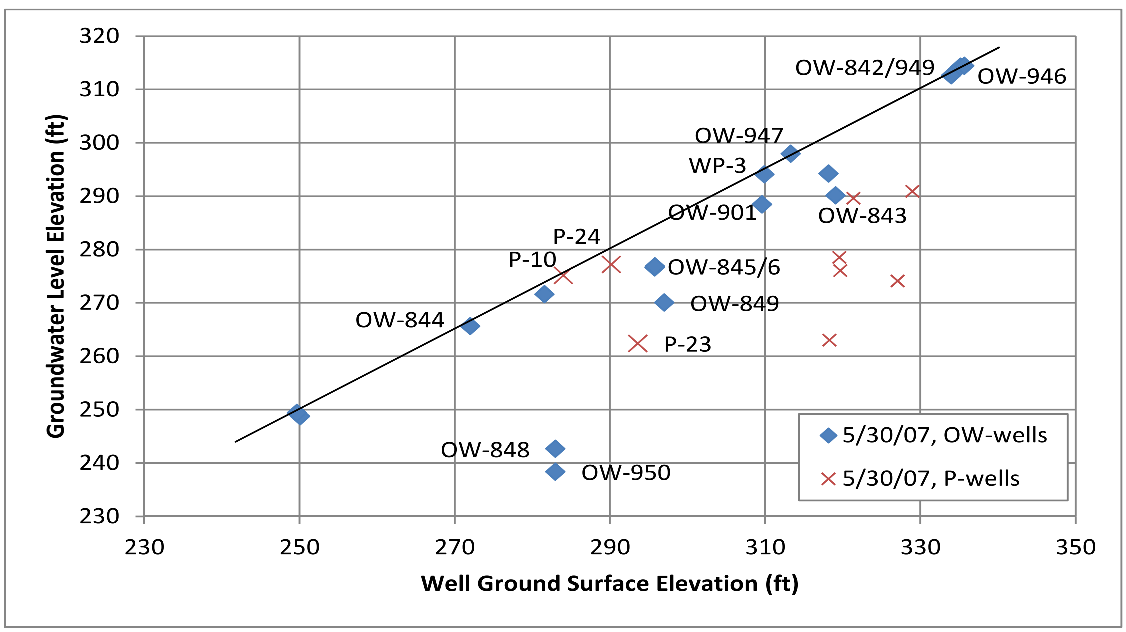


Figure 2.4.122-1. NAPS Unit 3 groundwater head observations on 5/30/2007 as a function of ground surface elevation at the well

[3] For most of the P-series wells surrounding the Units 1 and 2 UHS impoundment, the well stick-up was not specified; these head observations are plotted against the well reference point elevations.

While no observations fall significantly above the envelope line in Figure 2.4.12-1, a number of observations fall significantly below the line. The staff examined the current site topography, as shown on FSAR Figure 2.4-206, and determined that the wells with observations below the line in Figure 2.4.12-1 tended to be located above and near a significant topographic slope. For example, OW-848 and OW-950 are on the bluff above the proposed North Anna 3 intake bay, and OW-849 and OW-843 are above the cut-slope for the switch yard. In contrast, the observations that lie close to the line in Figure 2.4.12-1 tended to be in areas of relatively flat topography, or near the bottom of topographic slopes. For example, OW-844 lies just below the cut-slope down to the Unit 1/2 operations level.

The COL applicant's pre-construction model, calibrated using the May 30, 2007 groundwater observations, resulted in groundwater heads at several observation wells that were above the envelope line shown in Figure 2.4.12-1. The greatest deviations were at wells OW-945, a relatively low-lying area where the model produced flooded conditions, and OW-844, located at the bottom of a cut-slope. The deviation at OW-844 was about 1.22 m (4 ft). Based on the observations shown in Figure 2.4.12-1, the staff concluded that groundwater head measured in a well located at a surface elevation of 88.39 m (290 ft) (the North Anna 3 design plant grade) would be unlikely to exceed 85.34 m (280 ft). The COL applicant's post-construction model predicted heads about 1.22 m (4 ft) greater than this in the power block area: 86.53 m (283.9 ft) at the Ancillary Diesel Building, located near the cut-slope down to the power block. The staff concluded that the COL applicant's groundwater model will tend to over-estimate groundwater heads below a cut-slope such as that planned around the North Anna 3 power block area.

Conclusions about the maximum groundwater heads at the North Anna 3 site that are based on the observed groundwater heads on May 30, 2007, assume that these observations represent maximum historical values. The staff evaluated this assumption by examining the historical record of water level in a USGS well in Louisa County, approximately 11.5 mi from the North Anna 3 site and completed in the fractured rock aquifer[4]. The staff determined that water levels in this USGS well, interpolated to the North Anna 3 observation well sampling dates, were correlated with North Anna 3 well OW-842 observed water levels (correlation coefficient of 0.85). Water levels for the two wells, shown in Figure 2.4.122-2, indicate that the North Anna 3 sampling times may not have coincided with the maximum groundwater levels at the North Anna 3 site. The maximum groundwater level in the USGS well occurred in April 2010. Given the correlation between the water levels in the two wells, the staff determined that the maximum groundwater elevation in well OW-842 may be several feet higher than the elevation observed on May 30, 2007. This implies that the upper end of the envelope line in Figure 2.4.12-1, would increase several feet; the increase at a ground surface elevation of 88.39 m (290 ft) would be less.

Given the staff's independent evaluation of the available data and the staff's confirmatory analysis of the COL applicant's model results, the staff determined that the COL applicant's groundwater model provided conservative estimates of post-construction maximum groundwater elevation in the power block area. Because the model predicted a maximum head in the power block that is well below the DCD requirement, the staff concluded that the applicant's maximum groundwater elevation site characteristic of 86.53 m (283.9 ft) NAVD88 is conservative and acceptable. Accordingly, the staff considers RAI 02.04.12-1 and RAI 02.04.12-2 resolved and closed.

[4] USGS 380131078001001 46N 1 SOW 056, accessed at http://waterdata.usgs.gov/nwis

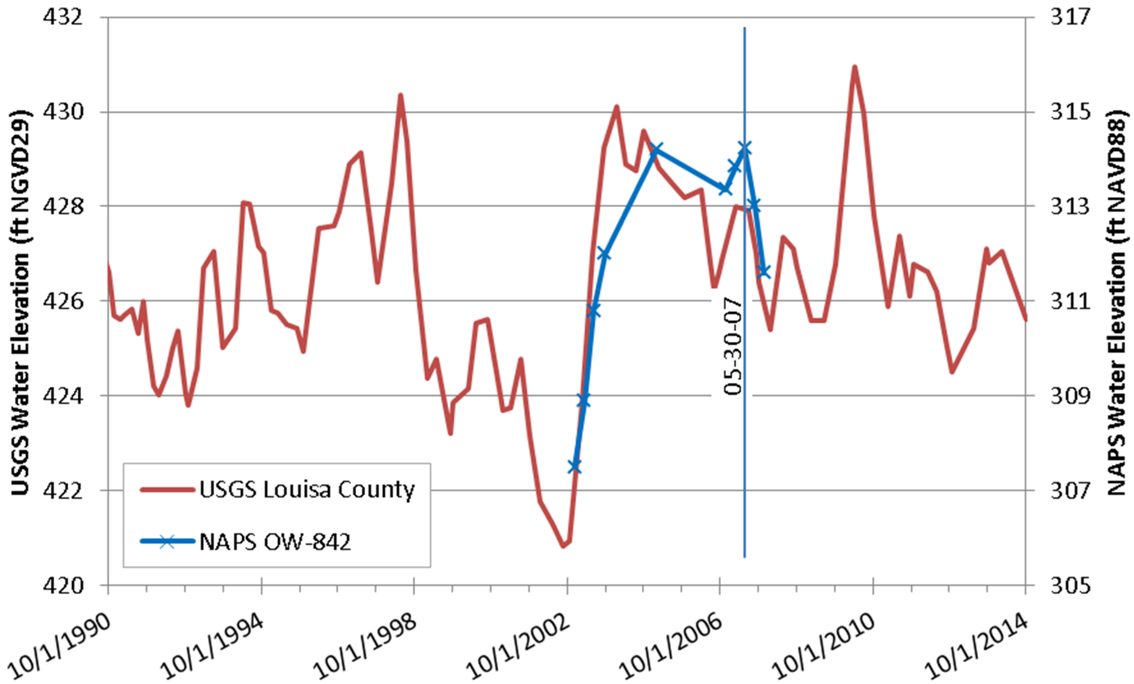


Figure 2.4.122-2. Water levels for the USGS Louisa County well and NAPS Unit 3 well OW-842

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 North Anna 3 COL 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).

While the applicant did not submit specific information on potential effects of seismic events on worst-case groundwater conditions, the staff reviewed available literature on seismic effects on groundwater-surface elevations (e.g., Montgomery and Manga 2003; Wang and Manga 2010; Roeloffs 1996; Bredehoeft 1967) and considered North Anna 3 site-specific conditions. Groundwater in the power block area is unconfined, transmissive depth is from 30 to 100 m (98 to 328 ft) below ground surface, with an estimated effective porosity of 0.25. The staff considered the design earthquakes given in North Anna 3 COL FSAR Table 2.5.2-218, "Mean Magnitude and Distance for LF and HF Response Spectra for Three MAFEs," and used the idealized unconfined aquifer analysis of Bredehoeft (1967) to estimate a maximum increase in groundwater-surface elevation of 0.30 m (1 ft). Given the margin in the maximum groundwater elevation estimated by the COL applicant using the groundwater model discussed above, the staff concluded that no plausible scenarios present conditions in which seismic events could have significant effects on groundwater-surface elevations at this site.

2.4.12.5 Post Combined License Activities

There are no post COL activities related to this section.

2.4.12.6 Conclusion

The staff reviewed the application and confirms that the COL applicant addressed the required information as it relates to groundwater, and no outstanding information remains to be addressed in the North Anna 3 COL FSAR related to this section.

In addition, the staff compared the additional information in the COLA to the relevant NRC regulations, the guidance in Section 2.4.12 of NUREG-0800 SRP, and other NRC RGs. The staff's review concludes that the COL applicant has provided sufficient information to satisfy the requirements of NRC regulations. The staff has determined that the COL applicant has adequately addressed COL Items 2.0-12-A and 2.0-23-A as they relate to groundwater.

As set forth above, the applicant presented and substantiated information relative to the groundwater effects important to the design and siting of this plant. The staff has reviewed the available information provided and, for the reasons given above, concludes that the identification and consideration of the potential effects of groundwater in the vicinity of the site are acceptable and meet the requirements of 10 CFR 50.55, "Conditions of construction permits, early site permits, combined licenses, and manufacturing licenses," 10 CFR 50.55a, 10 CFR 100.20(c)(3), 10 CFR 100.23(d), and 10 CFR 100.20(c), with respect to determining the acceptability of the site.

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

2.4.13.1 Introduction

This section provides a characterization of the attenuation, retardation, dilution, and concentrating properties governing transport processes in the surface-water and groundwater environment at the site. This section's goal is not to provide an assessment of the impacts of a specific release scenario but to provide a suitable conceptual model of the hydrological environment for other assessments. Since it would be impractical to characterize all the physical and chemical properties (e.g., hydraulic conductivities, porosity, mineralogy, etc.) of a time-varying and heterogeneous environment, this section characterizes the environment in terms of the projected transport of a postulated release of radioactive waste. The accidental release of radioactive liquid effluents in ground and surface waters is evaluated using information on existing uses of groundwater and surface water and the known and likely future uses as the basis for selecting a location to summarize the results of the transport calculation. The source term from a postulated accidental release is reviewed under Section 11.2 of NUREG-0800 following the guidance in Branch Technical Position (BTP) 11-6, "Postulated Radioactive Releases Due to Liquid-Containing Tank Failures" and ISG DC/COL-ISG-013, "Assessing the Radiological Consequences of Accidental Releases of Radioactive Materials from Liquid Waste Tanks for Combined License Applications." The source term is determined from a postulated release from a single tank outside of the containment. The results of a consequence analysis are evaluated against SRP Section 11.2 and BTP 11-6 guidance and the effluent concentration limits (ECLs) of Table 2, Column 2 in 10 CFR Part 20, Appendix B, as SRP acceptance criteria. Under SRP guidance, the ECLs of 10 CFR Part 20, Appendix B are applied as acceptance criteria and are not intended for demonstrating compliance with ECLs.

The following specific areas are reviewed by the staff: (1) alternative 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) a 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) the ability of the groundwater and surface water environments to delay, disperse, dilute, or concentrate accidentally released radioactive liquid effluents during transport; and, (4) the assessment of scenarios wherein an accidental release of radioactive effluents is combined with potential effects of seismic and non-seismic events.

2.4.13.2 Summary of Application

North Anna 3 COL FSAR Section 2.4.13, Revision 9, "Accidental Releases of Liquid Effluents to Ground and Surface Waters," incorporates by reference ESP SSAR, Revision 9, Section 2.4.13, "Accidental Releases of Liquid Effluents to Ground and Surface Waters." This section of the North Anna 3 COL FSAR addresses the accidental release of radioactive liquid effluents in ground and surface waters.

In addition, in North Anna 3 COL FSAR Section 2.4.13, the COL applicant addressed COL item 2.0-24-A identified in ESBWR DCD Tier 2, Revision 10, Table 2.0-2 and ESP Permit Condition 3.E(3).

<u>*COL Item:*</u>

- COL Item 2.0-24-A COL Applicant to Address SRP 2.4.13

<u>*Permit Condition:*</u>

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

The COL applicant addressed these issues by including in North Anna 3 COL FSAR, Revision 9 Section 2.4.13 the following information as a supplement to ESP SSAR Section 2.4.13:

The COL applicant described the accident scenario and resulting source term. For the source term, the COL applicant considered tanks that are part of the Liquid Waste Management System (LWMS) and the Condensate Storage and Transfer System (CSTS). The COL applicant described design features of these systems intended to preclude accidental releases into potential liquid pathways, consistent with ESP Permit Condition 3.E (3). The COL applicant nevertheless considered rupture of the CST as the postulated source, because this tank is the largest above-grade tank located outside of containment. The CST is described in ESBWR DCD Section 9.2.6.2. The tank was postulated to instantaneously release 80 percent of its volume to the unconfined aquifer.

The COL applicant determined that a direct surface water pathway would be precluded by design, and identified a groundwater pathway from the CST to the North Anna 3 intake basin. The COL applicant described two conceptual models: a primary conceptual model with North Anna 3 not operating and an alternative conceptual model with North Anna 3 operating. Groundwater travel time was estimated using site data.

The COL applicant described a radionuclide transport analysis, including the calculation of radionuclide concentrations and doses, and comparison with acceptance criteria based on 10 CFR Part 20. The COL applicant's transport analysis was primarily based on a method of characteristics solution to the one-dimensional advection-dispersion equation with first-order decay and linear equilibrium adsorption. The transport analysis was conducted using three stages. The initial stage of the transport analysis considered advection and radioactive decay only. The second stage of the COL applicant's analysis included the effect of advection, radionuclide decay, and adsorption in computing radionuclide concentrations at the groundwater discharge location. The third stage of the COL applicant's analysis included the effect of dilution of groundwater discharged to the North Anna 3 intake basin, and considered the effect of the two conceptual models on dilution.

The COL applicant computed doses to an individual from consumption of water, consumption of fish and invertebrates, and from swimming, boating, and shoreline activities. The COL applicant estimated that the total body dose to a child from all exposure pathways would be 28 mrem.

Early Site Permit Variance:

The following variance from the ESP SSAR is discussed in Section 2, "Variances," of Part 7 to the COLA:

- NAPS ESP VAR 2.0-5 Distribution Coefficients (Kd)

The COL applicant requested VAR 2.0-5 to use the distribution coefficients provided in North Anna 3 COL FSAR Table 2.4-206 rather than the corresponding values in ESP SSAR Tables 1.9-1 and 2.4-20.

2.4.13.3 Regulatory Basis

The regulatory basis of the information incorporated by reference is addressed in NUREG-1966, the FSER related to ESBWR DCD, and in NUREG-1835, the FSER related to the North Anna ESP.

The relevant requirements of NRC regulations for the pathways of liquid effluents in ground and surface waters, and the associated acceptance criteria, are specified in Section 2.4.13 in NUREG-0800 SRP and ISG DC/COL-ISG-014, "Assessing the Radiological Consequences of Accidental Releases of Radioactive Materials from Liquid Waste Tanks in Ground and Surface Waters for Combined License Applications." The applicable regulatory requirements are as follows:

- 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 margin for the limited accuracy, quantity, and time in which the historical data have been accumulated.

- 10 CFR 100.20(c), as it relates to the consideration given to the hydrological characteristics of the site.

- 10 CFR 100.23(d) sets forth the criteria to determine the citing factors for plant design bases with respect to seismically induced floods and water waves the site.

The related acceptance criteria from SRP Section 2.4.13 are as follows:

- Alternate Conceptual Models: Alternate conceptual models of hydrology in the vicinity of the site are reviewed.

- Pathways: The bounding set of plausible surface and subsurface pathways from the points of release are reviewed.

- Characteristics that Affect Transport: Radionuclide transport characteristics of the groundwater environment with respect to existing and known and likely future users should be described.

- Consideration of Other Site-Related Evaluation Criteria: The applicant's assessment of the potential effects of site-proximity hazards, seismic, and nonseismic events on the radioactive concentration from the postulated tank failure related to accidental release of radioactive liquid effluents to ground and surface waters for the proposed plant site is needed.

BTP 11-6 provides guidance in assessing a potential release of radioactive liquids following the postulated failure of a tank and its components, located outside of containment, and impacts of the release of radioactive materials at the nearest potable water supply, located in an unrestricted area, for direct human consumption or indirectly through animals, crops, and food processing.

In addition, the hydrologic characteristics should be consistent with appropriate sections from RG 1.113, "Estimating Aquatic Dispersions of Effluents from Accidental and Routine Reactor Releases for the Purpose of Implementing Appendix I."

2.4.13.4 Technical Evaluation

As documented in Section 2.4.13 of NUREG-1966 and Section 2.4.13 of NUREG-1835, the staff reviewed and approved information related to accidental release of radioactive liquid effluent in ground and surface waters for the certified ESBWR DCD, Revision 10, and Section 2.4.13 of the North Anna ESP SSAR, respectively. The staff reviewed Section 2.4.13 of the North Anna 3 COL FSAR, Revision 9, and checked the referenced ESBWR DCD and the North Anna ESP SSAR to ensure that the combination of the information in the North Anna 3 COL FSAR and the information in the ESBWR DCD and ESP SSAR represent the complete scope of information relating to this review topic.

The staff's review confirms that the information in the application and the information incorporated by reference address the required information related to "Accidental Release of Radioactive Liquid Effluent in Ground and Surface Waters."

The staff's technical review of this application was limited to the supplemental information pertaining to COL item 2.0-24-A and ESP Permit Condition 3.E(3), as addressed in the following sections. Also discussed within this context are RAIs and variance NAPS ESP VAR 2.0-5.

Radionuclide Transport Analysis

Information Submitted by COL Applicant:

The COL applicant described the accidental radionuclide release source in North Anna 3 COL FSAR Section 2.4.13.1, and stated that tanks from the LWMS and the CSTS were evaluated. The COL applicant described design features of these systems intended to preclude accidental releases into potential liquid pathways, consistent with ESP Permit Condition 3.E(3). The COL applicant nevertheless considered rupture of the CST as the postulated source, because this tank is the largest above-grade tank located outside of containment. In RAI 02.04.13-6 dated January 07, 2015 (ADAMS Accession No. ML14347A004), the staff requested the basis for the source term concentrations provided in North Anna 3 COL FSAR Table 2.4-206. In response to RAI 02.04.13-6 dated January 27, 2015 (ADAMS Accession No. ML15028A392), the COL applicant described the input streams to the CST and referred to the ESBWR DCD tables from which concentrations of these input streams were derived. The COL applicant stated that the North Anna 3 COL FSAR 2.4.13 analysis used a bounding CST concentration for each radionuclide based on the largest of the LWMS and CSTS input streams. Resolution of RAI 02.04.13-6 is discussed in Section 11.2 of this SER.

The COL applicant described the accidental release scenario, rupture of the CST, in North Anna 3 COL FSAR Section 2.4.13.2. The CST selected as the source is located at a grade elevation of 88.24 m (289.5 ft) NAVD88 and has a volume of 4885 m^3 (172,512 ft^3). The COL applicant postulated that the tank instantaneously releases 80 percent of its volume, 3908 m^3 (138,010 ft^3), to the unconfined aquifer, consistent with BTP 11-6.

The COL applicant stated that the basin surrounding the CST precludes an uncontrolled release directly to the ground surface. On this basis, the COL applicant did not consider a surface water pathway.

Based on observed groundwater head contour maps, the COL applicant identified the groundwater transport pathway to be north-northeast toward the cove used for the North Anna 3 intake in Lake Anna. The COL applicant assumed transport would occur along a straight-line path between the CST and the cove, a distance of 234.70 m (770 ft). The COL applicant stated that the existing groundwater supply well in the power block area will be closed before North Anna 3 construction, and as a result, groundwater from the postulated release will discharge to the Lake Anna cove that constitutes the North Anna 3 water supply intake.

The COL applicant described a primary conceptual model in which North Anna 3 is not operating, so that groundwater discharged to Lake Anna would be diluted by water in the North Anna 3 intake cove. For the primary conceptual model, the COL applicant adopted the culverts that connect the intake cove to the main body of Lake Anna as the release point for demonstrating compliance with 10 CFR Part 20, Appendix B, Table 2 radionuclide concentration limits. The COL applicant also described an alternate conceptual model in which North Anna 3 is operating, so that groundwater discharged to Lake Anna would be diluted with lake water before being pumped back into the North Anna 3 facility as makeup water, and ultimately be discharged with cooling tower blowdown to the discharge canal. The COL applicant adopted the end of the discharge canal as the release point for compliance with the 10 CFR Part 20, Appendix B, Table 2 radionuclide concentration limits.

The COL applicant based the groundwater radionuclide transport analysis on a method of characteristics solution to the one-dimensional advection-dispersion equation with first-order decay and linear equilibrium adsorption. The COL applicant neglected dispersion in deriving the analytical solutions for parent and progeny radionuclides. The COL applicant conducted the analysis using three stages of progressive refinement. At the first two stages, the COL applicant considered in the following stage only radionuclides whose concentrations were greater than 1×10^{-6} times the applicable concentration limit. The COL applicant provided calculated concentrations in groundwater in FSAR Table 2.4-206.

The COL applicant's first stage of analysis considered radioactive decay only, and computed radionuclide concentrations at the groundwater discharge location. The COL applicant computed a groundwater travel time of 1.07 yr. using a hydraulic conductivity of 3.02 m/day

(9.9 ft/day), a hydraulic gradient of 0.05, and an effective porosity of 0.25. The COL applicant included in the next stage of the analysis the 21 radionuclides for which the resulting concentrations were greater than 1×10^{-6} times the 10 CFR Part 20, Appendix B, Table 2 values. The second stage of the COL applicant's analysis included the effect of radionuclide decay and adsorption in computing radionuclide concentrations at the groundwater discharge location. The COL applicant stated that chelating agents, which could reduce radionuclide adsorption, are neither required nor planned for use in North Anna 3.

The COL applicant used site-specific distribution coefficient (K_d) values obtained in the laboratory using soil samples from 12 borings and water from the unconfined aquifer, with results listed in North Anna 3 COL FSAR Table 2.4-207. The COL applicant used the minimum observed value in the transport analysis. The COL applicant assumed the distribution coefficient of yttrium isotopes to be that of Sr-90. For those radioactive daughter products without measured values the COL applicant assigned the distribution coefficient values of the parent radionuclides. The COL applicant assumed Te-129m, Zr-95, Nb-95, and H-3 to be unaffected by adsorption. The COL applicant computed retardation factors using an effective porosity of 0.25 and a bulk density of 1.83 g/cm^3 (based on an assumed particle specific gravity of 2.65 g/cm^3 and a total porosity of 0.31). The COL applicant included in the next stage of the analysis the 10 radionuclides for which the resulting concentrations were greater than 1×10^{-6} times the 10 CFR Part 20, Appendix B, Table 2 values, these being H-3, Co-60, Ni-63, Sr-90, Y-90, Zr-95, Nb-95, Te-129m, Cs-137, and Pu-239.

The approach to selecting distribution coefficients described above represents a variance from the distribution coefficients as discussed in the ESP SSAR. The COL applicant formally stated 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 EPA (1999). The values used in FSAR Table 2.4-207 were based on site-specific measurements. The COL applicant justified the use of the North Anna 3 COL FSAR Table 2.4-206 distribution coefficient values because they were based on site-specific measurements, and compliance with the 10 CFR Part 20, Appendix B, Table 2 concentration limits was demonstrated using the North Anna 3 COL FSAR distribution coefficient values in the North Anna 3 COL FSAR Section 2.4.13 analysis of groundwater release.

The third stage of the COL applicant's analysis included the effect of decay, adsorption, and dilution of groundwater discharged to surface water under two conceptual models. The COL applicant's primary conceptual model assumed North Anna 3 was not operating and diluted the tank release volume in the volume of the Lake Anna cove, using the radionuclide groundwater concentrations from the second stage analysis. The COL applicant calculated a dilution factor of 26 for the primary conceptual model. The COL applicant's alternate conceptual model assumed North Anna 3 was in operation and diluted the groundwater discharge rate to the North Anna 3 intake cove by the total water withdrawal rate from Lake Anna for North Anna 3 operation, with the dilution factor reduced by the cycles of concentration. The COL applicant calculated a dilution factor of 38 for the alternate conceptual model using the maximum cycles of concentration (9). The COL applicant evaluated the "sum of fractions approach" described in 10 CFR Part 20 using the diluted concentrations and found the sum of fractions to be less than 1.0 under both scenarios.

The COL applicant computed doses to an individual from consumption of water, consumption of fish and invertebrates, and from swimming, boating, and shoreline activities using diluted concentrations from the primary conceptual model. The COL applicant estimated that the total body dose to a child from all exposure pathways would be 28 mrem.

The Staff's Technical Evaluation:

In RAI 02.04.13-1 dated August 19, 2008, (ADAMS Accession No. ML082320133), the staff requested information on the presence of chelating agents in the tank used for the source in the accidental release analysis. In North Anna 3 COL FSAR, Revision 9, Section 2.4.13.3.2.2, the COL applicant stated that chelating agents are neither required nor planned to be used. As a result, the staff considers RAI 02.04.13-1 resolved and closed.

The COL applicant assumed that there were no differences in the flow and transport characteristics between the saprolite and the shallow bedrock. The staff determined that this assumption is consistent with the hydrogeological conceptual model in North Anna 3 COL FSAR Section 2.4.12.

The staff verified that the groundwater transport analysis in North Anna 3 COL FSAR Section 2.4.13 used a hydraulic conductivity value that was the maximum observed value (3.02 m/day) from the site slug tests. In RAI 02.04.13-3 dated August 19, 2008 (ADAMS Accession No. ML082320133), the staff requested additional information about the consistency between the MODFLOW model used to model groundwater levels in North Anna 3 COL FSAR Section 2.4.12 and the contaminant transport model. The issue was that these two models used different values of hydraulic conductivity. In response to RAI 02.04.13-3 dated October 02, 2008 (ADAMS Accession No. ML082810405), the COL applicant provided a comparison between the values of hydraulic conductivity used in the two models. The COL 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 COL applicant's contaminant transport model was not consistent with the MODFLOW model because higher, more conservative values of hydraulic conductivity were used in North Anna 3 COL FSAR 2.4.13. The staff concluded that using conservative values in transport modeling was appropriate because it was desirable to calculate groundwater travel times in a conservative manner. The staff also concluded that it was not necessary for the transport model and the MODFLOW groundwater flow model to use the same values of hydraulic conductivity, because the two modeling efforts had different intended objectives.

In RAI 02.04.13-3, the staff requested additional information on alternative groundwater transport pathways considered by the COL applicant. In an October 2, 2008, response to RAI 02.04.13-3 (ADAMS Accession No. ML082810405), the COL applicant identified and considered the following five alternative transport pathways which were designated as follows:

a. Flow north-northeast in the saprolite to the North Anna 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; and

e. Flow in fractured bedrock to the North Anna 3 intake forebay.

The COL applicant concluded that, compared to the selected pathway, the other saprolite pathways were longer and less plausible when evaluated against the observed groundwater heads and the post-construction MODFLOW model results. The COL applicant stated that the selected pathway was more conservative than the bedrock pathway, because the hydraulic conductivity in the bedrock generally decreased with depth due to a decrease in the number and extent of fractures. The staff noted that effective porosity was also expected to decrease with depth, which would tend to increase groundwater velocity. Based on the slug and pressure test data for the shallow bedrock, the staff determined that the hydraulic conductivity of the shallow bedrock was comparable to that of the saprolite. The staff also determined that there was no site-specific information on which to base an effective porosity estimate for the shallow bedrock. The staff concluded that it was appropriate to base a conservative transport analysis on the site-specific properties of the saprolite. The staff evaluated the alternative transport pathways described by the COL applicant and determined that the selected pathway (pathway a. above) was conservative. This pathway was used by the COL applicant in FSAR Section 2.4.13 and by the staff in its independent confirmatory analysis. The staff finds the discussion of alternative transport pathways acceptable. Accordingly, the staff considers RAI 02.04.13-3 resolved and closed.

The COL applicant made laboratory measurements of adsorption coefficient (K_d) values for the transport analysis on 20 soil and weathered rock samples. The staff reviewed a report documenting the laboratory measurements of K_d for the transport analysis and determined that the K_d values were highly variable with ranges between one and four orders of magnitude for individual radionuclides. 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, in RAI 02.04.13-2 the staff requested information on the technical basis for neglecting this effect in a conservative analysis. 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. In RAI 02.04.13-2, the staff also requested information on the technical basis for neglecting this effect in a conservative analysis. In response to both of these issues (ADAMS Accession No. ML082810405), the COL applicant argued that the use of conservative K_d values (the COL applicant used the minimum measured K_d values) implicitly considered 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 concluded that the use of minimum measured K_d values was demonstrably conservative with respect to the effect of the pH on adsorption. Although the staff considers that a pathway containing significant gravel is plausible (e.g., a pathway through Zone IIb/III in North Anna 3 COL FSAR Figure 2.4-217), the staff determined that the impact of gravel on K_d would be small compared to the wide range of K_d values measured by the COL applicant. The staff therefore concludes that a transport analysis using minimum, site-specific measured K_d values is demonstrably conservative, and considers RAI 02.04.13-2 resolved.

The staff reviewed the COL applicant's transport analysis as described in North Anna 3 COL FSAR Section 2.4.13. The staff completed a confirmatory analysis that computed radionuclide concentrations and the limiting value of the radionuclide mixture (as described in 10 CFR Part 20, Appendix B, Table 2, Note 4) without regard to the time of arrival of each radionuclide at the accessible environment, thereby maximizing the value of the sum. For this analysis, the staff computed conservative radionuclide transport times using maximum observed hydraulic conductivity and radionuclide-specific K_d values determined as the smaller value of the minimum measured K_d and the 0.01 quantile[5] estimated from the measured values. Radionuclides without measurements were assigned a K_d value of the 0.1 quantile estimated from the mean and standard deviation from NUREG/CR-6697, Development of Probabilistic RESRAD 6.0 and

[5] Estimated using the method of moments from the measured $\ln(K_d)$ values. The 0.01 quantile is expected to be exceeded by 99% of measured Kd values.

RESRAD-BUILD 3.0 Computer Codes" (ADAMS Accession Number: ML010090284), Attachment C, Table 3.9-1 (Yu et al. 2000). Radionuclide concentrations in groundwater at the discharge location were computed based on these transport times. The staff considered the two surface water dilution scenarios described by the COL applicant in North Anna 3 COL FSAR Section 2.4.13 and concluded that dilution in the volume of the North Anna 3 intake basin cove without North Anna 3 operating (the COL applicant's primary conceptual model) was a bounding approach. The staff verified that the COL applicant's alternative conceptual model (recirculation with North Anna 3 operating, and dilution in the discharge canal) resulted in greater dilution. The staff computed a dilution factor of 0.037 by assuming the entire source release was uniformly mixed with the North Anna 3 intake basin cove. The staff computed the mixture sum by dividing each concentration by its 10 CFR Part 20, Appendix B, Table 2 limit and summing over all radionuclides. This conservative approach resulted in a sum of 0.86, of which 0.35 was due to H-3, 0.04 to Sr-90, and 0.47 to Cs-137. This value was less than the 10 CFR Part 20, Appendix B, Table 2 limit for a radionuclide mixture (1.0).

The transport analysis described above assumed constant K_d values along the transport pathway. The measured K_d values reported by the applicant were obtained on small samples of soil/rock taken from locations across the site. The staff evaluated the degree of conservatism in assuming that the minimum K_d value measured in a small-scale sample represented the average K_d along the transport pathway. This analysis was completed for the Sr-90 and Cs-137 K_d data (the most significant sorbing contributors to the radionuclide mixture sum) using the methods described in NUREG/CR-6565 (Meyer et al. 1997). The results indicated that there is less than a 1 percent chance that the average Sr-90 and Cs-137 K_d values at the site are as low as the minimum measured values.

No accidental releases directly to surface water are described in North Anna 3 COL FSAR Sections 2.4.13 and 11.2.3.2. Surface water releases considered in the North Anna 3 COL FSAR were due to groundwater transport and discharge to surface water features as described above. Based on the COL applicant's description of the design features intended to preclude the release of radioactive liquid effluents, the staff concludes that a direct release to surface water is not plausible.

In RAI 02.04.13-4 dated March 29, 2009 (ADAMS Accession No. ML090840271), the staff requested information demonstrating that the accidental release analysis described in North Anna 3 COL FSAR Section 2.4.13 is bounding. Based on the information provided in North Anna 3 COL FSAR Section 2.4.13, described above, and on the staff's independent confirmatory analyses, the staff concludes that the transport analysis described in North Anna 3 COL FSAR Section 2.4.13 constitutes a bounding analysis. Accordingly, the staff considers RAI 02.04.13-4 resolved and closed.

Section 11.2.4 of this SER provides the staff findings associated with the COL applicant's radiological dose analysis and associated RAIs.

2.4.13.5 Post Combined License Activities

There are no post COL activities related to this section.

2.4.13.6 Conclusion

The staff reviewed the COLA and confirmed that the COL applicant addressed the relevant information and no outstanding information remains to be addressed in the North Anna 3 COL FSAR related to this section.

In addition, the staff compared the additional information in the COLA to the relevant NRC regulations, the guidance in Section 2.4.13 of NUREG–0800, and NRC RGs. The staff's review concludes that the COL applicant has provided sufficient information to satisfy the requirements of NRC regulations. The staff has determined that the COL applicant has adequately addressed NAPS COL Item 2.0-24-A as it relates to accidental releases of liquid effluents in ground and surface waters. The staff notes that mitigating design features described in the North Anna 3 COL FSAR would further bound groundwater or surface water releases described above.

The review confirms that the COL applicant has satisfactorily addressed the potential for radionuclides to impact receptors under five alternative groundwater transport pathways. The release scenario considered was a worst-case release to groundwater resulting from a catastrophic release of the contents of the CST, the largest above-grade tank located outside containment. Conservative assumptions (i.e., promoting transport and high concentrations) were used in an approach to determine the activity concentrations of radionuclides at locations of groundwater discharge to surface water, relative to the ECLs specified in 10 CFR Part 20, Appendix B, Table 2, Column 2. As described above, the calculated activity concentrations satisfied the ECLs and sum-of-fractions criteria at the groundwater discharge locations using conservative dilution assumptions. The staff concludes that the analysis and its results provide sufficient information to satisfy the requirements of 10 CFR 100.20(c), 10 CFR 100.23(d), and 10 CFR 52.79(a)(1)(iii).

2.4.14 Technical Specification and Emergency Operation Requirements

2.4.14.1 Introduction

The technical specifications (TSs) 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 TSs 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 TSs; (4) potential effects of seismic and nonseismic information on the postulated TSs 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 North Anna 3 COL FSAR addresses TSs and emergency operation requirements. The COL applicant addressed the information as follows:

COL Items:

- NAPS COL 2.0-25-A — Technical Specification and Emergency Operation Requirements, COL Applicant to provide site-specific information in accordance with SRP 2.4.14

The COL applicant provided North Anna 3 COL FSAR Section 2.4.14 to address ESBWR DCD COL Item 2.0-25-A and referenced Sections 2.4.2 and 2.4.12 of the North Anna 3 COL FSAR regarding design basis floods and maximum groundwater elevation and their impacts on safety-related SSCs. The COL applicant concluded that the combination of the ESBWR DCD design and the plant grade elevation do not necessitate emergency procedures or TSs to prevent hydrological phenomena from degrading the UHS.

- NAPS ESP COL 2.4-2 Shut Down Water Level

The COL applicant provided site-specific information in North Anna 3 COL FSAR Section 2.4.14 to address ESP COL Action Item 2.4-2. The COL applicant stated that North Anna 3 will be shut down when the water level in Lake Anna drops below the elevation of 73.50 m (241.14 ft) NAVD88. The COL applicant added that this operational restriction is not related to the protection of safety-related SSCs or degradation of the UHS and is therefore not a TS limiting condition for operation (LCO).

2.4.14.3 Regulatory Basis

The relevant requirements of the Commission regulations for the TSs and emergency operation requirements, and the associated acceptance criteria, are in Section 2.4.14 of NUREG–0800. The applicable regulatory requirements are as follows:

- 10 CFR Part 100, as it relates to identifying and evaluating hydrological features of the site. The requirements to consider physical site characteristics in site evaluations are specified in 10 CFR 100.20(c).

- 10 CFR 100.23(d), sets forth the criteria to determine the citing factors for plant design bases with respect to seismically induced floods and water waves at the site.

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

- 10 CFR 50.36, “Technical Specifications,” as it relates to identifying limiting conditions on TSs for safe operation of the plant.

The following related acceptance criteria are summarized from SRP Section 2.4.14:

- Bases for Emergency Actions: To meet the requirements of 10 CFR 50.36 and 10 CFR Part 100, an assessment of the hydrological bases for emergency actions is needed.

- Available Response Time: To meet the requirements of 10 CFR 50.36 and 10 CFR Part 100, estimates of available response times to initiate and complete emergency procedures are needed.

- Technical Specifications: To meet the requirements of 10 CFR 50.36 and 10 CFR Part 100, the applicant’s proposed TSs related to emergency procedures are reviewed.

- Consideration of Other Site-Related Evaluation Criteria: To meet the requirements of 10 CFR 50.36 and 10 CFR Part 100, the applicant’s assessment of the potential effects of site-related proximity, seismic, and non-seismic information on the postulated TSs and emergency operations is needed.

In addition, the hydrologic characteristics should be consistent with appropriate sections from: RGs 1.29, 1.59, and 1.102.

2.4.14.4 Technical Evaluation

As documented in Section 2.4.14 of NUREG-1966, the staff reviewed and approved information related to TSs and emergency operation requirements for the certified ESBWR DCD, Revision 10. The staff reviewed Section 2.4.13 of the North Anna 3 COL FSAR, Revision 9, and checked the referenced ESBWR DCD and the North Anna ESP SSAR to ensure that the combination of the information in the North Anna 3 COL FSAR and the information in the ESBWR DCD and ESP SSAR that represent the complete scope of information relating to this review topic.

The staff's review confirms that the information in the application and the information incorporated by reference address the required information related to "Accidental Release of Radioactive Liquid Effluent in Ground and Surface Waters."

In addition the staff reviewed the resolution to ESBWR DCD COL Item 2.0-25-A, related to the TSs 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 ESBWR DCD design, the COL applicant's selection of design basis plant grade, and the flood protection measures described in Section 2.4.10 of this SER, no emergency procedures or TSs are necessary to prevent hydrological phenomena from degrading the UHS.

Appendix A of the North Anna ESP specifies that the minimum lake water level for operation of North Anna 1, 2, and 3 is elevation 73.50 m (241.14 ft) NAVD88. In North Anna 3 COL FSAR Section 2.4.14 the COL applicant committed to shut down North Anna 3 when the water level in Lake Anna drops below elevation 73.50 m (241.14 ft) NAVD88. 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 section.

2.4.14.6 Conclusion

The staff reviewed the application and checked the referenced DCD and confirms that the COL applicant has addressed the required information, and no outstanding information remains to be addressed in the North Anna 3 COL FSAR related to this section. The review confirmed that no emergency procedures or TSs are necessary to prevent hydrological phenomena from degrading the UHS.

In addition, the staff compared the additional information in the COL to the relevant NRC regulations, the guidance in Section 2.4.14 of NUREG–0800, and NRC RGs. The staff's review concludes that the applicant has provided sufficient information to satisfy the requirements of NRC regulations. The staff has determined that the applicant has adequately addressed NAPS COL Item 2.0-25-A as it relates to TSs and emergency operation requirements.

As set forth above, the applicant has presented and substantiated information relative to the TSs and emergency operations important to the design and siting of this plant. The staff has reviewed the available information provided and for the reasons given above, concludes that the identification and consideration of the TSs and emergency operations is acceptable and meets the requirements of 10 CFR 50.36, 10 CFR 52.79(a)(1)(iii), 10 CFR 100.20(c), and 10 CFR 100.23(d) with respect to determining the acceptability of the site.

2.5 Geology, Seismology, and Geotechnical Engineering

In Section 2.5, “Geology, Seismology, and Geotechnical Engineering,” of the North Anna 3 FSAR, the applicant described the geologic, seismic, and geotechnical engineering properties of the North Anna 3 COLA 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 and ESBWR DCD Revision 10; 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 North Anna 1 and 2, abandoned foundation mats for Units 3 and 4, and the independent spent fuel storage installation (ISFSI).

The COL FSAR, Section 2.5, provides variances to the ESP SSAR based on new information regarding: (a) the **M**5.8 earthquake that occurred on August 23, 2011, in Mineral, Louisa County, Virginia, and the results of a geological reconnaissance to investigate any surface features associated with the earthquake in the site vicinity; (b) incorporation of the CEUS-SSC model (NUREG-2115); and (c) additional borings to support North Anna 3 ESBWR investigation. The COL FSAR Section 2.5 provides information to satisfy ESP permit conditions (conditions 4, 5, 6, 7); ESP VARs 2.5-2, 2.5-4, 2.5-7; and ESP COL Action 2.5-1. The staff has previously reviewed Section 2.5 of the North Anna 3 ESP SSAR and its findings are documented in NUREG-1835.

The staff reviewed North Anna 3 COL FSAR Section 2.5, interacted with the applicant during public meetings, and issued RAIs to confirm the assertions made by the applicant in the North Anna 3 COL FSAR. In early versions of the North Anna 3 COL FSAR, the applicant used seismic source models developed in 1986 and 1989 by the EPRI, as the starting point for characterizing potential regional seismic sources and resulting vibratory ground motion, and then updated these seismic source models in light of more recent data and evolving knowledge. The applicant later replaced the original EPRI (1989) ground motion models (GMM) with more recent EPRI models (2013), and applied the performance-based approach described in RG 1.208, “A Performance-Based Approach to Define the Site-Specific Earthquake Ground Motion,” which incorporates PSHA, to develop ground motion response spectra (GMRS) for the site. The applicant subsequently replaced those models with the new seismic source characterization model for the central and eastern United States (CEUS-SSC) published in NUREG-2115, “Central and Eastern United States Seismic Source Characterization for Nuclear Facilities” in response to RAI 02.05.02-4 dated February 13, 2012 (ADAMS Accession No. ML12048A096), which requested the applicant to evaluate the seismic hazard in light of the August 23, 2011, Mineral, Virginia, earthquake.

Further, following the 2011 Fukushima Dai-Ichi nuclear power plant accident in Japan, which occurred as a result of the Great Tohoku earthquake and the subsequent tsunami, the NRC Near-Term Task Force (NTTF) issued a series of recommendations for reevaluating and improving nuclear power plant safety in the U.S. Consequently, on March 12, 2012, the NRC issued an information letter requesting that licensees of all operating nuclear power plants in the U.S. reevaluate the seismic hazard at their respective plants using the most recent data and evaluation methodologies available. That information letter also requested that licensees of operating plants in the CEUS use the seismic source model provided in NUREG-2115 to characterize seismic hazard at their respective plants. Consistent with existing guidance in RG 1.208, pertaining to the need to consider the latest information in the evaluation of seismic hazard, the NRC also requested that all COL and ESP applicants in the CEUS address seismic hazard for their respective proposed plant sites using information in NUREG-2115 and modify the GMRS, if needed. The staff issued this request to North Anna 3 in RAI 01.05-1 dated June 25, 2012 (ADAMS Accession No. ML12214A593).

In a December 18, 2013, response to RAI 01.05-1 (ADAMS Accession No. ML14013A113), the applicant stated that RAI 01.05-1 is no longer applicable to the North Anna 3 site, because it replaced the previous EPRI seismic source models with the CEUS-SSC model presented in NUREG-2115 as the starting point for developing GMRS for the North Anna 3 site in response to RAI 02.05.02-4 dated February 13, 2012 (ADAMS Accession No. ML12048A096).

With this change in the base seismic source model, some of the RAIs the staff previously asked of the applicant became unnecessary, as described in SER Section 2.5.2.4. Therefore, this SER references only the most recent version of the North Anna 3 COL FSAR and the staff’s technical evaluation of that version without discussing the replaced portions of the previous North Anna 3 COL FSAR and some of the staff’s earlier RAIs, which are now unnecessary and closed without specific resolution. The following sections of this report discuss the RAIs that remain applicable to the staff’s review following the change in the base seismic source model, along with the new RAIs related to the most recent version of the North Anna 3 COL FSAR.

2.5 Geology, Seismology, and Geotechnical Engineering

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 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 3 COLA. 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 RAIs, open items, and confirmatory analyses performed by the staff. SER Section 2.5.1.5 discusses any post COL 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.

COL FSAR Section 2.5.1, and by reference the ESP SSAR Section 2.5.1, describes the geologic information that the COL applicant collected during site investigations to address regional and site-specific geologic characteristics derived from previous work and from surface and subsurface investigations. The COL applicant stated it reviewed previous site investigations for North Anna 1 and 2, and abandoned Units 3 and 4 for the geologic properties of the COL site. Additionally, COL FSAR Section 2.5.1, and by reference the ESP SSAR Section 2.5.1, includes newly published information and the recent geologic, seismic, geophysical and geotechnical investigations conducted for North Anna 3. Finally, COL FSAR Section 2.5 includes information on the **M**5.8 earthquake that occurred on August 23, 2011, in Mineral, Louisa County, Virginia, and the results of the geological field reconnaissance program to investigate any surface features associated with the earthquake in the site vicinity.

The COL applicant conducted these investigations to assess geologic and seismic suitability of the site, to determine whether new geologic or seismic data exist that could significantly impact seismic design based on the results of PSHA, and to provide the geologic and seismic data appropriate for plant design.

2.5.1.2 Summary of the Application

Section 2.5.1 of the North Anna 3 COL FSAR, incorporates by reference Section 2.5.1 of the North Anna 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 North Anna 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 3 ESP SER (NUREG-1835) and summarized in Part 3, Section E of the North Anna ESP (ADAMS Accession No. ML073180440).

COL Items, ESP Variances, and ESP Permit Conditions:

- NAPS COL 2.0-26-A

The applicant incorporated by reference Section 2.5.1 of the North Anna 3 ESP SSAR to address NAPS COL 2.0-26-A (ESBWR DCD COL Item 2.0-26-A) which requires that a COL applicant referencing the ESBWR design to provide basic geologic and seismic information for the site in accordance with SRP 2.5.1.

- NAPS ESP VAR 2.0-4

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

- NAPS ESP COL 2.5-1

The applicant provided additional information to address ESP COL Action Item 2.5-1, which states that the COL applicant should perform additional borings in the subsurface to identify any weathered or fractured rock beneath the new foundations.

- ESP Permit Condition 3.E(4)

The applicant provided additional information to address ESP Permit Condition 3.E(4), which requires the replacement of weathered or fractured rock at the foundation level with lean concrete before initiation of foundation construction.

- ESP Permit Condition 3.E(5)

The applicant provided additional information to address ESP Permit Condition 3.E(5), which prohibits the applicant from using engineered fill with high compressibility and low maximum density, such as saprolite, in the construction of North Anna 3.

- ESP Permit Condition 3.E(6)

The applicant provided additional information to address ESP Permit Condition 3.E(6), which 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 applicant should notify the NRC no later than 30 days before any excavations for safety-related structures are open for NRC's examination and evaluation.

Regional Tectonic Setting

COL FSAR Section 2.5.1.1.4 describes the new PSHA based on the CEUS-SSC model described in NUREG-2115. The CEUS-SSC model (NRC, 2012) replaces the previous PSHA based on the Electric Power Research Institute–Seismicity Owners Group (EPRI-SOG) model (EPRI, 1988, 1989) and the Lawrence Livermore National Laboratory model (LLNL, 1993, NUREG/CR-5250, “Seismic hazard characterization of 69 nuclear plant sites east of the Rocky Mountains.”). The applicant described the Extended Continental Crust-Atlantic Margin Zone (ECC-AM) as the CEUS-SSC host source for the North Anna 3 site.

Principal Tectonic Structures

COL FSAR Section 2.5.1.1.4.c indicates that the host seismotectonic zone for the site is the ECC AM (Figure 2.5.1-1 of this report) and that this zone includes Mesozoic extensional structures formed during the opening of the Atlantic Ocean. The COL applicant stated that no basin-margin faults have been reactivated during the Quaternary in the site region and that any reactivation of faults bordering or beneath Mesozoic basins is addressed in the CEUS-SSC model. The Stafford fault system, a Tertiary tectonic structure and also located within the ECC-AM, does not reveal any geologic or geomorphic evidence of Quaternary activity based on the COL applicant’s field and aerial reconnaissance. The COL applicant indicated that the Stafford fault system is not included as a Quaternary structure in Crone and Wheeler (2000) and thus concluded that it is not a capable tectonic source. In the Quaternary Tectonic Features Section, the COL applicant explained that aftershock data from the August 23, 2011, **M**5.8 Mineral earthquake delineates a previously unmapped geologic structure named the “Quail fault” (Horton et al. 2012, 2014, 2015). The COL applicant concluded that this structure does not fit the criteria for a repeated large magnitude earthquake (RLME) source per NUREG-2115. The FSAR provides information regarding other tectonic features in the site region that have been considered as possibly

Quaternary age such as the paleoliquefaction sites of Obermeier and McNulty, the Everona-Mountain Run Fault Zone, and the East Coast Fault System. None of these tectonic features fit the criteria for a RLME source. Each of these features is considered within the ECC-AM source zone in the CEUS-SSC model.

Seismic Sources Defined by Regional Seismicity

COL FSAR Section 2.5.1.1.4.d describes modifications made to seismic sources defined by regional seismicity based on new data and information in CEUS-SSC model. The Central Virginia Seismic Zone (CVSZ) is located within the ECC-AM seismotectonic source zone of the CEUS-SSC model and includes the August 23, 2011, Mineral, Virginia, earthquake (Figure 2.5.1-1 of this report). The COL applicant stated that the **M**5.8 Mineral earthquake main shock is included in the updated seismicity catalog and indicates reverse motion at a final depth of 6.0 km (4 mi). The COL applicant modeled a possible rupture plane based on aftershock data (Figure 2.5.1-2 of this report). Researchers investigating the epicentral area immediately after the earthquake described several liquefaction features associated with the earthquake.

The COL FSAR also describes the Giles County Seismic Zone located within the Paleozoic extended zone (PEZ) seismotectonic source zone and that the maximum magnitudes (M_{max}) for the Giles County Seismic Zone and Eastern Tennessee Seismic Zone (ETSZ) sources were incorporated into the CEUS-SSC model. The COL applicant used the Charleston and New Madrid Seismic Zones as RLME sources from the CEUS-SSC model to predict seismic hazard at the North Anna 3 site. See specific details regarding the sensitivity analysis of these RLME sources in SER Section 2.5.2.

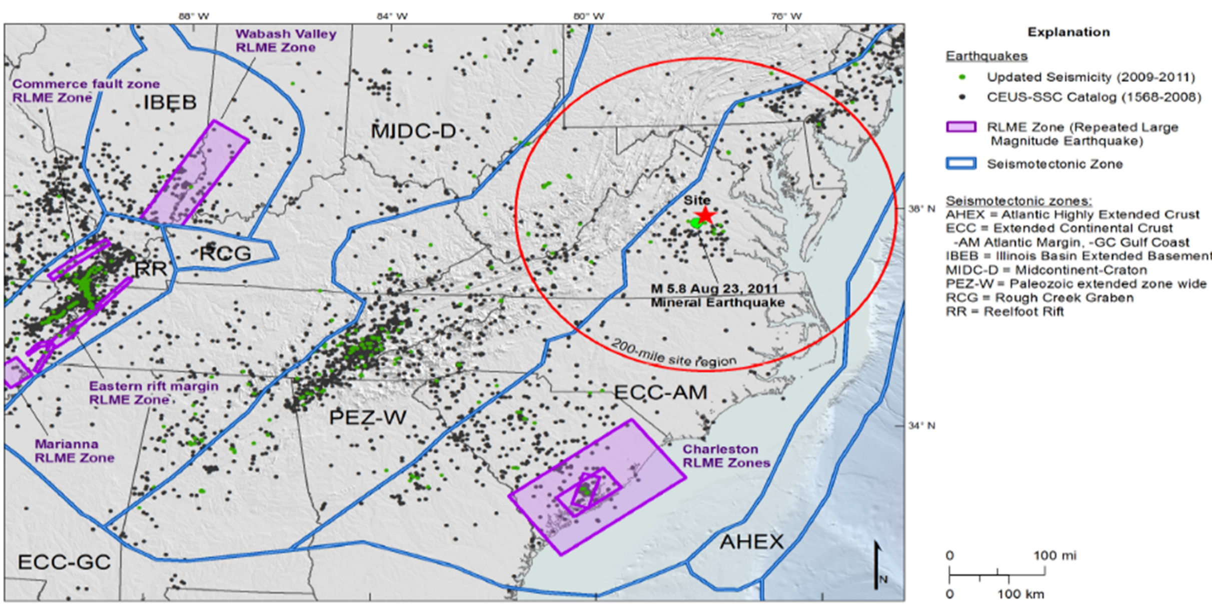


Figure 2.5.1-1. NAPS site region with seismotectonic source zones and the August 2011 Mineral, Virginia, earthquake (from FSAR Figure 2.5.1-202, Rev. 8)

Geologic Bases for Defining Relevant Source Zones

COL FSAR Section 2.5.1.1.6 details the geologic bases for defining relevant source zones. The North Anna 3 site is located within the ECC-AM seismotectonic source zone, a region comprised of rifted and extended continental crust that developed from the Mesozoic rifting that created the Atlantic Ocean and an older basal detachment fault that separates the over-thrusted Appalachian terranes from underlying Precambrian rocks of the North American craton. The COL applicant explained that a global study of earthquakes in stable continental regions (SCRs) (Johnston et al., 1994) and the CEUS-SSC model indicate that Mesozoic and younger extended crust has produced all M ≥ 7 stable craton earthquakes worldwide. The Paleozoic extended crust source zone, located immediately west of the ECC-AM, is comprised of terrane rifted during the Iapetan crustal extension. The COL applicant stated that normal faults formed during the opening of the Iapetus Ocean in this zone created zones of crustal weakness that exhibit a higher rate of seismicity and appear to coincide with the Giles County and the ETSZs.

Information on the August 23, 2011 Mineral, Virginia, Earthquake

The North Anna 3 site is located within the CVSZ, an area of persistent, low-level seismicity in the Piedmont Province and the ECC-AM seismotectonic zone. COL FSAR Section 2.5.1.1.7 describes the seismicity characteristics of the Mineral earthquake and the geologic field reconnaissance completed by the COL applicant to evaluate and document surface deformation from the Mineral earthquake. The COL applicant delineated a zone of possible surface deformation from the Mineral earthquake by fitting a rupture plane to aftershocks relocated by McNamara et al. (2014) and projecting this plane up-dip to the surface (Figure 2.5.1-2 of this report). The rupture plane strikes approximately N30ºE, dipping 45-50º SE with a length of ~6.2 mi (10 km) between the town of Quail, Virginia, and the headwaters of Despar Creek. The COL applicant indicated that the Mineral earthquake was a reverse faulting event that ruptured at a shallow depth (6.0 ± 3.1 km) and the up-dip surface projection of its rupture plane is located within the Chopawamsic Formation (Figure 2.5.1-3) (Burton et al. 2014).

The COL applicant performed a geologic reconnaissance field program (FSAR Section 2.5.1.1.7b) and acquired and processed Light Detection and Ranging (LiDAR) data covering a region encompassing the rupture plane of the Mineral earthquake and the proposed North Anna North Anna 3 site (Figure 2.5.1-4). The COL applicant used LiDAR as a basis for its geomorphic evaluation to document any coseismic surface rupture or other visible deformation at the surface in the Mineral earthquake epicentral region. The LiDAR package included a bare earth Digital Elevation Model (DEM), hillshade, slope and contour maps and orthophotography. The COL FSAR describes the search for evidence of regional fault-related geomorphic features, including geomorphic lineaments caused by active faulting, stream gradient changes or offsets, and contrasting large topographic features. On the ground field reconnaissance by the COL applicant included a search for ground fissures or compressional ground buckling, springs or artesian conditions, changes in vegetation growth, minor fault scarps, fault controlled drainages, and cracked or offset pavement along roads that might indicate surface deformation.

The COL applicant identified strong topographic lineaments in the LiDAR data and suggested that the lineaments reveal contrasts in erosion susceptibility between different geologic units. No liquefaction features were found during the field reconnaissance; however, the COL applicant stated that a few liquefaction features generated by the Mineral earthquake are described by researchers who investigated the epicentral area immediately following the earthquake. The COL applicant concluded that the **M**5.8 earthquake did not produce any discernible rupture or deformation at the ground surface and the Mineral earthquake did not rupture on a previously mapped fault.

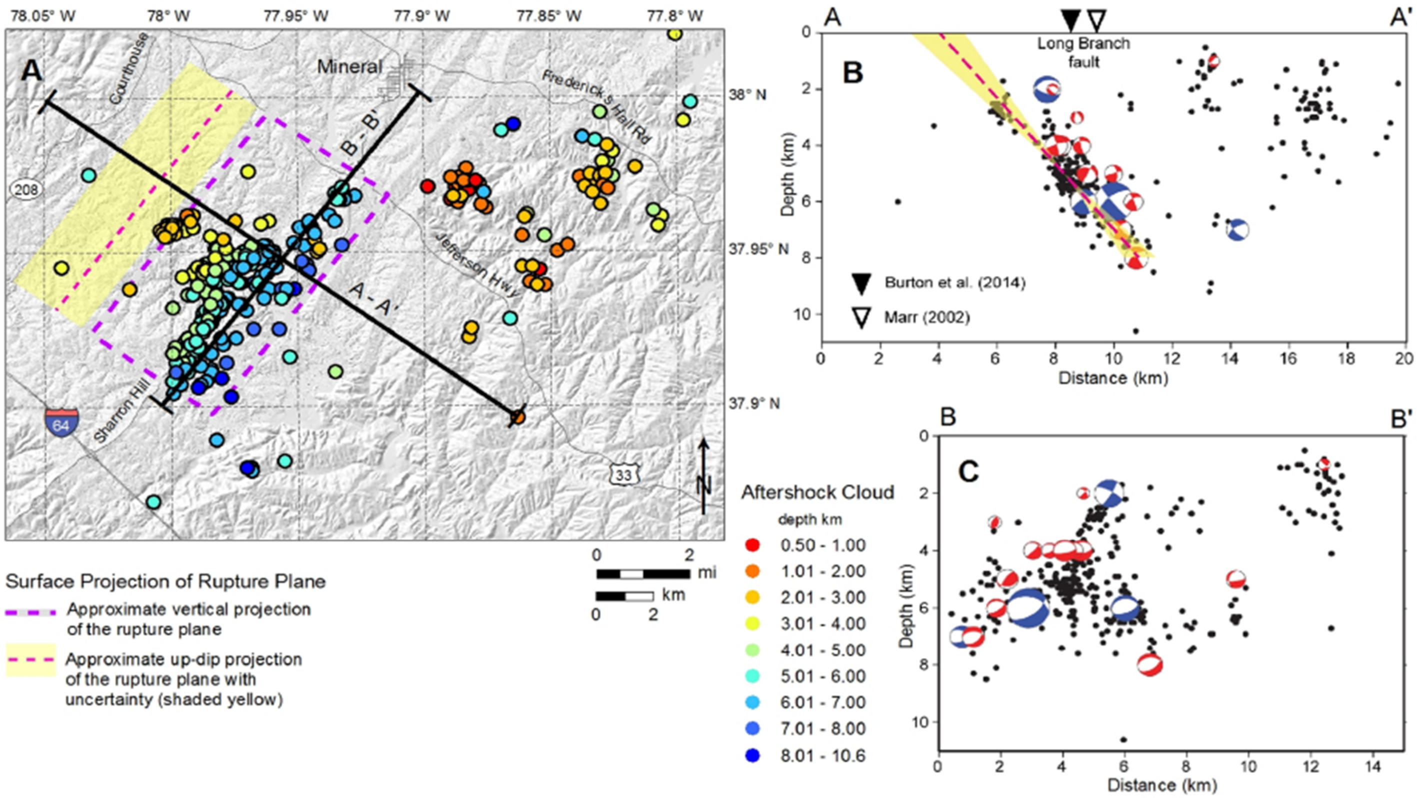


Figure 2.5.1-2. August 2011 Mineral, VA, earthquake aftershocks map and cross-sections illustrating subsurface rupture plane (from McNamara et al. (2014) taken from FSAR Figure 2.5.1-209, Rev. 9

Site Area Stratigraphy

COL FSAR Section 2.5.1.2.3 presents additional information based on supplemental borings collected at the North Anna 3 site in support of the ESBWR DCD, which include 93 borings, 23 cone penetrometer tests (CPTs), along with test pits, borehole geophysical logging, shear wave suspension loggings, and electrical resistivity tests. Details of this subsurface investigation are in FSAR Section 2.5.4 and in appendices 2.5.4 AA, 2.5.4 BB, 2.5.4 CC. The COL applicant briefly described the extent of various zones of fresh to weathered rock, including saprolite, as modified by the supplemental boring program.

The COL FSAR Section 2.5.1.2.3 also adds new information regarding the Ellisville pluton, based on new geologic mapping at the 1:24,000 scale in the northern half of the Ferncliff, Virginia, 7.5 minute quadrangle that suggests that the Ellisville pluton (approximately 440 Ma) cross-cuts and post-dates the Chopawamsic thrust fault (Hughes and Hibbard, 2012).

Site Area Structural Geology

The previous ESP SSAR Section 2.5.1.2.4 lists seven bedrock faults identified within a 5-mile radius of the site: Spotsylvania thrust, Chopawamsic thrust, Long Branch thrust, Sturgeon Creek fault, Unnamed fault (“a”) traversing the North Anna 3 site, Unnamed fault (“b”) separating the Ta River Metamorphic Suite from the Quantico Formation, and Unnamed fault (“c”) separating the

Northeast Creek pluton from the Quantico Formation. In the COL FSAR Section 2.5.1.2.4, the COL applicant stated that none of these faults are capable tectonic sources per RG 1.208.

Site Engineering Geology Evaluation

The COL FSAR Section 2.5.1.2.6 briefly describes the engineering behavior of soil and rock quality designations (RQD) and references details in Appendices 2.5.4 AA, 2.5.4 BB, and 2.5.4 CC. The COL applicant stated that results from the previous geotechnical investigations (ESP SSAR References 7 and 8), and for both the ESP subsurface investigation (ESP SSAR Appendix 2.5.4 B) and the North Anna 3 subsurface investigation (Appendices 2.5.4AA, 2.5.4BB, and 2.5.4CC) indicate that Zone III, III-IV, and IV Rock are suitable bearing surfaces for founding seismic Category I structures and that the density and area extent of jointing and fracturing in these zones is not extensive enough to affect engineering behavior of the rock. The COL applicant also stated that weathered and fractured rock at the foundation level for safety-related features would be excavated and replaced with lean concrete before initiation of foundation construction. In addition, the COL applicant also stated that future excavations for safety-related structures would be geologically mapped in order to detect and evaluate unknown geologic features at the site.

2.5.1.3 Regulatory Basis

The regulatory basis of the information incorporated by reference is addressed within the FSER related to the ESBWR DCD and its supplements and in NUREG-1835.

The applicable regulatory requirements for reviewing the applicant's discussion of geologic and seismic information are:

10 CFR 52.79(a)(1)(iii), "Contents of applications; technical information in the final safety analysis report," relates to identifying geologic site characteristics 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.

10 CFR Part 100, Section 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 2.5.1:

Regional Geology: In meeting the requirements of GDC 2 in Appendix A of 10 CFR Part 50, 10 CFR 52.17, 10 CFR 52.79 and 10 CFR 100.23 (c) and guidance in RGs 1.206, 1.208 and 4.7, the description of regional geology is acceptable if a complete and documented discussion is presented for the geologic setting, tectonic framework and conditions caused by human activities, that have the potential to affect the safe siting and design of the plant. This section should contain a review of regional stratigraphy, lithology, structural geology, geologic and tectonic history, tectonic features (with emphasis on the Quaternary period), seismology, geomorphology, paleoseismology, and physiography within the 320 km (200 mi) site region or beyond as necessary to provide a framework within which significance to safety can be evaluated concerning geology, seismology, and conditions caused by human activities. Geologic maps and cross-sections constructed at scales adequate to illustrate relevant regional features should be included in the application.

Site Geology: In meeting requirements of 10 CFR 52.79 and 10 CFR 100.23, and regulatory positions presented in RG 1.208, 1.206, and RG 4.7, the description of site geology is considered acceptable if it contains a description and evaluation of geologic (including tectonic and non-tectonic) features, geotechnical characteristics, seismic conditions, and conditions caused by human activities at appropriate levels of detail within areas defined by circles drawn around the site using radii of 40 km (25 mi) for site vicinity, 8 km (5 mi) for site area, and 1 km (0.6 mi) for site location. In addition, the geologic characteristics should be consistent with appropriate sections from; RG 1.208, and RG 1.206.

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 Section 2.5.1 of the North Anna 3 COL FSAR and checked the referenced ESBWR DCD, Revision 10 and the North Anna 3 ESP SSAR, to ensure that the combination of the DCD, the North Anna 3 ESP SSAR and the COLA represents the complete scope of information related to this review topic.[1]

The staff's review confirms that the information in the COL FSAR and incorporated by reference addresses the required information for geologic characterization information.

The staff's technical evaluation of COL FSAR Section 2.5.1 is limited to reviewing (1) the resolution of DCD COL Item 2.0-26-A and ESP Action 2.5-1; (2) adherence to Permit Condition Section(E)(6); (3) resolution of ESP VAR 2.0-4 and; (4) applicant's responses to RAIs, as addressed below.

<u>COL Items, ESP Variances, and ESP Permit Conditions:</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 stratigraphy, engineering geology evaluation, and groundwater conditions as determined from additional subsurface investigations conducted at the North Anna 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 concludes 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 North Anna 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 m (206 to 285 ft) and again from 56.9 to 89.0 m (187 to 292 ft) and from 53.0 to 84.7 m (174 to 278 ft). The elevations corresponded too moderately to highly weathered Zone III rock, slightly too moderately weathered Zone II-IV rock, and slightly weathered to fresh Zone IV rock, respectively. Because the applicant identified the subsurface elevation where weathered rock occurs beneath the foundations, the staff concludes this information is sufficient to satisfy the requirements of ESP Action Item 2.5-1. Therefore, the staff considers ESP COL Action Item 2.5-1 to be resolved.

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

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 planned action, 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 North Anna 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.

Permit Condition 3(E)(6) requires the applicant to provide geologic mapping information for future excavations of safety-related structures and to evaluate any unforeseen geologic features that are encountered. The applicant is also required to notify the NRC no later than 30 days before any such excavation is open for NRC examination and evaluation. An applicant for a construction permit (CP) or COL referencing this ESP shall perform geologic mapping of any excavation for a safety-related structure, evaluate any unforeseen geologic features that are encountered, and notify the NRC no later than 30 days before any such excavation is open for NRC examination and evaluation. This permit condition has been carried forward as a license condition for future excavations of safety-related structures (Section 2.5.1.4, this report).

The North Anna 3 COL FSAR Section 2.5.1, "Basic Geologic and Seismic Information," incorporates by reference the North Anna 3 SSAR Section 2.5.1. The staff reviewed the COL FSAR variance to the ESP SSAR (North Anna 3 ESP VAR 2.0-4) for the North Anna 3 FSAR Section 2.5.1 and submitted several RAIs. The staff's evaluation of this variance to the ESP SSAR in COL FSAR Section 2.5.1 and of the COL applicant's responses to staff RAIs is presented below.

Basic Geologic and Seismic Information

The COL FSAR Section 2.5.1, and by reference the ESP SSAR Section 2.5.1, includes newly published information and the recent geologic, seismic, geophysical, and geotechnical investigations conducted for North Anna 3. This includes information on the **M**5.8 earthquake that occurred on August 23, 2011, in Mineral, Louisa County, Virginia, and the results of the geological field reconnaissance program (FSAR Section 2.5.1.1.7b) to investigate any surface features associated with the earthquake in the site vicinity. In COL FSAR Section 2.5.1, Basic Geologic and Seismic Information, the COL applicant stated that they contacted the USGS, State geological survey organizations, and universities and identified relevant unpublished geologic literature, studies, and projects. Since a large part of this new information on the effects of the Mineral earthquake is not yet in peer reviewed publications, staff asked the applicant in RAI 02.05.01-1 dated April 22, 2014 (ADAMS Accession No. ML14112A156), to provide further details regarding research by others and to explain how they have considered the findings and interpretations of others in their characterization of the CVSZ and the effects of the Mineral earthquake.

In a May 21, 2014 response to RAI 02.05.01-1 (ADAMS Accession No. ML14143A239), the COL applicant provided a list of persons contacted within various organizations and a summary of the topics that were discussed. The COL applicant attended professional conferences, visited USGS and the Virginia Department of Mines, Minerals and Energy (DMME) offices and talked with geoscientists who were actively collecting and analyzing data from the Mineral earthquake including assessment of aftershock data, LiDAR analyses, geologic mapping and trenching, and investigation of liquefaction sites. This information guided the COL applicant in its own geologic reconnaissance of the epicentral area. The COL applicant used aftershock data analysis by M. Chapman of Virginia Tech to direct the field team to areas where surface effects from the Mineral earthquake would most likely have occurred. LiDAR data covering the epicentral area was subsequently obtained from interstate 64 to the northeast shore of Lake Anna. The COL applicant reviewed and compared various mapping products from USGS, DMME and NC State University researchers, included information from the ESP application and incorporated the information into the Geologic Reconnaissance Report. Key elements of the Geologic Reconnaissance Report are included in the revised FSAR Section 2.5.1 because of FSAR revisions made by the COL applicant in various RAI responses (RAI 02.05.01-4, 5, 02.05.01-8). The COL applicant provided a summary of the geologic reconnaissance program in FSAR Section 2.5.1.1.7b and c.

The staff reviewed the COL applicant's RAI response and also talked with geoscientists presenting recent research on the effects of the Mineral earthquake at the GSA southeastern section meeting in Blacksburg, VA, March 2014. In addition, staff audited the COL applicant's Geologic Reconnaissance Report in Frederick, MD on March 11, 2014. The staff's audit summary is available in ADAMS Accession No. ML14203A211. The Geologic Reconnaissance Report includes a compilation and evaluation of published information, communications with other researchers, and a geomorphic evaluation of LiDAR data acquired by Dominion for this project related to the potential for surface deformation in the site vicinity for North Anna Power Station North Anna 3. Based on the RAI response, staff's own contact with active investigators and staff's audit of the COL applicant's Geologic Reconnaissance Report, staff acknowledges that the COL applicant reached out to known active investigators to capture the breadth of scientific understanding currently available for the geologic effects of the Mineral earthquake. Accordingly and in compliance with 10 CFR 100.23 and 10 CFR 52.79, the staff considers RAI 02.05.01-1 resolved and closed.

Regional Tectonic Setting

In FSAR Section 2.5.1.1.4, Regional Tectonic Setting, the COL applicant describes the orientation of tectonic stress in the site region. The staff notes that Mazzotti and Townend (2010) determined that the principle horizontal stress direction in the CVSZ is essentially east to west, rotated 48 degrees clockwise from the regional northeast to southwest stress direction. In RAI 02.05.01-2 dated April 22, 2014 (ADAMS Accession No. ML14112A156), the staff asked the COL applicant to provide a discussion regarding the current local stress field within CVSZ and the focal mechanisms of the Mineral earthquake and aftershocks and the impact on suitably or susceptibly oriented faults in the area.

In a May 21, 2014, response to RAI 02.05.01-2 (ADAMS Accession No. ML14143A239), the COL applicant stated that the recently revised world stress map indicates an overall NE-SW maximum horizontal compressive stress orientation throughout the eastern and central US (Hurd and Zoback, 2012). This was based on borehole breakout tests and hydrofracturing, and to a lesser extent on earthquake focal mechanisms. The COL applicant stated that for the CVSZ specifically, Mazzotti and Townend (2010) based their findings on 13 earthquake focal mechanisms. Hurd and Zoback (2012) also report an E-W direction to stress for the CVSZ. The COL applicant concluded that this is strong corroborating evidence that the E-W stress field is real and deviates from the regional NE-SW stress direction. The E-W stress field is more consistent with the Mineral earthquake data than the regional NE-SW stress field. For the focal mechanisms of the Mineral earthquake, the COL applicant cited McNamara et al. (2014) who found that locations and focal mechanisms from the Mineral earthquake and aftershocks indicate a rupture plane striking approximately N36 degrees E, dipping 49 degrees ESE, with a reverse slip focal mechanism. The COL applicant stated that other NE to SW oriented structures, aligned with the regional tectonic fabric, are thus favorably oriented for reactivation within the local stress field.

The staff considered the RAI responses and reviewed the findings of Mazzotti and Townend (2010) and Hurd and Zoback (2012). The staff agrees with the COL applicant's conclusions in that the local stress field is consistent with the character of the Mineral earthquake and that other NE-SW striking structures are favorably oriented for reactivation in this area. Accordingly and in compliance with 10 CFR 100.23 and 10 CFR 52.79, the staff considers RAI 02.05.01-2 resolved and closed. The COL applicant provided a proposed COL revision to include portions of the RAI response in a future revision of the North Anna 3 FSAR. The staff finds the proposed COL FSAR changes acceptable and verified that the appropriate changes are incorporated into the FSAR, Revision 9, and, therefore, Confirmatory Item 2.5.01 from the staff's advanced SER for North Anna 3 is resolved and closed.

Central Virginia Seismic Zone

The COL applicant stated in the section on the CVSZ, that researchers who investigated the epicentral area immediately following the 2011 Mineral earthquake describe several liquefaction features generated by the earthquake. In RAI 02.05.01-3 dated April 22, 2014 (ADAMS Accession No. ML14112A156), the staff asked the COL applicant to provide additional details regarding these recent features as well as the paleoliquefaction features documented by Obermeier and McNulty (1998), all within 30 miles of North Anna 3. The staff asked the COL applicant to discuss the possible impact to the SSC of the eastern part of the CVSZ in light of new age determinations on the paleoliquefaction sites.

In a June 23, 2014, response to RAI 02.05.01-3 (ADAMS Accession No. ML14177A441), the COL applicant explained that immediately following the August 23, 2011, Mineral earthquake, an Earthquake Engineering Research Institute (EERI) Geotechnical Extreme Events Reconnaissance (GEER) team of engineers and geologists initiated a regional ground reconnaissance program and identified two sites along the South Anna River where liquefaction occurred (EERI 2011) (Yancey-3 & BOR-2 sites). The COL applicant plotted the locations on high-resolution topographic hill shade maps derived from LiDAR data to show the local geomorphic context for these sites. Both these sites are within the 25-mile radius of North Anna 3.

The Yancey-3 site is located within the incised South Anna river channel near the intersection of Yanceyville and Vigor Roads and the South Anna River. These sand boils are small and the ejected material is described as well-graded sand with silt and gravel (Green et al., 2014). The Bor-2 site is about 3 km northwest of the Yancey-3 site, in a tributary channel of the South Anna River. Material ejected is described as silt. The EERI team reported that even though the sand boils resulted from liquefaction, the material properties, stratigraphy and liquefaction source zone were less than ideal. The COL applicant stated that given the magnitude and period of the Mineral earthquake, widespread liquefaction would not be expected.

The applicant also provided information about 3 paleoliquefaction sites that lie just beyond the site vicinity (Obermeier and McNulty, 1998) and a new figure (FSAR Figure 2.5.1-225) showing the locations of both the paleoliquefaction and the Mineral earthquake liquefaction sites relative to North Anna 3. The paleoliquefaction sites that are located on the James, Rivanna, and South Anna Rivers reveal a few small clastic dikes in riverbank deposits. Radiocarbon dates for the James River site indicate an age of a few hundred years. The other sites might be early to late Holocene age based on the severe weathering of the clastic dikes. Recent radiocarbon and Optically Stimulated Luminescence dates suggest ages between 2,000 to 900 years before present (Harrison et al., 2014). These dates were presented in conference and the specific context of the samples could not be evaluated with respect to previous dates. The COL applicant concluded that both the paleoliquefaction and the recent liquefaction sites are consistent with a local moderate-magnitude earthquake, similar to the 2011 Mineral earthquake.

The staff considered the information and maps provided in the RAI response and notes that the Mineral earthquake would not likely cause widespread, numerous liquefaction features based on the size of the earthquake and the lack of ideal liquefaction conditions in the region. The staff also reviewed the information in the Obermeier and McNulty (1998) publication. The staff agrees with the COL applicant’s conclusion that the paleoliquefaction features likely reflect moderate-size earthquakes, possibly similar to the Mineral earthquake. The staff notes that the North Anna 3 and the CVSZ are located in the ECC-AM host zone of the CEUS-SSC model that includes a large Mmax distribution for the zone and recurrence parameters derived from the historical seismicity. The staff thus concludes that the CEUS-SSC adequately captures the current understanding of the CVSZ. Accordingly and in compliance with 10 CFR 100.23 and 10 CFR 52.79, the staff considers RAI 02.05.01-3 resolved and closed. The COL applicant provided a proposed COL revision to include portions of the RAI response in a future revision of the North Anna 3 FSAR. The staff finds the proposed COL FSAR changes acceptable and verified that the appropriate changes are incorporated into the FSAR, Revision 9, and, therefore Confirmatory Item 2.5-02 from the staff’s advanced SER for North Anna 3 is resolved and closed.

Mineral Virginia Earthquake

In COL FSAR Section 2.5.1.1.7, the staff reviewed new information regarding the 2011 Mineral Virginia Earthquake. The COL applicant stated that up-dip surface projections of aftershock data (now called Quail fault) served as a guide for geologic field reconnaissance to determine the possibility of surface deformation caused by the Mineral 2011 earthquake (Figure 2.5.1-2). In RAI 02.05.01-4a dated April 22, 2014 (ADAMS Accession No. ML14112A156), the staff asked the COL applicant to comment on the uncertainty of the surface projection of the geophysical data and discuss other clusters of aftershocks located to the northeast of the main cluster that might align with other structures. The staff also asked the COL applicant regarding other possible expressions of surface deformation, such as deformation expressed as an uplifted area in the hanging wall of the Quail fault.

In a June 10, 2014, response to RAI 02.05.01-4a (ADAMS Accession No. ML14162A436), the COL applicant stated that the field program focused on evidence for surface deformation in the epicentral area and the possible surface rupture zone. The surface rupture trace is one possible zone and was used as guide for field and remote sensing investigation. The COL applicant used information from McNamara et al. (2014) that provides a catalog of 365 aftershocks. The map of aftershock data reveal three discrete clusters of concentrated seismicity surrounded by a broader region of diffuse seismicity. The largest cluster contains the main shock. The staff notes that many investigators evaluated these data and proposed best-fit planes, which are intended to represent the location and geometry of the Mineral earthquake source. Horton et al. (2012, 2015) name the large cluster with the main shock, the Quail fault. The COL applicant focused their field program in the area where this fault projects to the surface as well as in the epicentral area (Figure 2.5.1-4). The Quail fault rupture plane is approximately 10 km long, 6 km wide, strikes N30E, and dips SE 45-55 degrees at depths from 8 to 2 km.

The COL applicant stated that the other subsidiary clusters lie east of the main cluster, typically contain aftershocks with local magnitudes of 2.6 or less, and are located at shallow depths less than 4 km. No studies available at this time have defined rupture planes or characterized potential sources from these subsidiary clusters. Also, McNamara et al. (2014) describe only one focal mechanism for aftershocks outside the main cluster, and its orientation is significantly different than those of the main cluster. The COL applicant stated that these subsidiary clusters of aftershocks do not appear to be structurally linked with the main aftershock plane and likely represent minor triggered slip on multiple, minor shears of limited extent in a zone of otherwise highly deformed bedrock. The COL applicant provided an enhanced map and cross section of the McNamara et al. (2014) aftershock data with labels to indicate the location of known surface faults, focal plane mechanisms, and the projection of the rupture plane to the surface with uncertainty zones (Figure 2.5.1-2).

Based on the staff's examination of aftershock locations and in consideration of modeled best fit planes (Horton et al., 2015), the staff concludes that surface deformation associated with the Mineral earthquake would most likely be found in the surface projection zone defined by the main aftershock cluster, and within the boundaries of the COL applicant's field reconnaissance program. The staff also agrees with the COL applicant that fitting a plane to subsidiary aftershock clusters is inappropriate due to the diffuse distribution of hypocenters and the lack of focal mechanisms to constrain rupture orientation. The staff examined the waypoint stations and the extent of the stream profile evaluation and considered the analysis of aftershock data reported in McNamara et al. (2014). The staff determined that the scope of the field program covered the fault zone surface projection as well as the hanging wall area located above the epicentral area and concluded that this was the appropriate focus given the published aftershock data. Accordingly and in compliance with 10 CFR 100.23 and 10 CFR 52.79, the staff considers RAI 02.05.01-4a resolved and closed. The COL applicant provided a proposed COL revision to include portions of the RAI response in a future revision of the North Anna 3. The staff finds the proposed COL FSAR changes acceptable and verified that the appropriate changes are incorporated into the FSAR, Revision 9, and, therefore, Confirmatory Item 2.5-03 from the staff's advanced SER for North Anna 3 is resolved and closed.

Chopawamsic Fault

The COL applicant concluded, in COL FSAR Section 2.5.1.1.7, that the Chopawamsic fault is the nearest mapped structural surface to the projected surface expression of Quail fault on which a fault could be located and is a possible candidate for the causative fault for the Mineral earthquake. The staff notes that there are issues and recent changes to the mapped traces of faults in this area including the Chopawamsic fault. In RAI 02.05.01-4b dated April 22, 2014 (ADAMS Accession No. ML14112A156), the staff asked the COL applicant to provide more details regarding the location of the Chopawamsic fault.

In response to RAI 02.05.01-4b dated June 10, 2014 (ADAMS Accession No. ML14162A436), the COL applicant provided a revised history of mapping in the area and focused on the most recent mapping of Hughes and Hibbard, 2012 and (Burton et al. 2014) that place the Chopawamsic fault further northwest of previous interpretations. The staff notes that the

Chopawamsic fault, therefore, is most likely structurally below the aftershock cluster and the rupture plane of the Mineral earthquake and is not a source candidate for that earthquake.

Based on analysis of LiDAR based slope and relief maps, the COL applicant describes a NW facing and a SE facing pair of topographic scarps bounding the neck region of the Ellisville pluton, where granodiorite is in contact with the Chopawamsic Formation. (Burton et al. 2014) interpret both these contacts to be faulted and named the fault along the NW facing scarp the Harris Creek fault. The COL applicant suggests that the topographic scarps are likely an expression of erosion susceptibility differences between the granodiorite and the Chopawamsic Formation (metavolcanic, felsic to mafic compositions) rather than a tectonic expression. The applicant, using geologic and LiDAR derived elevation maps, points out that where the lithologic units divert from the trace of the fault, the scarp follows the lithologic contacts rather than the fault.

The staff notes that the NW facing topographic scarp is more or less coincident with the newly identified Harris Creek and Roundabout Farm faults and the surface projection of the Mineral earthquake rupture plane. The staff also note that the maps and figures (RAI 2.05.01-4b response, Figures 5A, 5B, and 6) provided for explaining the erosion susceptibility differences did not clearly support the observations stated in the text and that other interpretations were possible. Therefore, in a supplemental RAI 02.05.01-8 dated August 1, 2014 (ADAMS Accession No. ML14283A557), the staff asked the COL applicant to provide clarification and further justification that this is not a neotectonic signature in the landscape.

In a September 30, 2014, response to RAI 02.05.01-8a (ADAMS Accession No. ML14274A303), the COL applicant stated that the Harris Creek fault is largely coincident with the northwest-facing topographic scarp along approximately 10 km of the fault's mapped extent. The COL applicant provided several new figures (RAI response 02.05.01-8a, Figure 1B, 2A, 2B, 3A, and 3B) that illustrate the expression and extent of the topographic scarp and the geologic traces of the Harris Creek fault and Roundabout Farm faults. The staff observes, in the new figures, that the Harris Creek fault places Ellisville pluton granodiorite alongside Chopawamsic Formation for most of its extent and that the Harris Creek fault extends beyond or bifurcates from the topographic scarp to the SW and to the NE along the fault trace. There is a notable difference in erosion resistance between the granodiorite and the Chopawamsic formation lithology. The neck region of the Ellisville pluton is highly foliated (Burton et al., 2012) and susceptible to weathering and erosion whereas the Chopawamsic Formation, which includes mylonite, metafelsite, quartzite and schist, is more resistant to erosion. The Chopawamsic quartzite and schist (Ocqs map unit, Figure 2.5.1-3) is a relatively resistant unit within the Chopawamsic Formation and forms a series of linear ridges and topographic in the epicentral area. The COL applicant pointed out that the lineament, as characterized over most of its length, does not extend beyond Beaver Creek. The alignments of short, discontinuous and subtle landforms (i.e., ridges, spurs, small drainages) northeast of Beaver Creek do not match the continuity and prominence of the topographic scarp to the SW and are not coincident with the mapped trace of the Harris Creek fault. The staff notes that this difference is illustrated in RAI 02.05.01-8 dated August 1, 2014 (ADAMS accession No. ML14283A557), Figures 3A and 3B.

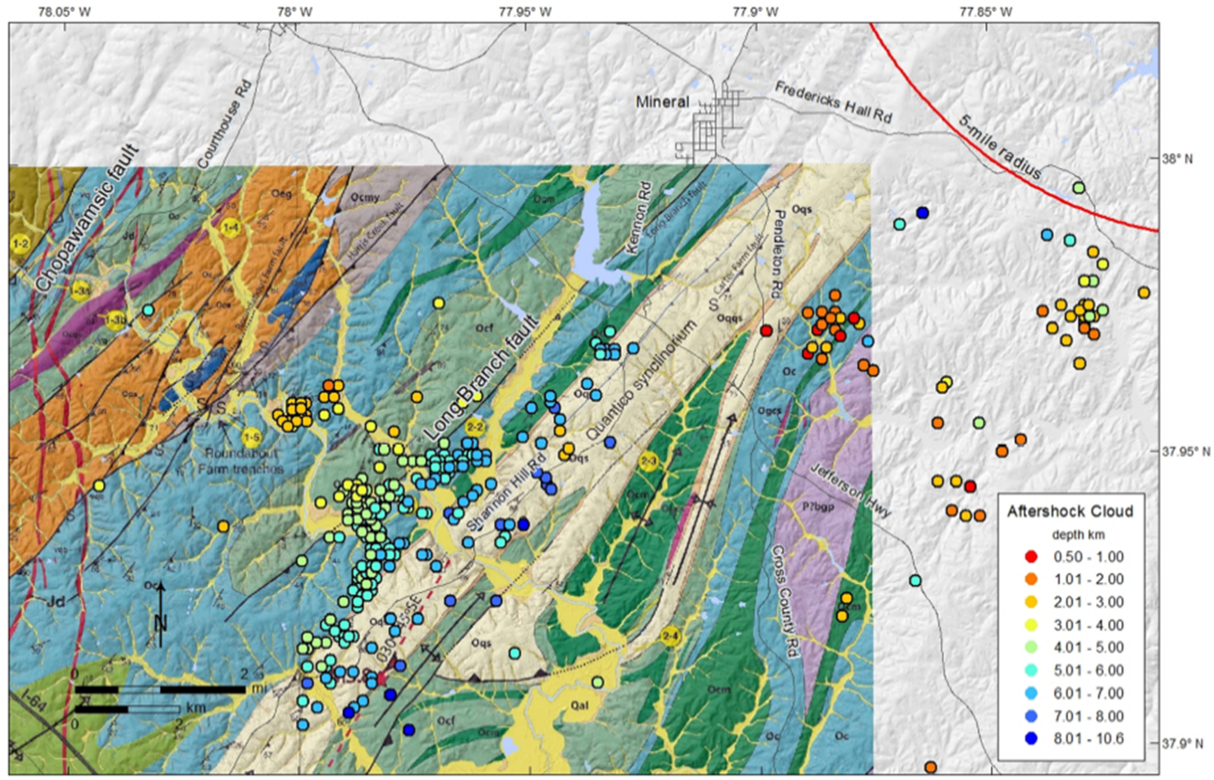


Figure 2.5.1-3. Recent geologic map (Burton et al. [2014]) and aftershocks (McNamara et al. 2014) in the 2011 Mineral, VA, earthquake epicentral area within 25 miles of the NAPS site (from FSAR Figure 2.5.1-210C, Rev. 9)

In supplemental RAI 02.05.01-8 dated August 1, 2014 (ADAMS Accession No. ML14283A557), the staff also asked the COL applicant for additional information regarding the tectonic significance high relief values concentrated in the up-dip projection of the Quail fault and the epicentral area in general as illustrated in Figure 6 of previous response to RAI 02.05.01-4, Part B.

In response, the COL applicant provided new map figures to provide a basis for their analysis regarding surface deformation related to the Mineral earthquake. Figure 2.5.1-5 shows a newly derived relief map using a linear color ramp to symbolize the local relief value across the epicentral area and to the NE, closer to North Anna 3. The staff notes that, in the area around the Ellisville pluton neck, high to low relief boundaries closely correspond to geologic map unit contacts. This supports the COL applicant's suggestion that the steep relief gradients are related to lithologic difference between map units rather than subtle tectonic uplift related to shallow earthquakes. The Chopawamsic Formation, to the NW and SE of the Ellisville pluton neck, is more erosion resistant than the Ellisville and, therefore, supports higher elevation and higher relief zones. In addition, staff notes, that the South Anna river system crosses the same geologic contacts by the Elllisville neck and the Mineral earthquake epicentral area. The river is a significant erosional agent in the area and lowers elevations in its basin but also contributes to the development of high local relief within its basin (Compare Figures 2.5.1-5 and 2.5.1-6). The staff also notes that high relief values diminish to the NE, near the basin divide between the South Anna and the North Anna river systems. The most continuous areas of low relief can be found along prominent drainage divides and areas of higher elevation, which represent areas farthest removed from the increased erosion rates associated with trunk streams. The staff agrees with the COL applicant that the landscape revealed in the new relief and elevation maps supports the interpretation that erosion rates increase toward the trunk of major drainages, and this enhances differential erosion rates associated with variable lithology. Accordingly and in compliance with 10 CFR 100.23 and 10 CFR 52.79, the staff considers RAI 02.05.01-8a resolved and closed.

The COL applicant stated that the FSAR would be updated to reflect aspects of this response. The staff finds the proposed COL FSAR changes acceptable and verified that the appropriate changes are incorporated into the FSAR, Revision 9, and, therefore, Confirmatory Item 2.5-04 from the staff's advanced SER for North Anna 3 is resolved and closed.

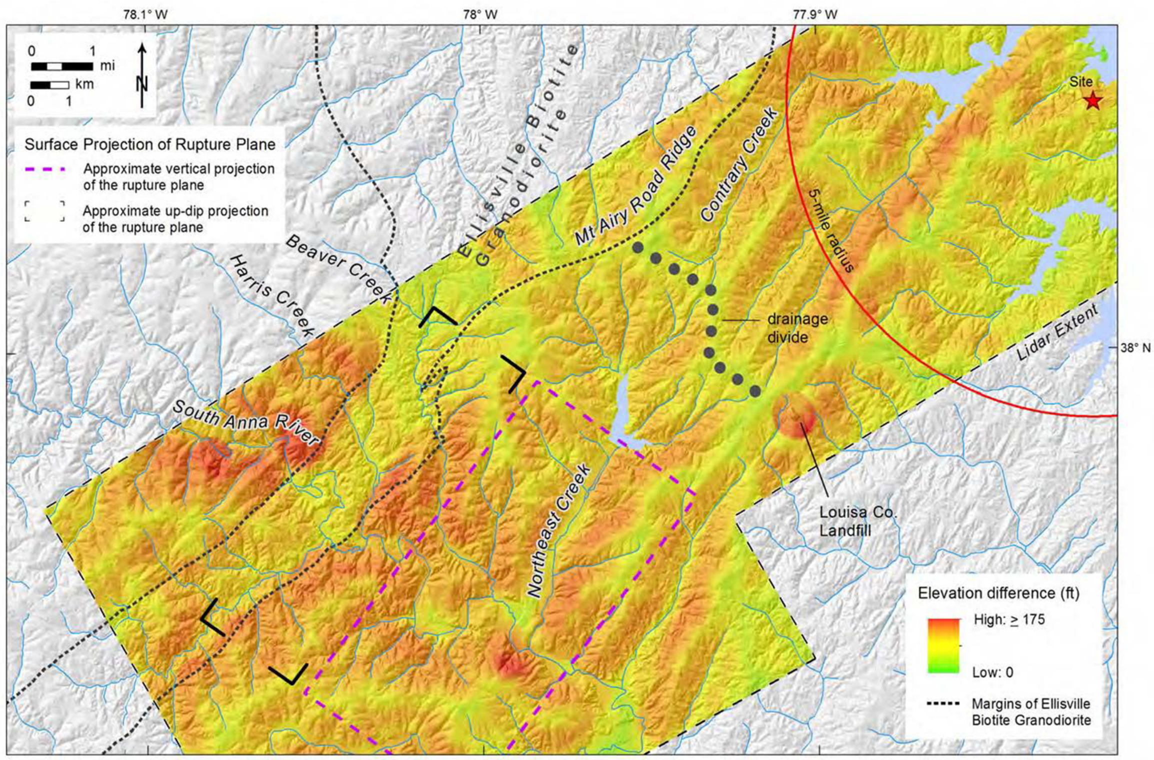


Figure 2.5.1-5. LiDAR-Derived Relief Map of the 2011 Mineral, VA, Earthquake Vicinity (from FSAR Figure 2.5.1-212A, Rev 9). Relief is represented as elevation difference within 0.5 km. The margin of Ellisville Biotite Granodiorite based on Burton et al. (2014) and Dicken et al. (2005)

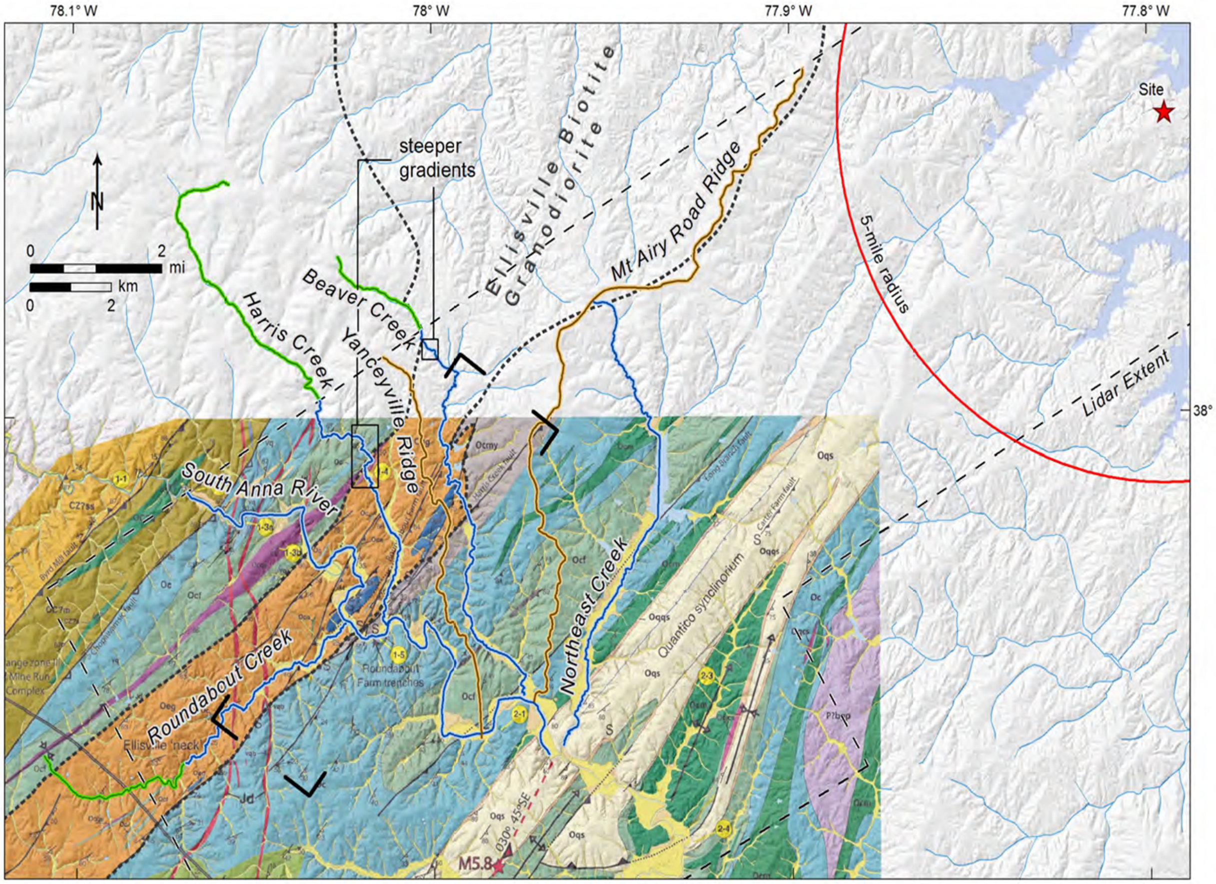


Figure 2.5.1-6. Stream and Ridge Topographic Profiles from FSAR Figure 2.5.1-216, Rev 9.0. The four brackets denote the approximate up-dip projection of the aftershock plane (Quail fault). Blue and green lines indicate locations of stream profiles from LiDAR and NED data, respectively. Brown lines indicate locations of profiles on ridgeline topographic profile

Long Branch Fault

The COL applicant stated that the Long Branch fault (LBF) as currently mapped is too far to the east of the surface projection of the Mineral earthquake rupture plane and thus dismiss it from consideration as an active structure in the Mineral earthquake. The staff notes that there are issues and recent changes to the mapped trace of the LBF. At least two groups of geoscientists have suggested the LBF might be an active structure in the Mineral EQ: Hughes and Hibbard (2012), and Harrison et al. (2011). In RAI 02.05.01-4c dated April 22, 2014 (ADAMS Accession No. ML14112A156), the staff asked the COL applicant to discuss the relevance of the suggestions of other geologists regarding the SW extension of the LBF and the potential of LBF in conjunction with the geophysical data from the Mineral earthquake to have been active during this earthquake.

In a June 10, 2014, response to RAI 02.05.01-4c (ADAMS Accession No. ML14162A436), the COL applicant reviewed the geologic mapping of (Burton et al. 2014); Hughes and Hibbard (2012); Dicken et al. (2005); and Marr (2002). The LBF is not consistently located between these publications. However, the most recent mapping (Burton et al. 2014), mapped at 1:24,000, indicates the LBF strikes N35E, and is assumed to be dipping to the 40 to 50 degrees SE, congruent with foliation in the Chopawamsic Formation subunits. The COL applicant indicated that regardless of the specific interpretation for the location of LBF, all interpretations place the fault above deep aftershocks; therefore, the fault is structurally higher than the rupture plane of the Mineral earthquake and is not likely an active structure in the Mineral earthquake. The COL applicant added that there is no alignment of aftershock data in the main or subsidiary clusters that align with previously identified faults ‘a’ and ‘b’ in the North Anna 3 site area.

The COL applicant also stated that, based on the new mapping, the Chopawamsic fault is about 5 km northwest of the projected rupture plane (refer to previous RAI 02.05.01-4b) and the LBF is about 5 km southeast of it, placing the rupture plane of the Mineral earthquake in between these two faults in the subsurface. The COL applicant also pointed out that prior to the recent detailed geologic mapping (Burton et al., 2014), there were no faults previously mapped in the up dip projection of the Mineral earthquake rupture plane.

The COL applicant reviewed the LiDAR data and found a variety of topographic lineaments collinear with the southern extension of the LBF, consistent with the Burton et al. (2014) geologic map. However, the COL applicant interpreted this topographic expression to be bedrock structure exerting strong control on landscape morphology rather than geologically recent faulting.

The staff considered the COL applicant’s response and independently reviewed the geologic mapping of the LBF included in publications (Burton et al., 2014; Hughes and Hibbard, 2012; Dicken et al., 2005; and Marr, 2002) and concluded that, regardless of the particular investigator’s interpretation of the location of the LBF, the fault in all cases directly overlies deep aftershocks and must be structurally higher than the rupture plane of the Mineral earthquake. Therefore the fault is unlikely to be the seismic source of the Mineral earthquake. The staff notes that the earlier mapping efforts were completed at scales of 1:100,000. The most recent mapping completed by (Burton et al. 2014), was done at a 1:24,000 scale, which provides more detail or more resolution than the others and might be the most accurate geologic map of this structure to date. The staff concludes that current data indicate the LBF is not structurally involved with the Mineral earthquake rupture. Accordingly and in compliance with 10 CFR 100.23 and 10 CFR 52.79, the staff considers RAI 02.05.01-4c resolved and closed. The COL applicant stated that a COL revision, that will include portions of this RAI response, will be included as part of the response to RAI 02.05.01-5 in a future revision of the North Anna 3 FSAR. The staff finds the proposed COL FSAR changes acceptable and verified that the appropriate changes are incorporated into the FSAR, Revision 9, and, therefore, Confirmatory Item 2.5-05 from the staff’s advanced SER for North Anna 3 is resolved and closed.

Geologic Reconnaissance Program

FSAR Section 2.5.1.1.7(b), Geologic Reconnaissance, provides information regarding the field reconnaissance program completed to evaluate potential surface deformation associated with the Mineral earthquake. The FSAR placed a special focus on the up dip projection of the Quail fault, evaluation of geomorphic features in the epicentral landscape, and a field map with routes and waypoints (Figure 2.5.1-4). The details of the field reconnaissance are reported in the Geologic Reconnaissance Report that staff audited on March 11, 2014. The summary of the staff’s audit can be reviewed in (ADAMS Accession No. ML14203A211). The COL applicant provided a summary of the geologic reconnaissance program in FSAR Section 2.5.1.1.7b and c. The report addressed the question of whether the August 23, 2011, Mineral earthquake did or did not cause surface faulting or surface deformation. The report detailed geologic field reconnaissance and geomorphic analyses performed using high-resolution LiDAR elevation data in the region of the August 2011 **M**5.8 Mineral, Virginia, earthquake’s epicentral region specifically acquired by Dominion for this field program. The report also included a compilation and evaluation of published information, communications with other researchers, all related to the potential for surface deformation in the site vicinity for North Anna Power Station North Anna 3. The staff issued an RAI relevant to the information found in this report. Thus in RAI 02.05.01-5 dated April 22, 2014 (ADAMS Accession No. ML14112A156), the staff asked the COL applicant to provide additional details about the data analysis and the field program including:

a) At each waypoint, what was examined and what is its significance.

b) Provide a high resolution LiDAR map (scale ~1:10,000) for areas immediately west of North Anna 3 where fault ‘a’ might be located, such as waypoint sites 23, 24, and 25.

c) Discuss longitudinal stream profile analysis completed in the epicentral area. Discuss any anomalies revealed by this analysis that could indicate subtle tectonic deformation in the hanging wall of the Quail fault, such as gradient changes, offset stream terraces, elevated topography.

d) Explain how you evaluated the Quaternary geology of the epicentral area and the distribution, correlation and elevation of river terraces on the South Anna River. Discuss any indication of subtle surface uplift in river terraces on the hanging wall of Quail fault that might indicate prolonged or repeated surface deformation.

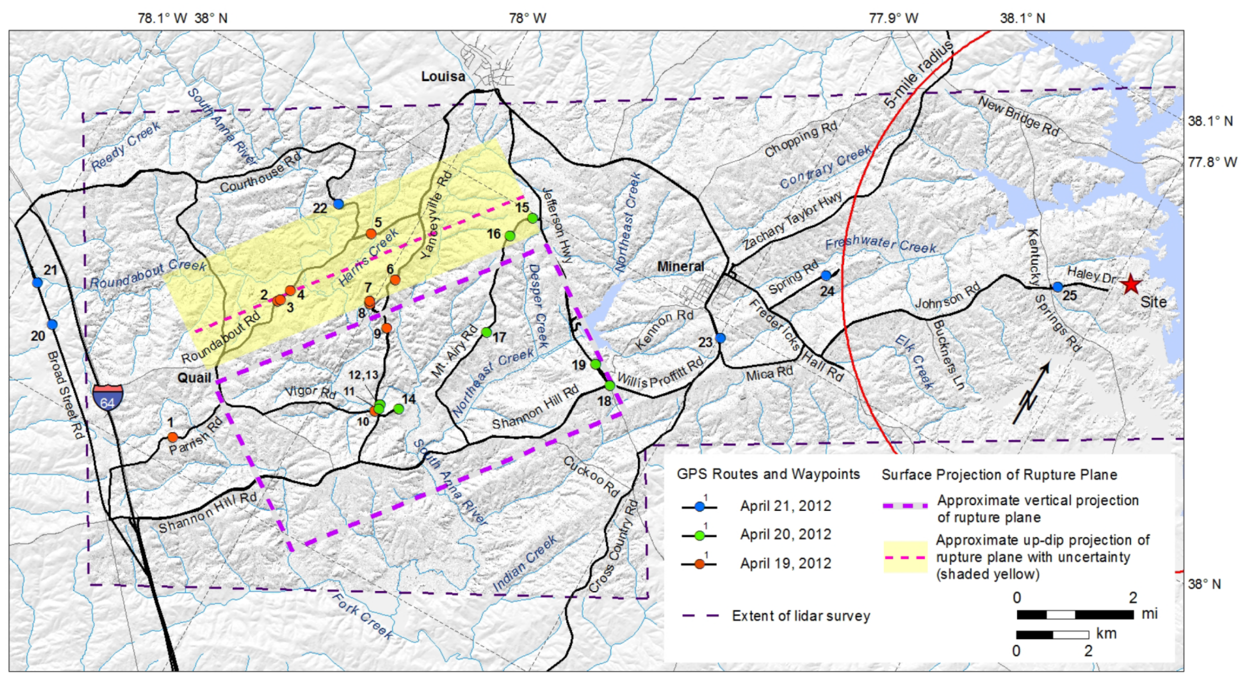


Figure 2.5.1-4. NAPS Geologic Field Reconnaissance after the 2011 Mineral, VA, earthquake showing traverse routes, waypoints and the LiDAR survey boundary (from FSAR Figure 2.5.1-204, Rev. 9)

In a June 10, 2014, response to RAI 02.05.01-5a and b (ADAMS Accession No. ML14177A441), the COL applicant provided a table with details for the significance of each waypoint visited during the field reconnaissance program. Observations at some of the waypoints confirm structural, geomorphic features or relationships previously published by others or observed by Dominion. The staff notes in particular that Waypoint 25, located just outside the plant boundary, is along the extended strike of fault ‘a’, as mapped by Mixon et al. (2000). The waypoint is located on a flat, broad ridge crest, with a deeply weathered soil profile. This ridge crest is likely one of the more stable landforms in this area and useful to evaluate potential deformation or activity on fault ‘a’. The COL applicant provided several detailed LiDAR-based elevation panels of the waypoints they examined to evaluate the possible extent of fault ‘a’. The staff notes that there are no anomalous features revealed in the detailed LiDAR-based elevation panels to indicated surface faulting or deformation. The COL applicant pointed out that the lack of expression of fault ‘a’ in this area support previous studies that determined fault ‘a’ to be pre-Quaternary.

During the May 8, 2014, site audit, as summarized in (ADAMS Accession No. ML14203A179), the staff visited several waypoint stations to fully understand how the LiDAR and field reconnaissance were used to verify geologic features, map contacts and geomorphic landforms. The staff talked with geologists David Fenster (Bechtel, Dominion contractor) and Scott Lindvall (LCI, Bechtel contractor) regarding the extent of fault ‘a’ across Lake Anna to the northeast and further to the southwest with respect to the locations of the 1970’s Dames and Moore exploratory trenches 1 through 3. The staff toured the site vicinity to examine the geomorphic landforms and geologic characteristics of the site vicinity especially with respect to possible surface deformation related to neotectonism in the site vicinity. The staff examined upland surfaces near the possible extension of fault ‘a’, at waypoint 25, and observed no evidence of anomalous deformation. The staff visited exposures of crystalline rock near the Chopawamsic fault and the Ellisville pluton neck and noted the foliation in the granodiorite. The staff also visited the possible exposure of the southeastward extension of the LBF and the location of the small, limited liquefaction related to the Mineral Virginia earthquake. The staff was able to verify the significance of the waypoint stations that the COL applicant examined within their field reconnaissance program after the Mineral earthquake. The staff also determined that the scope of the field reconnaissance was focused in the area where we would expect to see possible effects of the Mineral earthquake on the landscape.

In a June 23, 2014, response to RAI 02.05.01-5c and d (ADAMS Accession No. ML14177A441), the COL applicant provided a figure to indicate the five stream profiles derived from LiDAR data and discussed the analysis of longitudinal stream profiles in the epicentral area to determine if subtle anomalies in the profiles indicate possible surface deformation from the Mineral earthquake (Figure 2.5.1-7). Most profiles were vertically exaggerated 25 times. The analysis revealed several subtle anomalies such as gradient changes and knick points that could be related to many geologic conditions or processes but none that could unequivocally be attributed to tectonic deformation in the hanging wall of the Quail fault. The staff examined the stream profiles and agrees that the profiles show well-graded streams and that anomalies are observable only at great vertical exaggeration. The COL applicant concluded that there is no consistent relationship of anomalies in streams crossing the up-dip projection of the Mineral earthquake rupture plane. However, the COL applicant stated that there is a consistent relationship between lithology changes and stream profile anomalies.

In describing the South Anna River, the COL applicant suggested that, in addition to lithology changes along the stream profile, large increases in drainage area at the confluence of Roundabout, Harris, and Beaver Creeks likely drive a noticeable gradient change along that stretch of river. A dramatic increase in drainage area impacting a river implies an increase in stream power, which governs the ability of the river to incise its channel and modify the gradient. However, staff notes that it is not possible to verify that statement based on the figures provided. Therefore, in supplement RAI 02.05.01-8c dated August 1, 2014 (ADAMS Accession

No. ML14283A557), the staff asked the COL applicant for further clarification on the analysis of stream profiles and changes in stream power along the course of South Anna River.

In a September 30, 2014, response to RAI 02.05.01-8c (ADAMS Accession No. ML14274A303), the COL applicant stated that a subtle gradient change lies near a 20 percent increase in drainage area due to confluences of Roundabout and Harris Creeks, and upstream of a 17 percent increase in drainage area due to confluences of Beaver and Northeast Creeks and provided a new figure for the South Anna River profile with drainage area increases (RAI 02.05.01-8 Figure 11). The staff notes that Dominion considered and performed additional assessments on some profiles, such as stream gradient (SL) index (Hack, 1957), slope versus distance, and drainage basin versus distance (for South Anna River only) but these methods did not provide useful results for evaluating the subtle anomalies due in part to the extremely low gradient of the streams and the high-frequency (HF) data noise (Figure 2.5.1-8).

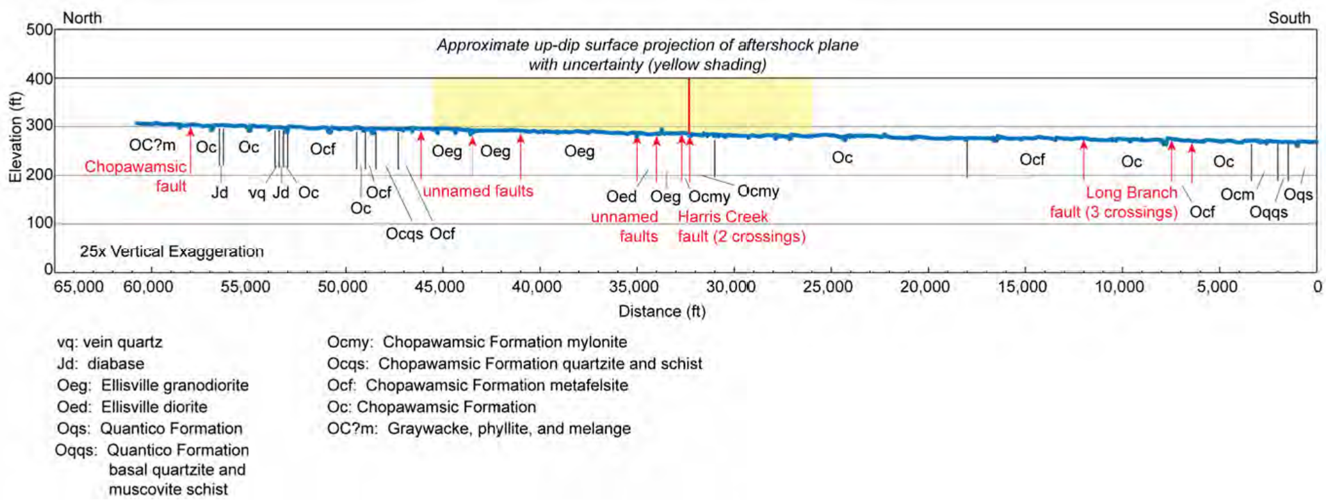
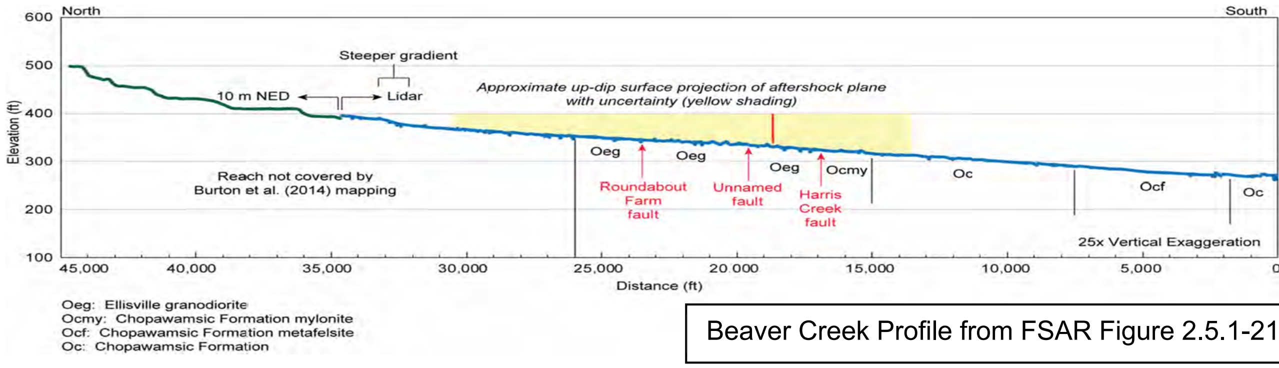
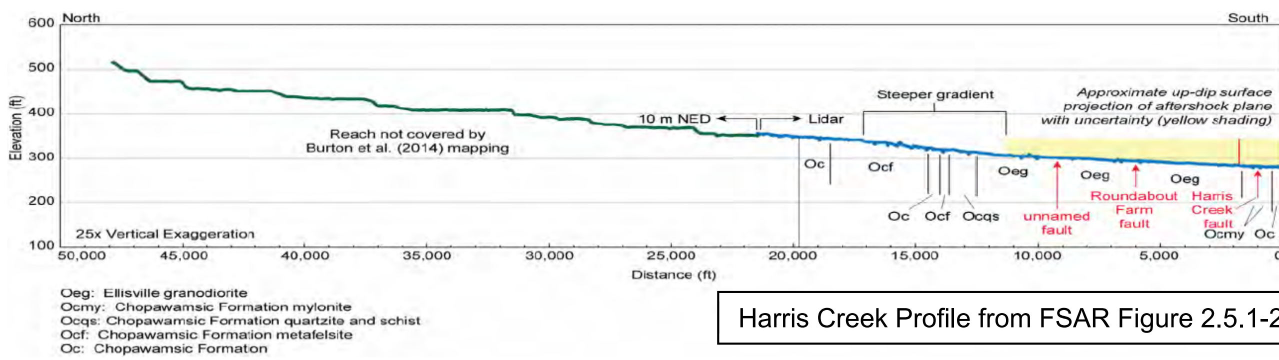


Figure 2.5.1-7. South Anna River Profile Showing Geology of Burton et al. (2014) from FSAR Figure 2.5.1-223, Rev. 9



Beaver Creek Profile from FSAR Figure 2.5.1-217



Harris Creek Profile from FSAR Figure 2.5.1-219,

Figure 2.5.1-8. Stream Profiles with Geology of Burton et al. (2014) from FSAR Figure 2.5.1-217 and -219, Rev. 9

The stream profile analysis also reveals a series of possible river terraces along South Anna River. The river terraces were identified in the LiDAR data products but were not evaluated in the field program. The COL applicant stated many geologic conditions and processes could be in operation to drive river incision and the development and preservation of terrace surfaces such as: climate change, stream capture, changes in sediment influx, eustatic sea level change, and tectonic activity. The LiDAR data reveal several possible terrace surfaces along the South Anna River, and the COL applicant plotted representative elevation points along the South Anna River profile. The COL applicant stated that they have not correlated terrace sets along the profile. The staff notes that terraces are more abundant downstream of the surface projection of the Mineral earthquake rupture plane, at greater heights above the channel than in the upstream reach and also along the low-gradient reach of the river. This is the same reach of river where there is a sharp increase in stream drainage area. The COL applicant stated that an increase in drainage area increases the river's capacity to incise its channel and to keep pace with the impacts imposed by any of the geologic conditions or processes previously mentioned. Therefore, staff concludes that a greater number of terraces, at greater height above the channel on the low gradient reach of the South Anna River, is expected and does not uniquely indicate tectonic activity.

The staff noted that the geologic map used (assemblage of earlier geologic mapping) for the stream profile analysis is not the same as the more recent geologic map (Burton et al., 2014), used to respond to RAI 02.05.01-4 and features previously discussed such as the Harris Creek and Chopawamsic faults, lithologic contacts, and the topographic scarps are not the same or are not indicated on maps or on the various stream profiles provided in addressing RAI 2.5.1-5c.

Therefore in supplemental RAI 02.05.01-8b dated August 1, 2014 (ADAMS Accession No. ML14283A557), the staff asked the COL applicant to provide clarification and coordination between the discussions for topographic scarps and geologic faults in RAI 2.5.1- 5c with the analysis of stream profiles in RAI 2.5.1-4b.

In a September 30, 2014, response to RAI 02.05.01-8b (ADAMS Accession No. ML14274A303), the applicant stated that the profiles show that streams crossing the epicentral area are all very well graded (smoothly descending curve) and that the profiles do not show significant anomalies associated with the up-dip projection of the Mineral earthquake rupture plane or any of the faults mapped by (Burton et al. 2014), including the Harris Creek fault. The COL applicant provided new figures of these profiles on a geologic base map from (Burton et al. 2014). The staff notes that there are two slight anomalously steep gradients in the stream profiles of Harris and Beaver Creeks. The steep gradients do not correlate with the up-dip projection of the rupture plane, the Harris Creek fault, Roundabout Farm fault, or other faults. They are located on or near the Chopawamsic Formation contact with the Ellisville granodiorite, suggesting a lithologic correlation. The COL applicant stated that the steepened southeast facing gradient is likely not tectonic, because it is inconsistent with deformation produced by a southeast-dipping reverse fault, such as the Mineral earthquake rupture. The staff notes that the higher gradient reach of Harris Creek crosses five lithologic units in close succession, including Chopawamsic metafelsite (Ocf); Chopawamsic Formation undifferentiated (Oc), Chopawamsic metafelsite (Ocf), Chopawamsic quartzite and schist (Ocqs), and Ellisville granodiorite (Oeg) (FSAR Figure 2.5.1-219). The Chopawamsic quartzite and schist represents a relatively resistant unit that forms a series of linear ridges and topographic highs in the area so this characteristic could cause stream gradient anomalies. Based on the new figures and explanation provided by the COL applicant, staff's concerns are addressed. Accordingly and in compliance with 10 CFR 100.23 and 10 CFR 52.79, the staff considers RAI 02.05.01-8b resolved and closed.

The COL applicant stated that the FSAR will be updated to focus on the two most prominent gradient changes in the profiles, eliminate some of the description of the very subtle features in the profiles that may be beyond the threshold of detection, and to include updated figures showing (1) relief and elevation from the LiDAR and (2) profiles annotated with the Burton et al. (2014) geology. The staff finds the proposed COL FSAR changes acceptable and verified that the appropriate changes are incorporated into the FSAR, Revision 9, and, therefore, Confirmatory Item 2.5-06 from the staff's advanced SER for North Anna 3 is resolved and closed.

Conclusions on Possible Surface Deformation Associated with the Mineral, Virginia Earthquake

Based on the forgoing discussions, the staff concludes that the topographic expression of a portion of the Harris Creek fault and the pattern of local relief in the area is best explained by differential erosion of contrasting lithologies and higher rates of erosion near the South Anna River, rather than neotectonic surface deformation. The staff also concludes that the updated stream profiles with the more recent geologic mapping of Burton et al. (2014) clarifies that only two of the observed river anomalies on Harris and Beaver Creeks are significant, and they are located on or along the major lithologic contact between the Chopawamsic Formation and the Ellisville granodiorite. Some of the potential stream anomalies originally identified are very subtle features and do not represent significant perturbations in the profiles and may in fact be artifacts from the LiDAR generated stream profiles.

Based on the COL applicant's field program in addition to fieldwork reported by USGS and other academic research teams that staff independently reviewed, the staff finds that there is no observable surface deformation associated with the **M**5.8 Mineral earthquake. Thus it is unlikely that any previous repeated events of a Mineral type earthquake in this area would be recorded in the landscape. Finally, staff concludes that larger magnitude events would likely be necessary to produce surface rupture or topographic expression in this landscape.

Site Area Stratigraphy

FSAR Section 2.5.1.2.3, Site Area Stratigraphy, the applicant described borings from the supplemental subsurface investigation described in greater detail in Section 2.5.4.3. In RAI 02.05.01-6 dated April 22, 2014 (ADAMS Accession No. ML14112A156), the staff asked the applicant to provide further explanations of site area stratigraphy and subsurface conditions.

In RAI 02.05.01-6a dated April 22, 2014 (ADAMS Accession No. ML14112A156), the staff asked the COL applicant if the severely weathered and jointed intervals in Zone III-IV and Zone IV rock, described in site area borings, indicate the presence of a geologic structure or shear zone. In a June 23, 2014, response to RAI 02.05.01-6a (ADAMS Accession No. ML14177A441), the COL applicant stated that even though these weathered and jointed intervals are found in several borings, no systemic distribution of the zones between borings could be determined; therefore, the zone cannot be mapped. The true orientation of the zones, based on dip of foliation, could not be determined because the core was not oriented. The COL applicant pointed out that several intervals are encountered in each borehole, and the severe weathering was typically found in mafic intervals and the closely spaced, tight joints were found in the felsic, biotite quartz gneiss. Because there was not a systematic distribution of these zones between bore holes and within elevation intervals, the COL applicant concluded there was no indication for a single geologic structure.

The staff reviewed the COL applicant's response to RAI 02.05.01-6a and also examined core at the North Anna 3 during a site audit conducted May 8, 2014, as documented in ADAMS Accession No. ML14203A179. The staff directly examined portions of several borings (W-1, -2, -3, -4, -5, -6, -7; M-1, M-27, B-905, B-920) to observe the severely weathered and jointed intervals within more competent Zone III-IV and Zone IV crystalline rock, as reported in the FSAR. The staff notes the essentially random distribution of these zones within each core and between cores. In addition, during the field trip portion of the audit, staff visited outcrops of the same rock formation and noted the same pattern of well-weathered intervals of mafic rock within fresher felsic gneiss. The staff agrees with the COL applicant's position that there is little reason to conclude that this represents a single, mapable geologic structure. Accordingly and in compliance with 10 CFR 100.23 and 10 CFR 52.79, the staff considers RAI 02.05.01-6a resolved and closed.

In RAI 02.05.01-6b dated April 22, 2014 (ADAMS Accession No. ML14112A156), the staff asked the COL applicant if the micro-shear zone identified in boring W-1, within Zone III-IV rock, is structurally associated with the severely weathered and jointed zone, or if this micro shear is structurally related to fault 'a', a previously identified fault and shear zone discovered during construction of Units 1 and 2 (fault 'a' observed in excavations for Units 1 and 2 and abandoned Units 3 and 4). In a June 23, 2014, response to RAI 02.05.01-6b (ADAMS Accession No. ML14177A441), the COL applicant replied that it does not think that the micro-shear zone is structurally associated with the severely weathered and jointed intervals discussed above based on the following reasons. The shear zone is found at elevation 210 ft in boring W-1 and at elevation 185.5 ft in boring W-5. In both borings, the shear zone is characterized by rock fragments, an indication of brittle deformation, mixed with yellow-brown clay and chlorite. The COL applicant stated that the material in the zone is characteristic of fault gouge. The COL applicant stated that the micro-shear zone in W-1 and W-5 is not associated with fault 'a' Dames and Moore (1973) trenched fault 'a' and determined the fault 'a' dipped 45 to 50 degrees NW.

Borings W-1 and W-5, located NW of fault ‘a’ would intersect fault ‘a’ at elevations much lower than where the micro-shear zone is located. The COL applicant looked for the micro-shear zone in adjacent borings and found no indication of this feature.
During the May 2014 site audit, as summarized in ADAMS Accession No. ML14203A179, the staff examined the micro-shear zone in W-1 and W-5 to understand the character and extent of the feature with respect to what was described in the FSAR. In the borings, the micro shear is a relatively thin layer. Furthermore, the micro-shear zone is not exposed at the surface in rock exposures in the site vicinity. The staff reviewed several Dames and Moore reports from the 1970’s regarding fault ‘a’ in addition to the findings in the ESP SER regarding fault ‘a’ (NUREG-1835). The micro-shear has similar features to fault ‘a’ but at a much less significant scale. Because the micro-shear zone in W-1 and W-5 is located NW of fault ‘a’ and likely also dips NW, it is structurally higher than fault ‘a’. The staff notes that significant structures such as fault ‘a’ typically have a zone of deformation and deformation fabric is not necessarily limited to a single fault plane so the micro-shear zone could be associated with fault ‘a’. Regardless of a structural association or not, the deformation associated with fault ‘a’ was determined to be geologically old, greater than 1 million years old. The staff considers the micro-shear zone in W-1 and W-5 likely to be the same age as fault ‘a’ and not a potential future surface deformation hazard to the site. Accordingly and in compliance with 10 CFR 100.23 and 10 CFR 52.79, the staff considers RAI 02.05.01-6b resolved and closed.

The staff reviewed the previous ESP SER and the investigations completed by Dames and Moore in the early 1970’s and notes that North Anna 3 abandoned Units 3 and 4 excavations revealed fault 'a' and that this fault traces across the ESP parameter envelope. In RAI 02.05.01-6 d dated April 22, 2014 (ADAMS Accession No. ML14112A156), the staff asked the COL applicant to describe what evaluation it completed to determine the potential for future surface deformation on fault ‘a’ in light of the Mineral earthquake and possible structural links to the Mineral earthquake epicentral area.

In a June 23, 2014, response to RAI 02.05.01-6d (ADAMS Accession No. ML14177A441), the COL applicant stated that Dames and Moore (1973) concluded that fault ‘a’ was pre-Quaternary and not a capable tectonic structure. The COL applicant provided a new figure on a LiDAR hillshade base with key North Anna 3 borings and the trace of fault ‘a’ as mapped by the Dames and Moore and as mapped by Mixon et al. (2000). Mixon et al. (2000) does not place fault ‘a’ at the same location as Dames and Moore. However, Dames and Moore explored the extent and character of fault ‘a’ in 3 onsite trenches so staff considers the Dames and Moore fault trace more accurate. The COL applicant stated that after the Mineral earthquake it initiated a geologic reconnaissance field program and acquired the high-resolution topographic LiDAR data. The purpose was to look for evidence of surface deformation from the Mineral earthquake. The COL applicant found no evidence for surface deformation along the extension of fault ‘a’ beyond the site boundaries, along Mixon et al.’s (2000) interpretation of the fault or the projection of the Dames and Moore’s mapped extent.

On March 11, 2014, the staff reviewed information supplied by the COL applicant in a reading room at the Bechtel Park Campus in Frederick, MD as summarized in (ADAMS Accession No. ML14203A211). The staff examined the LiDAR data and the geologic field reconnaissance Waypoints 23, 24, and 25 to specifically consider if LiDAR data revealed the presence of surface deformation along fault ‘a’. The staff also considered the COL applicant’s descriptions of Waypoints 23, 24, and 25 (previous RAI 02.05.01-5). The staff concludes that there is no obvious deformation revealed in the high-resolution LiDAR base maps. Accordingly and in compliance with 10 CFR 100.23 and 10 CFR 52.79, the staff considers RAI 02.05.01-6d resolved and closed.

The COL applicant provided a proposed COL revision to include portions of the RAI response in a future revision of the North Anna 3 FSAR. The staff finds the proposed COL FSAR changes acceptable and verified that the appropriate changes are incorporated into the FSAR, Revision 9, and, therefore, Confirmatory Item 2.5-07 from the staff's advanced SER for North Anna 3 is resolved and closed.

In FSAR Section 2.5.1.2.4, Site Area Structural Geology, the COL applicant concluded that none of the faults in the site area are considered capable tectonic sources, as defined in RG 1.208, Appendix A. The staff notes that the capable tectonic source definition in RG 1.208 is not the sole criteria for staff's safety finding for the site area (SRP 2.5.1.2) and for surface deformation (SRP 2.5.3). As discussed in RG 1.208, a PSHA characterizes seismic potential through consideration of the historic and geologic record from the Quaternary Period. In addition, 10 CFR 100.23(d)(2) specifically requires the potential for surface tectonic and non-tectonic deformation to be determined. Therefore, in RAI 02.05.01-7 dated April 22, 2014 (ADAMS Accession No. ML14112A156), the staff asked the COL applicant to describe the analysis that it completed to determine the potential for future surface deformation, tectonic and non-tectonic, at the site and to state whether these findings have an impact on the PSHA for North Anna 3.

In response to RAI 02.05.01-7, dated June 23, 2014 (ADAMS Accession No. ML14177A441), the COL applicant described its analysis to determine the potential for future surface deformation at the site by referencing previous regional geologic studies and its own previous work for Units 1 and 2; referencing current regional geologic mapping studies and its own recent geologic reconnaissance program and concluded that the potential for tectonic deformation at the site is negligible based on the results these investigations:

Since original site studies in the early 1970's, no new information has been reported to substantiate the existence of a Quaternary fault near the site.
The 2011 Mineral earthquake prompted new research on the part of government and academic institutions that included detailed geologic mapping at scales more detailed than previous mapping projects.

Dominion initiated its own investigation to determine impacts of the Mineral earthquake with acquisition of high resolution topographic data (LiDAR) and subsequent geomorphic desk-top analysis in addition to a field reconnaissance study in the epicentral area of the Mineral earthquake.

The COL applicant acknowledges that the Mineral earthquake occurred on a previously unmapped subsurface fault zone within the site vicinity and provides details in FSAR Section 2.5.2.2 regarding why this fault is not an RLME seismic source and how this earthquake is incorporated into the updated PSHA.

With respect to potential for non-tectonic surface deformation, the COL applicant discussed:

- The negligible impact of Quaternary glaciation;
- The lack of carbonate or evaporite rock in the metamorphic and igneous geology in the site vicinity;
- The lack of growth faulting in this area's geologic setting;
- The lack of Quaternary age volcanic centers within 200 mile radius of site;

- No oil or gas resources are expected to be found in the site area; and
- No mining of commercial value.

The COL applicant stated that an additional FSAR subsection would be added to FSAR Section 2.5.3 to describe the analysis completed to determine the potential for future tectonic and non-tectonic surface deformation at the site.

In consideration of the COL applicant's response to RAI 02.05.01-7, the staff independently reviewed several documents from previous North Anna 3 investigations completed in the early 1970's for the licensing of Units 1 and 2 (Virginia Electric and Power Company (VEPCO),1974 and 1973) and the material provided by the COL applicant in the ESP SSAR. These studies provide one basis for the applicant's analysis for future surface deformation potential. Geologic faulting discovered at the site during excavation of Units 1 through 4 was determined to be geologically old and unlikely to cause a future surface deformation problem for the site. The details of those studies are found in the ESP SSAR and the numerous Dames and Moore reports and letters to the NRC from the 1970's. The staff has also independently considered the findings in the current literature regarding the local impact of the Mineral earthquake and the possible impact on future surface deformation potential for the North Anna 3 site including but not limited to: Burton et al., 2014; Green et al. (2012); Harrison et al. (2014); Horton et al. (2012); Hughes and Hibbard, 2012; and Spears and Gilmer (2012). To date there has been no surface rupture related to the Mineral earthquake reported in publications or in conference presentations. The staff reviewed the COL applicant's geologic reconnaissance report in an audit in March 2014 as summarized in (ADAMS Accession No. ML14203A211), and considered the scope of that investigation with respect to how the COL applicant would determine the potential for tectonic deformation at the site. The staff concludes that the COL applicant executed what would be a typical geomorphic study designed to investigate questions of neotectonism in the landscape. The evaluation of longitudinal stream profiles, examination of geologic maps relative to high resolution topographic data (LiDAR), and field traverses to check the position of lithologic contacts and fault locations are part of such a typical investigative program.

The staff considered the COL applicant's analysis for non-tectonic surface deformation in conjunction with the regional and local geology of Appalachian Piedmont geology, where North Anna 3 is located. The staff find that non-tectonic hazards such as subsurface dissolution leading to surface collapse and volcanic hazard are not present and do not contribute to the future surface deformation hazard. The staff agrees with the COL applicant's response that oil and gas reserves are not likely in this geologic environment and therefore would not cause a man-made surface deformation hazard.

Based on the foregoing considerations for tectonic, non-tectonic and man-made surface deformation, the staff agrees with the COL applicant's findings that the potential for tectonic and non-tectonic deformation at the site is negligible. Accordingly, and in compliance with 10 CFR 100.23 and 10 CFR 52.79, the staff considers RAI 02.05.01-7 resolved and closed. The COL applicant provided a proposed COL revision to include portions of the RAI response in a future revision of the North Anna 3 FSAR. The staff finds the proposed COL FSAR changes acceptable and verified that the appropriate changes are incorporated into the FSAR, Revision 9, and, therefore, Confirmatory Item 2.5-08 from the staff's advanced SER for North Anna 3 is resolved and closed.

2.5.1.5 Post Combined License Activities

The staff identified the following licensing condition as the responsibility of the COL licensee. This License Condition relates to geologic mapping of both tectonic and non-tectonic surface deformation features at the site. This geologic license condition replaces ESP Permit Condition 3(E)(6).

> **License Condition 2.5.1-1.** The licensee shall (1) perform detailed geologic mapping of future excavations for North Anna 3 nuclear island structures; (2) examine and evaluate geologic features discovered in excavations for safety-related structures; and (3) notify the Director of the Office of New Reactors, or the Director's designee, once excavations for North Anna 3 safety-related structures are open for examination by staff.

2.5.1.6 Conclusion

The staff reviewed the COL FSAR, Revision 8, and considered the referenced ESP SSAR, Revision 9. The staff also considered the ESP FSER (NUREG-1835) in the review of the COL FSAR. The staff's review confirms that the applicant has addressed the relevant information to support 10 CFR 100.23 and 10 CFR 52.79 and there is no outstanding information to be addressed in the COL FSAR related to Section 2.5.1. 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 North Anna 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 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 VAR 2.0-4 is 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 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 3 COLA. 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 base covered in the application, and confirms that regulations have been met or fulfilled by the applicant.

North Anna 3 COL FSAR Section 2.5.2 presents the applicant's evaluation of the vibratory ground motion that relates to the North Anna 3 site. The vibratory ground motion is evaluated based on seismological, geological, geophysical, and geotechnical investigations carried out to determine the site-specific ground motion response spectrum (GMRS), which must meet the regulations for the SSE provided in 10 CFR 100.23. The GMRS is defined as the free-field horizontal and vertical response spectra at the plant site. The development of the GMRS is based on a detailed evaluation of earthquake potential, taking into account the regional and local geology, Quaternary tectonics, seismicity, and site-specific geotechnical engineering characteristics of the site subsurface material. The specific investigations necessary to determine the GMRS include the seismicity of the site region and the correlation of earthquake activity with seismic sources. Seismic sources are identified and characterized, including the rates of occurrence of earthquakes associated with each seismic source. Seismic sources that have any part within 320 km (200 miles) of the site must be identified. More distant sources that have a potential for earthquakes large enough to affect the site must also be identified. Seismic sources can be capable tectonic sources or seismogenic sources. The review covers the following specific areas: (1) seismicity, (2) geologic and tectonic characteristics of the site and region, (3) correlation of earthquake activity with seismic sources, (4) PSHA and controlling earthquakes, (5) seismic wave transmission characteristics of the site, (6) site-specific GMRS, and (7) any additional information requirements prescribed within the “Contents of Application” sections of the applicable subparts to 10 CFR Part 52.

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 North Anna 3 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 10 of the ESBWR DCD as follows:

<u>*COL Items:*</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, CB, and FWSC foundation input response spectra (FIRS) are enveloped by the ESBWR certified seismic design response spectra (CSDRS) referenced at the foundation level. In FSAR Section 2.5.2, the applicant provided site-specific information in accordance with SRP Section 2.5.2 to address COL Item North Anna 3 COL 2.0-27-A, and to resolve item 2.5-3, which addresses the provision for performing site-specific evaluations if the site-specific GMRS at foundation level exceeds the ESBWR DCD design response spectra referenced at the foundation level.

- NAPS ESP VAR 2.0-4

In response to the August 23, 2011, **M**5.8 earthquake that occurred in the town of Mineral, Virginia, of Louisa County, the applicant updated its selection of seismic source model. In NAPS ESP VAR 2.0-4, the applicant selected the new SSC model for CEUS published in NUREG-2115, hereafter referred to as the CEUS-SSC model, for conducting its PSHA, rather than the EPRI-SOG model (EPRI, 1986) used in developing the site ground motion for the ESP. In addition, the applicant requested that the North Anna 3 horizontal and vertical GMRS be defined at Elevation 68.3 m (224 ft) which corresponds to the deepest excavation at the site and lies on competent material rather than Elevation 76.2 m (250 ft). The applicant developed the

GMRS using the performance-based approach recommended in RG 1.208. The applicant then updated its selection of GMM from the EPRI (2004, 2006) model to the most recent EPRI (2013) model. Based on the evaluation, the applicant presented the following details related to the vibratory ground motion information for the North Anna 3 site.

Seismicity

FSAR Section 2.5.2.1 states that the applicant used the most recent earthquake catalog published as part of the CEUS-SSC model in its seismic hazard assessment at the North Anna 3 site. The CEUS-SSC earthquake catalog covers earthquakes in the CEUS region from 1568 through 2008. The applicant stated that the CEUS-SSC catalog is the starting point for developing an updated earthquake catalog for the North Anna 3 site. The applicant developed the updated catalog for the entire region covered by the CEUS-SSC for the period from January 1, 2009, through mid-December 2011. This period includes the August 23, 2011, Mineral, Virginia, earthquake, hereafter referred to as the Mineral earthquake, which occurred within the North Anna 3 site vicinity. The applicant followed the process used in the CEUS-SSC for developing an earthquake catalog. Consistent with the CEUS-SSC catalog, E[**M**] is the expected value of the true moment magnitude (**M**) and was calculated for all post-CEUS-SSC catalog earthquakes in the updated catalog.

The applicant reported 141 additional mainshock earthquakes with **M** greater than or equal to 2.9 in the 320 km (200 mi) site region and that the 2011 **M**5.8 Mineral earthquake was the most significant earthquake identified in the 2009 to 2011 earthquake catalog update. SER Figure 2.5.2-1 shows the seismicity of the North Anna 3 site region within the surrounding CEUS. The applicant also noted that a few moment magnitude values in the CEUS-SSC report were incorrect due to a period of manual processing of earthquake data at Saint Louis University and reported that in general these differences were small and had a negligible impact on any analysis performed in the CEUS-SSC report.

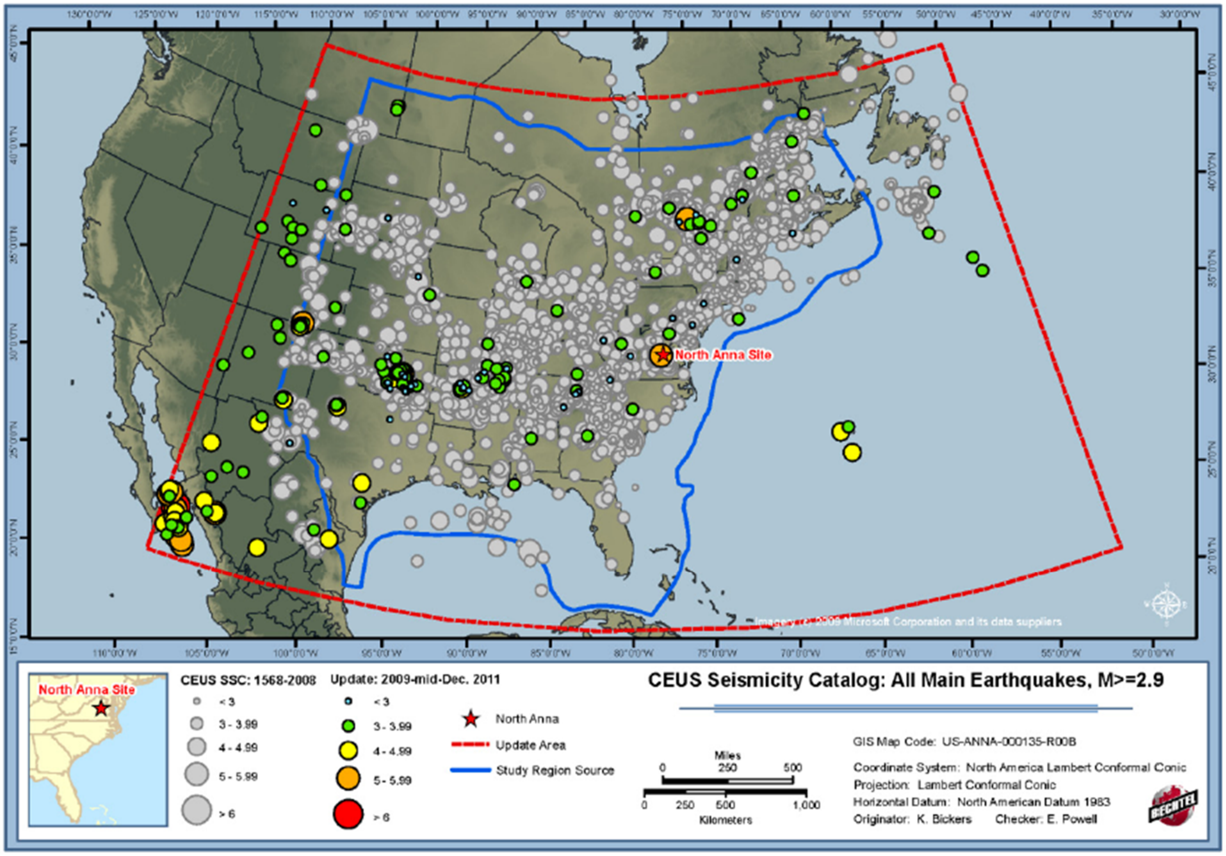


Figure 2.5.2-1. **Map Showing the COL Applicant's Updated Seismicity Catalog for the CEUS-SSC Region (FSAR Figure 2.5.2-202, Rev. 8)**

Seismic Information Related to the Mineral Earthquake

The applicant stated that the August 23, 2011, Mineral earthquake had a hypocenter located at latitude 37.936°N, longitude 77.933°W, and depth 6 km (3.7 mi), or approximately 18 km (10.8 mi) southwest of the North Anna 3 site. The applicant described the earthquake as occurring on a reverse fault within the CVSZ, a previously recognized zone of moderate seismicity. FSAR Section 2.5.2.1.3 states that the Mineral earthquake is the largest instrumentally recorded earthquake in eastern North America since the 1988 M5.9 Saguenay, Canada earthquake and that shaking was felt across a large area of the eastern U.S. including Washington, D.C., Philadelphia, PA, and portions of New York.

FSAR Section 2.5.2.1.3 states that there are different estimates of moment magnitude for the Mineral earthquake, ranging from M5.65 to **M**5.8. Following procedures outlined in the CEUS-SSC, the applicant determined that the best estimate (BE) uniform magnitude for the event was E[M]5.71.

The applicant stated that prior to the Mineral earthquake the largest earthquakes to occur in the CVSZ were an 1875 M4.8 and a 2003 M4.5 event that occurred in Goochland County, Virginia, south of the Mineral earthquake's epicenter.

The applicant stated that aftershocks of the Mineral earthquake ranged in depth from 1 to 7.5 km (0.6 to 4.5 mi), with magnitudes up to M3.9. Additionally, the applicant stated that global and USGS moment tensor solutions and the location of aftershocks for the Mineral earthquake defined a rupture plane 10 km (6.2 mi) in length striking approximately N26º – 30ºE and dipping 37º – 55ºSE (FSAR Table 2.5.2-204). The applicant used the up-dip projection of the rupture plane defined by aftershocks to highlight a zone on the surface that may have been susceptible to ground deformation from the mainshock. As discussed in SER Section 2.5.1.1.3, the applicant stated that field reconnaissance in the epicentral region of the Mineral earthquake revealed no discernable surface rupture or ground deformation.

The applicant discussed the two sets of three-component strong ground motion accelerograms of the **M**5.8 Mineral earthquake recorded at the North Anna 1 structure. One recording was located at the containment mat foundation approximately 16 m (54 ft) below plant grade and the second recording was at the containment operating deck approximately 6 m (20 ft) above plant grade. The applicant stated that the largest acceleration recorded at the foundation was 0.26 g, and the largest horizontal acceleration recorded at the operating deck level was 0.4 g. The applicant reported that these records are the closest available strong motion recordings of the Mineral earthquake. Based on the analysis of strong-motion recordings collected by the Center for Engineering Strong-Motion Data obtained at different distances from the Mineral earthquake, the applicant concluded that recorded ground motions correlated well with ground motion prediction equations for the CEUS at high frequencies (peak ground acceleration (PGA), 5 Hz but were lower than predicted at low frequency (1 Hz).

Geologic and Tectonic Characteristics of the Site and Region

FSAR Section 2.5.2.2 describes the seismic sources and seismic model parameters that the applicant used to calculate the seismic ground motion hazard at the North Anna 3 site. The applicant used the CEUS-SSC as a starting point for its hazard calculations rather than the EPRI-SOG model used in the ESP SSAR. Published in January 2012, the CEUS-SSC was developed following the Senior Seismic Hazard Analysis Committee (SSHAC) Level 3 procedures as outlined in NUREG/CR-6372, "Recommendations for Probabilistic Seismic Hazard Analysis: Guidance on Uncertainty and Use of Experts." It is a regional seismic source model to be used as a starting model in seismic hazard calculations for nuclear facilities in the CEUS region. The applicant stated that it conducted a review of the CEUS-SSC model to identify whether there was a need to update any of the seismic sources.

Summary of the Central and Eastern United States – Seismic Source Characterization Model

The applicant stated that the CEUS-SSC model contains two types of seismic sources: distributed seismicity sources and RLME sources. While the distributed seismicity sources were developed based on available earthquake locations and regional geologic and tectonic characterizations, the RLME sources were based on paleo- and historic earthquake records. The RLME sources represent the zones of repeated (two or more) RMLEs (M>6.5) in the CEUS region.

The CEUS-SSC model categorizes the distributed seismicity sources into two subgroups: maximum magnitude (M_{max}) zones and seismotectonic zones. These subgroups represent uncertainties in source characterizations and differences of opinions in seismic source identification in the region. In hazard estimates, the M_{max} and seismotectonic sources are weighted by 40 percent and 60 percent, respectively, to determine their contributions to the total seismic hazard at the site. The M_{max} zones are broad seismic sources identified based on limited tectonic information and represent potential seismic sources of future earthquakes. The seismotectonic sources are those developed by extensive analyses of regional geology and geophysics, tectonics, and seismicity in the CEUS region. Both the M_{max} and the seismotectonic zones also include alternative source geometries, accommodating inherent uncertainty in SSC. RLME sources are superimposed on the distributed seismicity sources when calculating total site hazard.

In FSAR Sections 2.5.2.2.2 and 2.5.2.2.3, the applicant stated that the PSHA conducted for the North Anna 3 site includes the contributions from all or parts of each distributed seismicity model (i.e. M_{max} and seismotectonic source zones) that lie within 1,000 km (620 mi) of the site. As a result, the applicant used the following alternative seismic source configurations for the M_{max} zones where Mesozoic-aged tectonic extension occurred (MESE) and did not occur (NMESE): MESE-N, MESE-W, NMESE-N, NMESE-W, and the Study Region. The Study Region is the largest seismic source in the CEUS-SSC model, and it represents the entire area of the CEUS region with no division between MESE and NMESE. The applicant considered narrow (N) and wide (W) extensions to represent varying alternative geometries of the MESE and NMESE sources resulting in four alternative configurations of the two overall classifications: MESE-N, MESE-W, NMESE-N, and NMESE-W. The applicant noted that the North Anna 3 site is located in the MESE M_{max} source zone in both interpretations. The applicant included the following seismotectonic source zones in the seismic hazard model for the North Anna 3 site: Atlantic Highly Extended (AHEX) Crust; Extended Continental Crust-Atlantic Margin (ECC-AM), PEZ including PEZ-N and PEZ-W; Midcontinent-Craton (MidC) including MidC-A, MidC-B, MidC-C, and MidC-D; St. Lawrence Rift (SLR); and Illinois Basin Extended Basement (IBEB) (SER Figure 2.5.2-2).

The applicant indicated that AHEX, ECC-AM, PEZ, and MIDC seismic sources were located within 320 km (200 mi) of the North Anna 3 site, and the North Anna 3 site itself is located within the ECC-AM seismic source. The applicant described the ECC-AM seismic source as a zone that encompasses portions of the Piedmont, Coastal Plain, and Continental Shelf physiographic provinces that experienced Mesozoic and younger extension. The applicant noted that the ECC-AM seismic zone is defined by the observation that earthquakes greater than M7 in SCRs occur within crust extended during the Mesozoic and younger period. Magnetic and gravity anomalies define the boundaries of the ECC-AM seismic zone near the North Anna 3 site.

The applicant stated that the AHEX seismic source lies offshore along the continental shelf at the eastern edge of the 320 km (200 mi) site radius. The applicant characterized the AHEX seismic source as a zone of thinned mafic oceanic crust extended during the Mesozoic. The third seismotectonic zone used, PEZ, represents the seismic zone in the western part of the North Anna 3 site region. Because the western boundary of this zone is not well constrained, the CEUS-SSC model has two alternative source geometries for this source representing a wide (W) or narrow (N) geometry: PEZ-W and PEZ-N. The applicant stated that the last seismotectonic zone, MidC, is a large areal zone encompassing the continental interior where very little or no significant tectonic deformation took place in the past several hundred million years. Since the MidC zone boundaries are also uncertain, this zone is defined by four alternatives: MidC-A; MidC-B; MidC-C; and MidC-D. The applicant stated that, although only MidC-A and MidC-B configurations are within the 320 km (200 mi) site radius, all four model alternatives were included in the baseline hazard calculation.

In FSAR Sections 2.5.2.2.4, the applicant summarized the RLME sources used in the North Anna 3 seismic hazard calculations. The CEUS-SSC model requires contributions from the RLME sources to be added to the seismic hazard estimates obtained from the distributed seismicity models. Figure 2.5.2-3 in this SER shows the locations of the RLME sources characterized in the CEUS-SSC model. The applicant stated that the RLME sources that contribute significantly to seismic hazard at the North Anna 3 site are Charleston, New Madrid Fault System, and the Wabash Valley sources.

Figure 2.5.2-2. **Map Showing the CEUS-SSC Seismotectonic Zones for One of the Four Alternative Models for the MidC Seismotectonic Zone (FSAR Figure 2.5.2-215, Rev. 8)**

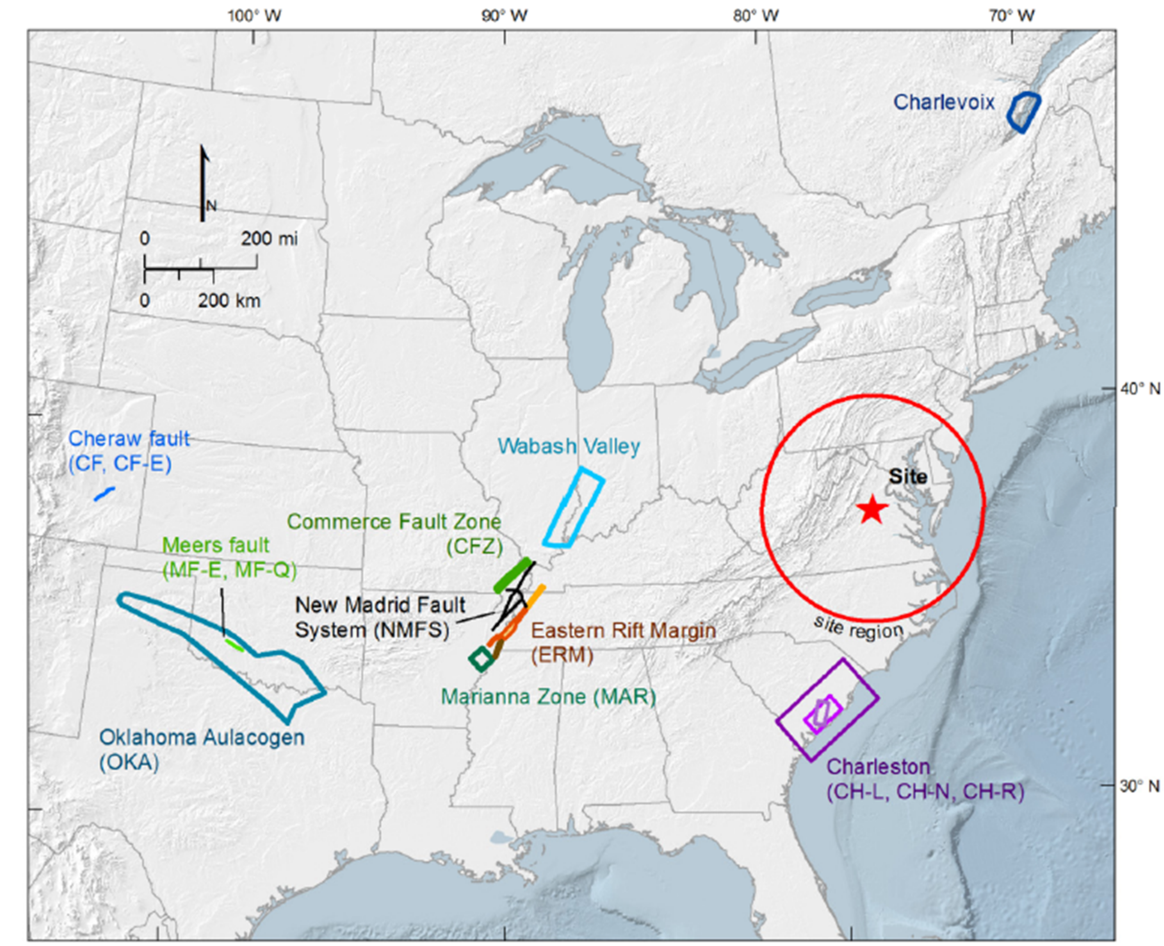


Figure 2.5.2-3. Map Showing the Repeated Large Magnitude Earthquake (RLME) Sources in the CEUS-SSC Model (FSAR Figure 2.5.2-218, Rev. 8)

Post-Central and Eastern United States – Seismic Source Characterization Studies

In FSAR Section 2.5.2.2.5, the applicant described geologic and seismic investigations of the North Anna 3 site region used to evaluate and potentially update the CEUS-SSC model. The applicant performed sensitivity studies to determine the impact of the Mineral earthquake on the M_{max} and earthquake recurrence distributions for the ECC-AM, MESE-N, MESE-W, and Study Region seismic sources. The applicant stated that because earthquakes in background zones are modeled as finite ruptures on randomly oriented faults, a future earthquake similar to the Mineral earthquake is included within the updated CEUS-SSC model.

In FSAR Section 2.5.2.2.3.1, the applicant noted that the E[M]5.71 Mineral earthquake, which occurred after the development of the CEUS-SSC earthquake catalog, is now the second largest earthquake not associated with an RLME in the ECC-AM. Based on sensitivity studies, the applicant increased the minimum M_{max} in the ECC-AM region from 6.0 to 6.1 (FSAR Table 2.5.2-211). The applicant performed a SSHAC Level 2 assessment to determine if incorporating the rupture plane of the Mineral earthquake as a new fault source was appropriate (FSAR Section 2.5.2.4). The applicant stated that although a potentially causative structure for the Mineral earthquake is defined, there are no constraints on slip rate, recurrence, and M_{max}. Therefore, the applicant incorporated the Mineral earthquake in the PSHA for the North Anna 3 site by increasing the M_{max} distribution for the ECC-AM zone. The applicant also indicated that it did not include the rupture plane of the Mineral earthquake as an RLME source since RLME sources are defined as locations of repeated large-magnitude (M≥6.5) earthquakes.

The applicant also discussed the impact of recent paleoseismic studies in the ETSZ. The applicant did not represent the ETSZ as an RLME since these studies did not provide information on earthquake recurrence interval or magnitude parameters for the ETSZ.

Correlation of Earthquake Activity with Seismic Sources

FSAR Section 2.5.2.3 describes the correlation of updated seismicity with the CEUS-SSC seismotectonic zones and RLME sources significant to the site (SER Section 2.5.2.2.2). The applicant discussed correlations of seismicity in the updated catalog with the Charleston, New Madrid Fault System, and Wabash Valley RLME sources (FSAR Figures 2.5.2-223 and 2.5.2-226), but identified no significant deviations from zones or faults defined within these sources. The applicant concluded that seismicity in the updated catalog was consistent with the patterns of seismicity for the PEZ, AHEX, SLR, and IBEB seismotectonic zones defined in the CEUS-SSC model.

Within the ECC-AM seismotectonic zone, the applicant identified elevated rates of seismicity in the CVSZ and the New York-Philadelphia region. The applicant noted that these zones are not RLMEs as there is no evidence for repeated, large-magnitude earthquakes or discrete faults associated with seismicity. The applicant indicated that while the 2011 Mineral earthquake and its aftershocks defined a northeast-striking and southeast-dipping rupture plane, there is not sufficient information to designate the rupture plane of the Mineral earthquake as an RLME. The magnitude of the Mineral earthquake, E[M]5.71, is less than the maximum magnitude for the ECC-AM (M_{max} = 6.5), its host seismotectonic zone. The applicant suggested that the largest earthquake possibly recorded in the ECC-AM is the 1755 Cape Ann, Massachusetts E[M]6.10 earthquake. However, the uncertainty in the location of the Cape Ann earthquake could place its epicenter in the Northern Appalachian (NAP) seismotectonic zone instead of the ECC-AM. Therefore, the applicant stated that if the Cape Ann earthquake occurred in the NAP, the largest event in the ECC-AM would then be the 2011 Mineral E[M]5.71 earthquake. The applicant noted that including the Mineral earthquake and other post-2008 seismicity in the updated CEUS-SSC catalog caused minor increases in seismicity rates (*a*-values) in the ECC-AM.

Probabilistic Seismic Hazard Analysis and Controlling Earthquake

FSAR Section 2.5.2.4 describes the applicant's PSHA calculations for the North Anna 3 site. The hazard curves generated by the applicant's PSHA represent the hazard calculated for generic hard rock conditions characterized by a shear wave (S-wave) velocity of 2.8 km/s (9,200 fps). In accordance with RG 1.208, FSAR Section 2.5.2.4 also describes the earthquake potential for the North Anna 3 site in terms of the most likely earthquake magnitudes and source-to-site distances, which are referred to as 'controlling earthquakes' at low-frequency (LF) (1 and 2.5 Hz) and HF (5 and 10 Hz) at the 10^{-4} and 10^{-5} mean annual frequencies of exceedance levels.

Probabilistic Seismic Hazard Analysis Inputs

The applicant's PSHA calculations used the CEUS-SSC model updated to include seismicity through December 2011 and the GMM described in EPRI Technical Report 3002000717,"Ground-Motion Model (GMM) Review Project, (EPRI, 2013)."

Seismic Source Model

The applicant stated that the PSHA inputs for the North Anna 3 site consist of the distributed seismicity sources (M_{max} and seismotectonic zones) or portions of these zones that are within 1,000 km (620 mi) of the North Anna 3 site. The applicant conducted PSHA sensitivity calculations to aid in the selection of an appropriate set of RLME sources to include in the PSHA from the CEUS-SSC model. Based on these results, the applicant included the Charleston, New Madrid Fault System, and Wabash Valley RLME sources because they contribute close to or greater than 1 percent to the total mean hazard at the North Anna 3 site. The seismic sources used in the PSHA calculations are summarized earlier in SER Section 2.5.2.2.2.

Ground Motion Models

The applicant used the EPRI (2013) GMM to calculate seismic hazard. The GMM developed by EPRI characterize the range of expected ground motions from a seismic source at seven oscillator frequencies; 0.5, 1, 2.5, 5, 10, 25, and 100 Hz. The applicant applied two different sets of GMMs depending on the seismic source under consideration: the 9 general, non-rift EPRI (2013) GMM relationships for the Midcontinent region were applied to all background seismic sources, and the 12 non-general, rift EPRI (2013) GMM relationships for the Midcontinent region were applied to all RLME sources.

Probabilistic Seismic Hazard Analysis Methodology and Calculation

Using the modified CEUS-SSC, with modified M_{max}, recurrence, and rate distributions described in FSAR Section 2.5.2.4.3 and summarized in this SER, and EPRI GMM (2013), the applicant performed the PSHA calculations using a fixed lower bound magnitude of M5.0 and modeled earthquakes occurring in the CEUS-SSC-distributed seismicity sources as point sources. The applicant applied the EPRI (2013) models for distance adjustment and additional aleatory variability resulting from the use of point sources (epicenter to model earthquakes) for distributed seismicity. The models assumed a random rupture location with respect to the epicenter. The applicant modeled earthquakes occurring in the RLME sources as extended ruptures and did not apply the distance adjustment and additional aleatory variability models to these sources.

The applicant performed the above PSHA calculations for ground motion frequencies of 0.5, 1, 2.5, 5, 10, 25 Hz, and PGA as described in RG 1.208. FSAR Figures 2.5.2-230 through 2.5.2-236 show the mean and fractile hazard curves for the seven oscillator frequencies.

Probabilistic Seismic Hazard Analysis Results

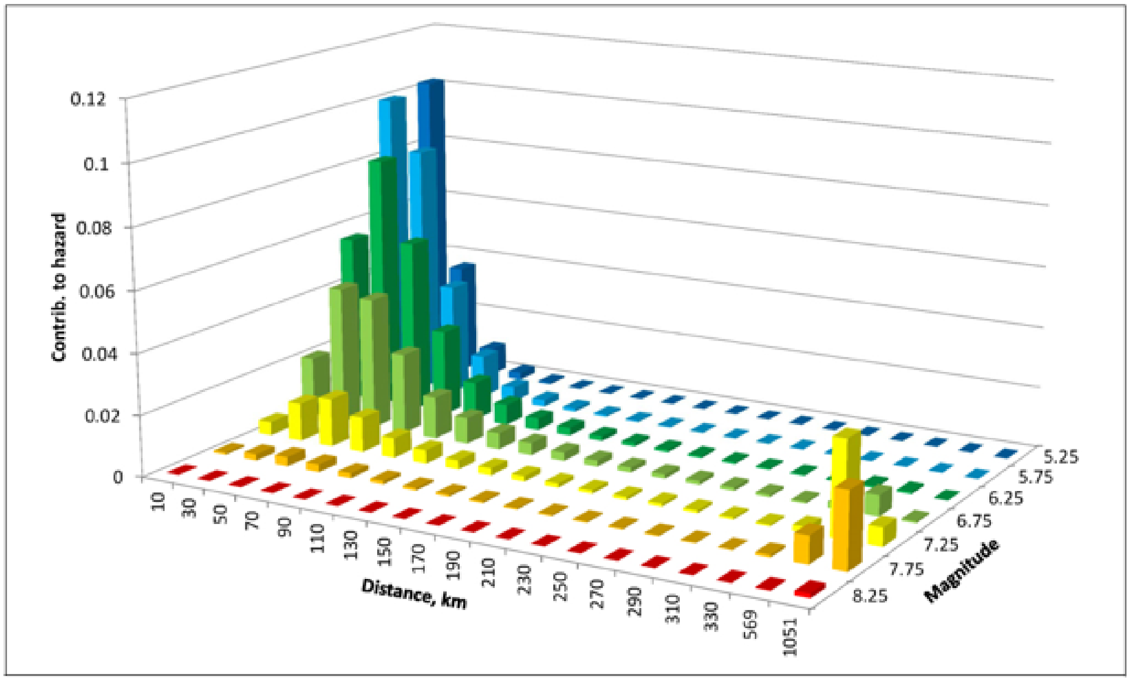
In order to determine which earthquakes are most significant to hazard at the North Anna 3 site, the applicant performed deaggregation for LF and HF ground motions. These earthquakes, termed controlling earthquakes, were determined by averaging the deaggregated impact of distance and magnitude on hazard at 1 and 2.5 Hz for LF and 5 and 10 Hz for HF following procedures outlined in RG 1.208, Appendix D. The applicant deaggregated the PSHA results at target mean annual frequencies of exceedance levels to determine the controlling earthquakes in terms of magnitude and site-to-source distance. SER Figure 2.5.2-4 shows the deaggregation plots for HF and LF 10^{-4} mean annual frequencies of exceedance hazard results. Following RG 1.208, the applicant selected the controlling earthquake for LF ground motions from the distance calculation of greater than 100 km (62 mi).

The applicant followed Approach 2A described in NUREG/CR-6728, "Technical Basis for Revision of Regulatory Guidance on Design Ground Motions: Hazard- and Risk-Consistent Ground Motion Spectra Guidelines." As part of Approach 2A, the applicant determined the site response analysis input ground motion by calculating spectral shapes based on NUREG/CR-6728 for HF and LF ground motions at 10^{-4}, 10^{-5}, and 10^{-6} mean annual frequencies of exceedance. The applicant anchored HF input ground motions at the PSHA values for frequencies of 2.5 Hz and higher and the LF input ground motions at the PSHA values for frequencies of 2.5 Hz and lower. FSAR Figure 2.5.2-257 shows the Uniform Hazard Response Spectrum (UHRS) that the applicant determined by enveloping the LF and HF input motions.

Table 2.5.2-1 Mean Magnitude and Distance for LF and HF Response Spectra for Three MAFEs (Table 2.5.2-218, Rev 9)

MAFE	**10^{-4}**	**10^{-5}**	**10^{-6}**
Low Frequency M	7.1	6.4	6.7
Low Frequency R (km)	340	21	16
High Frequency M	5.9	6.1	6.4
High Frequency R (km)	22	15	13

LF: low frequency, 1 to 2.5 Hz
HF: high frequency, 5 to 10 Hz
MAFE: mean annual frequency of exceedance



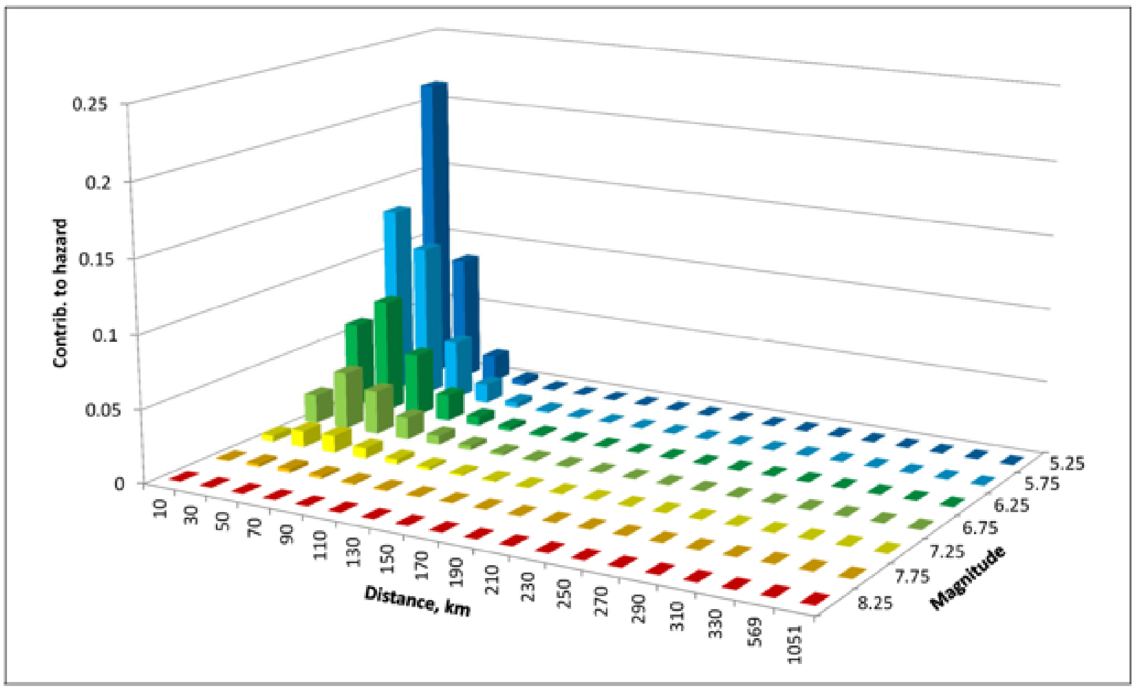


Figure 2.5.2-4. Deaggregation Results for LF (Upper) and HF (Lower) at the 10-4 Mean Annual Frequency of Exceedance Level (Figure 2.5.2-250 and Figure 2.5.2-251, Rev. 9)

Seismic Wave Transmission Characteristics of the Site

FSAR Section 2.5.2.5 describes the procedure the applicant used to assess the effects of soils on seismic wave transmission beneath the North Anna 3 site. The PSHA calculates hazard curves for generic hard rock conditions, characterized by S-wave velocity of 2.8 km/s (9,200 fps). For the North Anna 3 site, these hard rock conditions exist at depths ranging from 47.3 to 50.3 m (155 to 165 ft) below surface elevation 88.4 m (290 ft) NAVD88. To determine the near-surface soil UHRS, the applicant first developed soil/rock profile models for the North Anna 3 site; selected representative hard rock ground motions based on a hard rock seismic hazard calculations; and performed site response analysis to obtain the free-field soil UHRS at the elevation of the competent layer beneath the North Anna 3 site.

In FSAR Section 2.5.2.5, the applicant described two sets of site response analyses. The applicant used one analysis to develop the site-specific GMRS and the second analysis to perform the soil structure interaction (SSI) analyses. For the SSI analyses inputs, the applicant developed the performance-based surface response spectra (PBSRS) and FIRS. While the applicant described development of PBSRS and FIRS in FSAR Section 2.5.2.5, the summary and evaluation of the PBSRS, FIRS, and SSI analysis are discussed in SER Section 3.7.1.

The applicant stated that the geology of the site is complex, consisting of undulating layers of saprolite and rock of varying degrees of weathering. In order to account for the uncertainty in the material properties of the rock at the GMRS elevation across the footprint of the plant, the applicant developed BE velocity profiles for the GMRS elevation based on borings (B-901, B-907, and B-909) within the footprint of the RB/FB and the CB. The applicant developed separate models for the two buildings at the GMRS Elevation 68.3 m (224 ft) NAVD88 and enveloped the resulting response spectra to determine the site GMRS.

Site Response Model

According to the applicant, the geology at the North Anna 3 site consists of layers of saprolite overlying rocks of the Ta River Metamorphic suite that have varying degrees of weathering and fracturing. The applicant subdivided the saprolite and weathered rock layers into zones termed Zone I-IV based on physical characteristics. The applicant proposed to locate the GMRS at Elevation 68.3 m (224 ft) NAVD88 in the rock layer termed Zone IV, a layer of competent rock material. The applicant encountered CEUS generic hard rock conditions (i.e., an S-wave velocity of about 2.8 km/s [9,200 fps]) at a depth of approximately 47.2 m (155 ft) (Elevation 41.2 m [135 ft]).

In addition to the S-wave velocity profile, the applicant noted that the other material parameters used as inputs to the site response analysis include material unit weight, shear modulus, and damping. The applicant obtained soil and rock unit weights for the site response profile from laboratory test results and site characterization analysis. The applicant stated that unit weights for the rock units beneath the site range from 2,000 to 2,600 kg/m^3 (125 to 164 pounds per cubic foot).

The applicant determined that for saprolite and Zone III rock, strain dependent damping and shear modulus reduction curves were appropriate. For Zone III-IV and Zone IV rock, the applicant stated that the materials were expected to behave linearly, so no shear modulus reduction curve was required and a constant damping value was used.
The applicant modeled the variability in the site data by randomizing the S-wave velocity profile, the layer thickness, and the shear modulus reduction and damping relationships for the soil. In order to consider the appropriate level of variability in calculating soil profiles, the applicant

considered measurements beneath both the RB/FB and the CB when determining the standard deviation used in randomizing the soil profile. The applicant generated randomized profiles using the S-wave velocity correlation model developed by Silva et al. (1996). The applicant also randomized the shear modulus reduction and damping in the saprolite and Zone III rock. These artificial profiles represent the soil column from the top of the bedrock (rock with an S-wave velocity equal to that of reference rock [2.8 km/s (9,200 fps)]) to Elevation 68.3 m (224 ft) for calculating the GMRS. The applicant used these randomized profiles as input to the site response calculations, which are summarized below.

The applicant separately developed soil profiles for the RB/FB and the CB based on closest downhole measurements. The applicant randomized each of these profiles and calculated the expected site response at the GMRS elevation. In order to account for observed variability in physical characteristics across the site, the applicant enveloped the site response curves for RB/FB and CB profiles when calculating the GMRS. SER Figure 2.5.2-5 shows the input S-wave velocity profiles for the RB/FB and the CB.

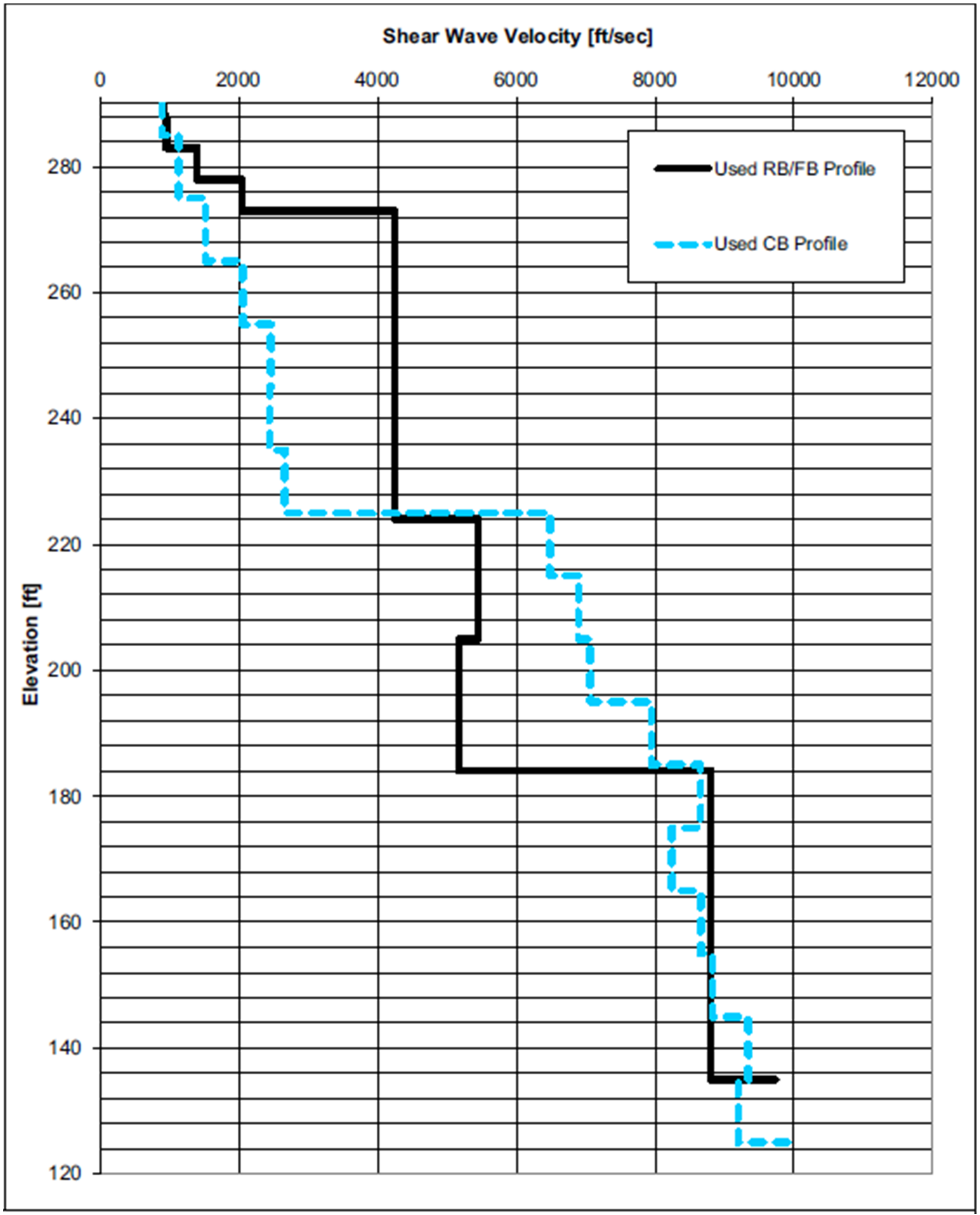


Figure 2.5.2-5. **Input Shear-wave Velocity Profiles for the RB/FB and CB Buildings Used for Site Response Calculations (FSAR Figure 2.5.2-259, Rev. 8)**

Site Response Methodology and Results

In FSAR Section 2.5.2.5.3, the applicant described its approach to developing site response analysis input and methodology. The applicant used the computer program P-SHAKE to calculate site response at the North Anna 3 site. The P-SHAKE program uses equivalent-linear site-response formulations in combination with Random Vibration Theory (RVT) to produce site response input at the reference rock/soil boundary that is propagated through the soil profile. The program takes input response spectra calculated using equations in NUREG/CR-6728 scaled to the hard rock UHRS and converts them to an acceleration power spectral density (PSD). The program calculates a transfer function for shear strain in each soil layer and convolves this with the PSD to calculate an effective strain that is used as input in the next iteration. The program iterates until convergence when the amplitude response spectrum (ARS) at each layer interface can be calculated from the PSD of the solution using the RVT approach.

The RVT method requires additional inputs, particularly strong-motion duration and effective strain ratio. The applicant used NUREG/CR-6728 to calculate strong-motion duration based on the HF and LF controlling earthquakes at the 10^{-4} and 10^{-5} annual frequencies of exceedance. The applicant determined the effective strain ratio using equation 2.5.2.5-1 in the FSAR.

To calculate the final site amplification effects of the soil, the applicant divided the response spectrum for the computed surface motion by the corresponding response spectrum for the hard rock input motion. The applicant calculated the ARS for each of the 60 site profiles and took the arithmetic mean to define the amplification function. The applicant performed the analysis for the HF and LF spectra at the 10^{-4} and 10^{-5} exceedance frequencies and enveloped the resulting ARS to determine the UHRS at the GMRS elevation. FSAR Figures 2.5.2-286 and 2.5.2-287 show the amplification functions determined by the applicant for the 10^{-4} and 10^{-5} exceedance frequencies respectively.

Ground Motion Response Spectra

FSAR Section 2.5.2.6 describes the method the applicant used to develop the horizontal and vertical site-specific GMRS. To obtain the horizontal GMRS, the applicant used the performance-based approach described in RG 1.208 and in ASCE/SEI Standard 43-05, “Seismic Design Criteria for Structures, System, and Components in Nuclear Facilities” (ASCE/SEI, 2005). The applicant developed the vertical GMRS using site-specific vertical to horizontal (V/H) response spectral ratios developed using guidance provided in NUREG/CR-6728 for CEUS sites.

Horizontal Ground Motion Response Spectra

The applicant calculated a horizontal, site-specific, performance-based GMRS using the method described in RG 1.208. The performance based method achieves the annual target performance goal (P_F) of 10^{-5} per year for the frequency of onset of significant inelastic deformation. This damage state (i.e., deformation) represents a minimum structural damage state – or essentially elastic behavior – and falls well short of the damage state that would interfere with functionality. The GMRS was calculated using the following relationship:

$$GMRS = DF * UHRS(10^{-4})$$

Where:

$$DF = max\{1.0, 0.6 * (A_R)^{0.8}\}$$
$$A_R = UHRS(10^{-5})/UHRS(10^{-4})$$

The applicant noted that when the value of A_R exceeds 4.2, RG 1.208 specifies that it is appropriate to use a GMRS value equal to 45 percent of the mean 10^{-5} UHRS. The applicant calculated a GMRS using the above approach for both the RB/FB and the CB at Elevation 68.3 m (224 ft) NAVD88 and enveloped them to determine the site-specific performance-based GMRS. SER Figure 2.5.2-6 shows the resulting horizontal GMRS.

Vertical Ground Motion Response Spectra

The applicant obtained the vertical GMRS by calculating site-specific V/H ratios and applying them to the horizontal GMRS. The applicant used information provided in NUREG/CR-6728 and velocities at the GMRS elevation to calculate a site-specific V/H ratio. SER Figure 2.5.2-6 shows the vertical GMRS for the North Anna 3 site using the V/H ratio shown in FSAR Figure 2.5.2-320.

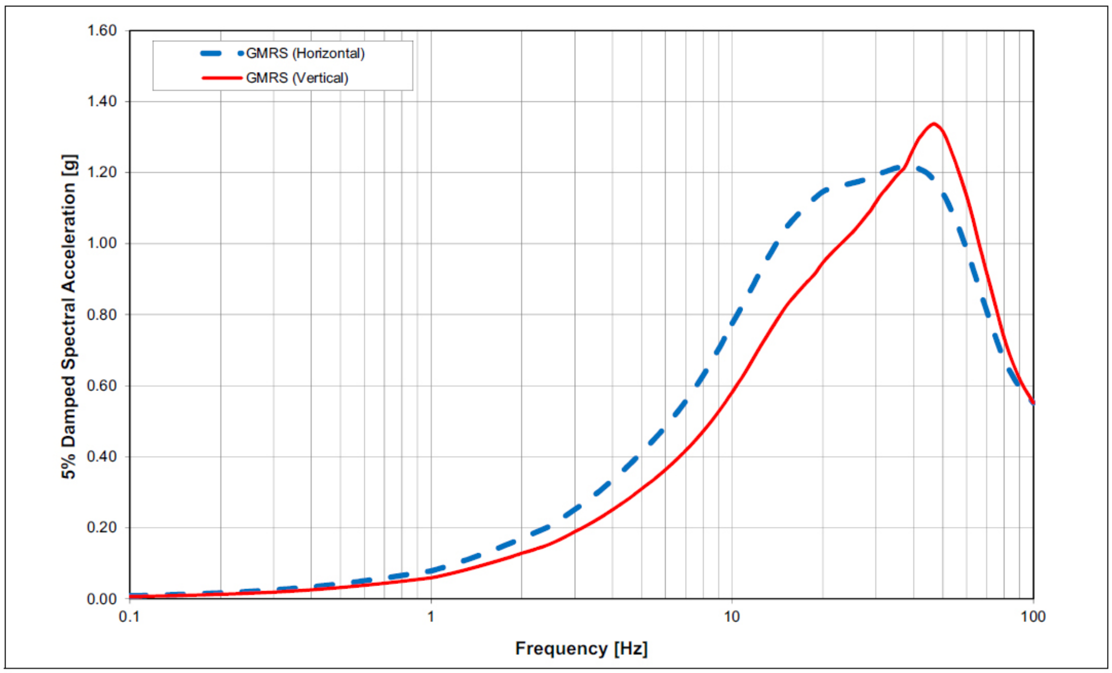


Figure 2.5.2-6. Horizontal and Vertical GMRS for the North Anna 3 Site at Elevation 68.28 m (224 ft) (FSAR Figure 2.5.2-313, Rev. 9)

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 COLA 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).

The applicable regulatory requirements for reviewing the applicant's discussion of vibratory ground motion are:

- 10 CFR 100.23, with respect to obtaining geologic and seismic information necessary to determine site suitability and ascertain that any new information derived from site-specific investigations does not impact the GMRS derived by a PSHA. The site-specific GMRS satisfies the requirements of 10 CFR 100.23 with respect to development of the SSE. In complying with this regulation, the applicant also meets guidance in RG 1.132, "Site Investigations for Foundations of Nuclear Power Plants," Revision 2; and RG 1.208.

- 10 CFR 52.79(a)(1)(iii), as it relates to 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.

The related acceptance criteria summarized from NUREG-0800 Section 2.5.2 are as follows:

- **Seismicity**: To meet the requirements in 10 CFR 100.23, this section is accepted when the complete historical record of earthquakes in the region is listed and when all available parameters are given for each earthquake in the historical record.

- **Geologic and Tectonic Characteristics of Site and Region:** Seismic sources identified and characterized by the LLNL and the EPRI were used for studies in the CEUS in the past.

- **Correlation of Earthquake Activity with Seismic Sources:** To meet the requirements in 10 CFR 100.23, acceptance of this section is based on the development of the relationship between the history of earthquake activity and seismic sources of a region.

- **Probabilistic Seismic Hazard Analysis and Controlling Earthquakes:** For CEUS sites relying on LLNL or EPRI methods and databases, the staff will review the applicant's PSHA, including the underlying assumptions and how the results of the site investigations are used to update the existing sources in the PSHA, how they are used to develop additional sources, or how they are used to develop a new database.

- **Seismic Wave Transmission Characteristics of the Site:** In the PSHA procedure described in RG 1.208, the controlling earthquakes are determined for generic rock conditions.

- **Ground Motion Response Spectra:** In this section, the staff reviews the applicant's procedure to determine the GMRS.

In addition, the geologic characteristics should be consistent with appropriate sections from: RG 1.60, "Design Response Spectra for Seismic Design of Nuclear Power Plants"; RG 1.132, RG 1.206; and RG 1.208.

2.5.2.4 Technical Evaluation

As documented in NUREG–1966, the staff reviewed and approved Section 2.5.2 of the certified ESBWR DCD, Revision 10. The staff reviewed Section 2.5.2 of the North Anna 3 COL FSAR, Revision 8, and checked the referenced ESP SSAR and the referenced ESBWR DCD to ensure that the combination of the information in the North Anna 3 COL FSAR, the ESP SSAR and the information in the ESBWR DCD appropriately represents the complete scope of information relating to this review topic.

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 and its supplement.

The staff reviewed Section 2.5.2 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 section.

During the course of staff's review of the application, the applicant changed its selection of reactor technology. Previously in RAI 2.5.2-1 dated December 21, 2010 (ADAMS Accession No. ML110270358), the staff had a concern about the elevation of the GMRS. In the response to RAI 2.5.2-1 dated March 22, 2011 (ADAMS Accession No. ML110880254), the applicant states this question is no longer applicable because of the FSAR revisions following the selection of a new reactor design. Therefore, RAI 2.5.2-1 is resolved and closed.

The staff's technical evaluation of this application is limited to the resolution of DCD COL Item 2.0-27-A, discussion of ESP VAR 2.0-4, and new and significant information regarding the August 23, 2011, Mineral earthquake, additional subsurface investigations, and the availability of the CEUS-SSC, as addressed below:

<u>*COL Items:*</u>

- NAPS COL 2.0-27-A

In accordance with COL Action Item 2.0-27-A, and to resolve COL item 2.5-3, the applicant updated the site subsurface material properties with results from COL field investigations. The applicant performed several additional borings to sample the subsurface and did additional field geophysical measurements. The staff reviewed the new information and found it important for the site response analysis. The staff used this information to perform updated confirmatory site response analysis described in Section 2.5.2.4.2 of this SER.

<u>*ESP Variance:*</u>

- NAPS ESP VAR 2.0.4

The applicant requested VAR 2.0-4 in order to use the spectral acceleration values at elevation 68.3 m (224 ft), rather than the ESP GMRS elevation of 76.2 m (250 ft). The applicant also updated its PSHA to incorporate the recent CEUS-SSC. The staff considered this variance request and determined that because the GMRS elevation was redefined based on the applicant's COL subsurface investigations, the use of the base of the RB/FB foundation for GMRS elevation in place of that determined as part of the ESP is acceptable. The staff also finds use of the CEUS-SSC acceptable as it represents the most up to date model of seismic sources in the Central and Eastern U.S.

Probabilistic Seismic Hazard Analysis Updates

On August 23, 2011, the **M**5.8 Mineral earthquake occurred approximately 23 km (14 mi) from the North Anna 3 site. The occurrence of a moderate magnitude earthquake within the site vicinity indicates that a previously unrecognized seismic source may exist that poses a hazard at the plant. This new and significant information led the staff to reopen the PSHA previously evaluated as part of the ESP. In RAI 2.5.2-4, dated November 1, 2011 (ADAMS Accession No. ML11305A261), the staff asked the applicant to assess the adequacy of the EPRI SOG (EPRI, 1986, 1989) seismic source model in light of the Mineral, Virginia earthquake. In RAI 2.5.2-8 dated July 8, 2015 (ADAMS Accession No. ML15233A433), the staff also asked the applicant to address any exceedances of the postulated GMRS by observed ground motions at the existing North Anna 1 in terms of the adequacy of the seismic design parameters in FSAR Section 3.7.1 to account for the recordings. The RAI also asked the applicant to specify the operability criteria for the as-found conditions of safety-related SSCs, until the SSC is restored to meet the original design basis and design criteria, to ensure that such demonstrations would consider the Mineral, Virginia earthquake recordings. In the response to RAI 2.5.2-4 dated February 13, 2012 (ADAMS Accession No. ML12048A096), the applicant responded that the record of the **M**5.8 Mineral earthquake is considered in development of the North Anna 3 SSE by including a comparison with the CSDRS. The applicant demonstrated that the Unit 1 containment mat earthquake recorded motion in all three directions are enveloped by the North Anna 3 CSDRS at all frequencies. Further, the applicant clarified the FSAR description of the seismic design parameters in FSAR Section 3.7.1 by noting that these site-specific recorded motions for North Anna are enveloped by the CSDRS, which is the licensing basis for all Category I structures. Regarding operability, the applicant included a criteria in Section 3.7.1 of the FSAR that the SSE design ground motion will be used in operability assessments to demonstrate plant safety for the as-found conditions of safety-related SSCs. Since the SSE design ground motion includes both the CSDRS and the site-specific FIRS, and the CSDRS envelopes these recordings and is the licensing basis for all Category I structures and would be used in determining operability or other demonstrations of plant safety, the staff considers RAI 2.5.2-8 resolved and closed. The staff verified that the appropriate change is incorporated in the FSAR, Revision 9, and, therefore, Confirmatory Item 2.5.2.01 from the staff's advanced SER for North Anna 3 is resolved and closed.

Following the Fukushima accident in Japan in March 2011, and subsequent NRC NTTF recommendations, on March 12, 2012, the NRC issued a letter, "Request for Information Pursuant to 10 CFR 50.54(f) Regarding Recommendations 2.1, 2.3, and 9.3 of the Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident" (ADAMS Accession No. ML12053A340), requesting the operating nuclear power plants to re-assess seismic hazards at their sites using the most recent seismic source models. Consistent with existing guidance in RG 1.208, pertaining to the need to consider the latest information in the evaluation of seismic hazard, the staff issued an RAI to all COL and ESP applicants. In RAI 1.5-1 dated June 25, 2012 (ADAMS Accession No. ML12177A435), issued to North Anna 3 to reassess the seismic hazard at their sites using the new seismic source models. In the response to RAI 1.5-1 dated July 30, 2012 (ADAMS Accession No. ML12214A593), the applicant stated that based on FSAR changes made in responding to RAI 2.5.2-4, RAI 1.5-1 no longer applied at the North Anna 3 site.

The staff reviewed the applicant's response to RAI 1.5-1, and agrees that the applicant's response to RAI 2.5.2-4, in which the applicant stated that CEUS-SSC model would be used for PSHA, adequately addressed issues in RAI 1.5-1. Therefore, the staff considers RAI 1.5-1 resolved and closed.

In the February 13, 2012, response, the applicant also stated that it would update its COLA to use the CEUS-SSC to perform a new hard rock PSHA and develop a new site-specific GMRS for the North Anna 3 site. The applicant stated that this new PSHA would incorporate earthquake data from January 2009 through December 2011, which is subsequent to the period covered by the CEUS-SSC earthquake catalog. The applicant then updated its selection of GMM from the EPRI (2004, 2006) model to the most recent EPRI (2013) model and presented the results in the updated version of the North Anna 3 COL FSAR. The staff verified that the appropriate updates are incorporated into the FSAR, Revision 9, and, therefore, Confirmatory Item 2.5.2.02 from the staff's advanced SER for North Anna 3 is resolved and closed.

The staff reviewed the applicant's response and associated FSAR updates. The CEUS-SSC, as published in NUREG-2115, is a seismic source model that represents the state of the practice concerning the conduct of PSHA in CEUS. Additionally, the applicant followed applicable guidance in updating the seismicity catalog, selecting seismic sources, and determining controlling earthquakes. Therefore, based on the updated PSHA source model, the updated site response analysis, and the staff's confirmatory analysis, discussed below, the staff considers RAI 2.5.2-4 resolved and closed.

In the response to RAI 2.5.2-4 dated February 13, 2012 (ADAMS Accession No. ML12048A096), the applicant stated that it would update the CEUS-SSC to account for seismicity occurring after the period covered by the CEUS-SSC. In its response to RAI 2.5.2-4, the applicant updated the CEUS-SSC to account for seismicity occurring after the period covered by the CEUS-SSC catalog. The applicant updated seismicity maps and evaluated the impact of updated seismicity on seismicity rates and b-values in the CEUS-SSC. The applicant did not provide detailed maps of where seismicity rates changed due to the catalog updates. In RAI 2.5.2-7 dated April 8, 2014 (ADAMS Accession No. ML14098A297), the staff asked the applicant to demonstrate quantitatively how the applicant updated the CEUS-SSC to incorporate recent seismicity. Specifically, the staff asked the applicant to demonstrate the updated recurrence rates, b-values, and comparisons of the hazard using the CEUS-SSC catalog, as published, and the updated catalog.

In the response to RAI 2.5.2-7 dated May 9, 2014 (ADAMS Accession No. ML14140A087), and supplemented on May 29, 2014 (ADAMS Accession No. ML14150A439), the applicant provided detailed information about how the updated seismicity catalog influenced rates and b-values in the CEUS-SSC and provided the requested comparison of hazard. The applicant provided plots (example shown on Figure 2.5.2-7 of this SER) of updated rates and b-values for the four distributed seismicity zones that the North Anna 3 site lays within (ECC-AM, MESE-N, MESE-W, and STUDY-R). Further In its response to RAI 2.5.2-7, the applicant provided a Table-1 and a Figure-13, comparing the updated and the baseline seismic hazard at a variety of input spectral acceleration levels. The applicant demonstrated that the updated seismic catalog increases hazard at the North Anna 3 site up to 9 percent for annual frequencies of exceedance lower then 10^{-4}.

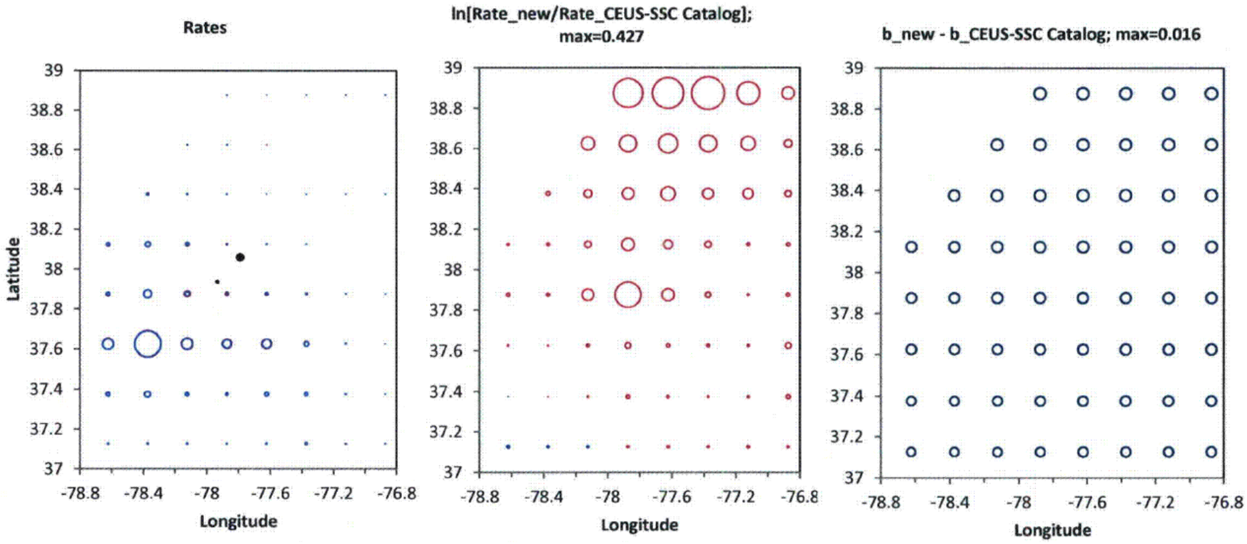


Figure 2.5.2-7. **Map *of Changes in Seismicity Rates and B-Values for* CEUS-SSC *Source Zone* ECC-AM, Case A *(*Figure *from Applicant Response to* RAI *2.5.2-7.)***

The staff reviewed information provided by the applicant in response to RAIs about the CEUS-SSC catalog updates and the Mineral earthquake. The staff conducted a site audit on May 8, 2014, as documented in ADAMS Accession No. ML14203A179, during which the staff and the applicant discussed the details of their approach to the catalog updates and site response.

The staff also conducted an independent confirmatory analysis of the PSHA. The staff calculated the hazard at the North Anna 3 site using the published CEUS-SSC for distances up to 500 km (310 mi) for distributed seismicity sources and 1,000 km (620 mi) for RLME sources. In its confirmatory analysis, staff used the EPRI (2013) GMM. Figure 2.5.2-8 of this SER compares the PSHA results from the staff's independent confirmatory analysis with those of the applicant for PGA and frequencies of 25, 10, 2.5, and 1 Hz. The staff's and the applicant's calculations are in acceptable agreement. The staff used its independent PSHA results to develop site specific UHRS at the 10^{-4} and 10^{-5} exceedance frequencies. SER Figure 2.5.2-9 compares 10^{-4} and 10^{-5} UHRS developed by the staff with those developed by the applicant. Because the UHRS results developed by the staff are in acceptable agreement with those developed by the applicant and the applicant has incorporated seismicity after the publication of the CEUS-SSC, including the Mineral earthquake, the staff finds the applicant's PSHA acceptable.

Based on the applicant's response, the results of staff's site audit and its independent confirmatory analysis, staff considers RAI 2.5.2-7 resolved and closed.

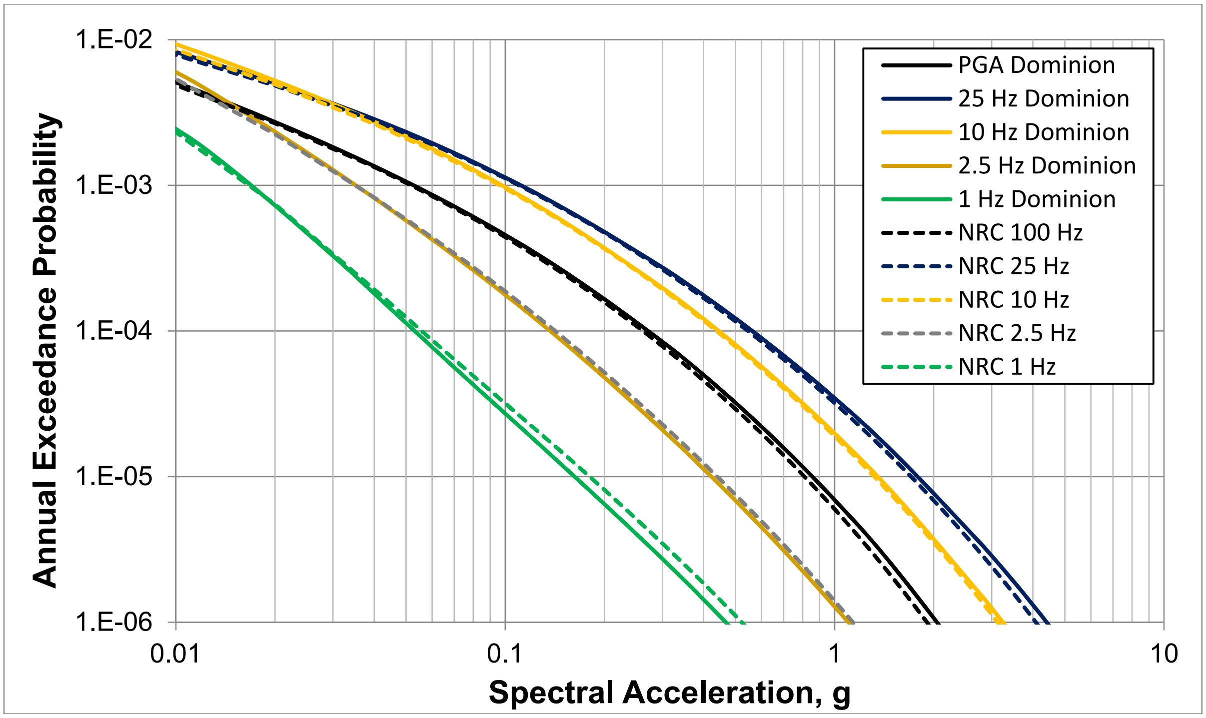


Figure 2.5.2-8. Comparison of the Applicant's Base Rock Hazard Curves with the Results of the Staff's Confirmatory Analysis

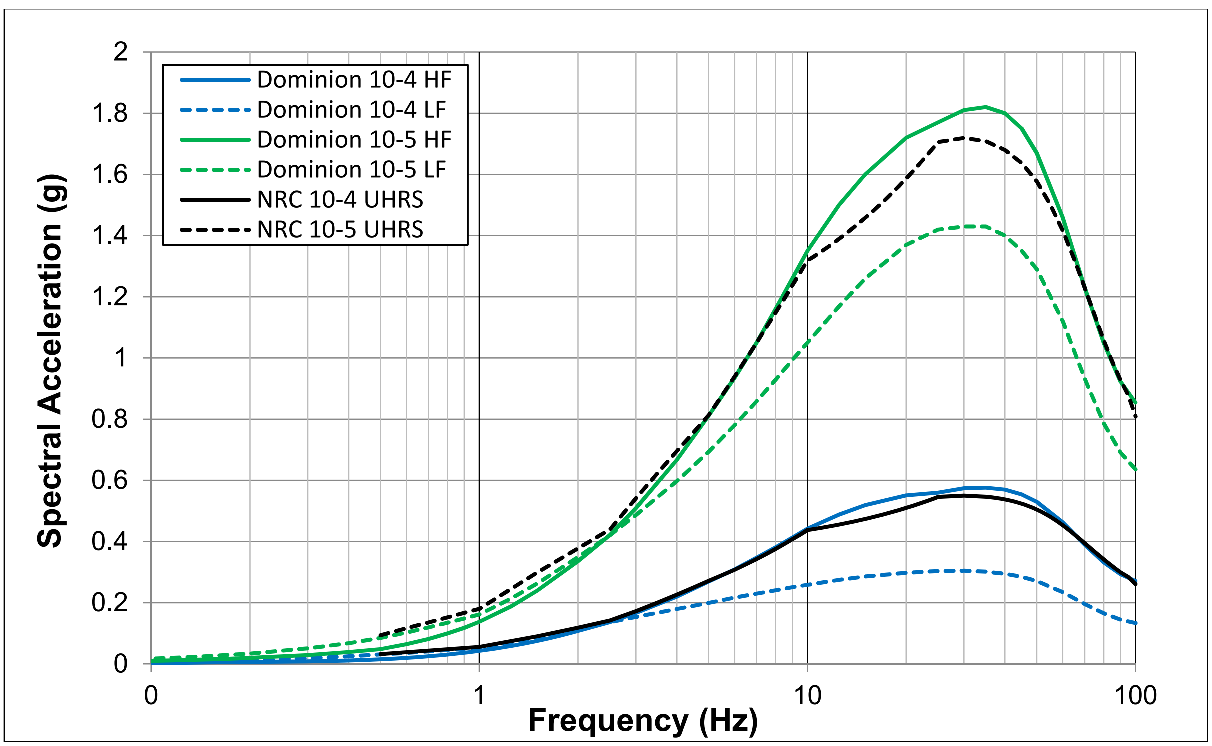


Figure 2.5.2-9. Comparison of the Applicant's UHRS at the 10-4 and 10-5 Annual Frequencies of Exceedance with the Results of Staff's Confirmatory Analysis

Ground Motion Response Spectra Updates

The applicant conducted additional site investigations subsequent to the issuance of the ESP. These investigations included additional geologic borings and subsurface geophysical measurements. As a result, the applicant developed new shear wave velocities for each of the rock units at the site. In addition, these additional borings revealed a more complex subsurface structure than was presented in the ESP SSAR. Therefore, in RAI 2.5.2-2a, dated December 21, 2010 (ADAMS Accession No. ML110340012), the staff asked the applicant to justify the use of one-dimensional site response methodology when significant topographic relief characterizes the subsurface layer interfaces. In RAI 2.5.2-2b, dated December 21, 2010 (ADAMS Accession No. ML110340012) the staff also asked, how the applicant ensured that the site response analysis captured this variability.

In the response to RAI 2.5.2-2a dated December 18, 2013 (ADAMS Accession No. ML14013A113), the applicant's response was revised. In the response to RAI 2.5.2-2b dated December 18, 2013 (ADAMS Accession No. ML14013A113), the applicant stated that even though there appears to be significant subsurface variability across the site and within the footprint of the plant, the distinction between different layers are, in fact, based on incremental differences in weathering. Because the criteria used to define the different layers within the rock are somewhat arbitrary, the layers are a result of the natural variability in the level of weathering across the site. The applicant stated that the vertical extent of this variability is small relative to the footprint of the plant, and concluded that a one-dimensional site response was appropriate. The applicant further stated that because this variability is the result of defining layers, not an actual stratification of the geology, that randomization of layer thicknesses, shear-wave velocity, and damping and shear modulus degradation curves accounts for this variability in site response. To further account for subsurface variability across the site, the applicant used data from three boreholes located within the footprint of the plant to generate shear-wave velocity profiles, and enveloped design response spectra from the RB/FB soil column and the CB soil column to determine the GMRS.

The staff reviewed the information provided by the applicant in response to RAI 2.5.2-2, and found that while the definition of different rock types (e.g., Zone III vs. Zone IV) was somewhat arbitrary, seismic shear-wave velocities varied greatly throughout the vertical soil profile of the site. As these shear-wave velocities correlate with different zones, the complex topography of the weathering profile across the site indicates that one-dimensional site response analysis may not be appropriate. In RAI 2.5.2-3a dated August 25, 2011 (ADAMS Accession No. ML11241A058), the staff asked the applicant to justify the one-dimensional site response analysis using only vertically propagating shear waves given the complex topography of the subsurface layers. In RAI 2.5.2-3b dated August 25, 2011 (ADAMS Accession No. ML11241A058), the staff requested that the applicant provide detailed site response input parameters. In RAI 2.5.2-3c dated August 25, 2011 (ADAMS Accession No. ML11241A058), the staff requested that the applicant explain how the shear-wave velocity profiles used in site response analysis were developed.

In the response to RAI 2.5.2-3a dated August 25, 2011 (ADAMS Accession No. ML11241A058), the applicant's response, supplemented on December 18, 2013 and February 23, 2015, stated that the use of one-dimensional site response analysis is appropriate because the soil and rocks at the site are all derived from the same parent rock. The applicant stated that the boundaries between rock types are gradational and so do not represent lateral impedance boundaries that may result in refraction, reflection, or trapping of shear waves traveling in horizontal directions. The applicant also stated that the uncertainties used in performing the site response such as varying the layer thicknesses, velocities, and shear modulus degradation and damping curves accounts for the variability in layer thickness across the site.

In order to ensure that appropriate uncertainties are included in their site response analysis, the applicant stated that they used geophysical data from three boreholes in their site response analysis. Data from boreholes B-901, B-907, and B-909 were used to develop a BE, log-mean, velocity profile for the RB/FB, and composite profiles, Profiles 1 and 2, were combined with the BE profile to develop the standard deviation profile for the RB/FB. The CB profile was developed using information from the closest borehole B-909. The applicant performed an independent site response analysis for each profile and enveloped the resulting response spectra to determine the GMRS for the site.

In addition, the applicant performed a sensitivity study in which the applicant calculated site response for all three boreholes individually. The applicant weighted these individual response spectra according to the borehole's proximity to the RB/FB centerline and enveloped. The applicant stated that the approach taken above to determine the GMRS is conservative relative to the results of the sensitivity study at all frequencies except for a small number of frequencies around 60 Hz.

The staff reviewed information provided by the applicant in response to RAI 2.5.2-3, but it was unclear to staff why the envelope of two site response calculations was used rather than the envelope of the three site response calculations undertaken by the applicant as part of its FIRS analysis. Therefore, in RAI 2.5.2-6 dated April 8, 2014 (ADAMS Accession No. ML14098A297), the staff requested that the applicant clarify why the GMRS was calculated as the envelope of the RB/FB and CB spectra and not the envelope of the profiles used for FIRS.

In a May 9, 2014 response (ADAMS Accession No. ML14140A087), the applicant clarified that information from all three boreholes (B-901, B-907, and B-909) was used to develop the soil profile for the RB/FB, and information from B-909 was used to develop the soil profile for the CB. The applicant stated that it used the envelope of the response spectra to represent the GMRS at the site because the envelope appropriately considered the uncertainties across the footprint of the site.

In the response to RAI 2.5.2-6 dated February 27, 2015 (ADAMS Accession No. ML15124A005), the applicant determined that the information provided sufficiently characterizes the subsurface geologic structure. The randomization procedures undertaken by the applicant appropriately account for the variability in layer thickness. Additionally, because the site materials are all derived from the same parent material, the use of multiple profiles ensures that horizontal variability in subsurface structure is accounted for.

The staff performed a confirmatory analysis of site response using values reported by the applicant for geophysical parameters. The staff independently developed BE velocity profiles, randomized the velocity profile and shear modulus degradation and damping curves and calculated site-specific amplification functions at the GMRS elevation. Figure 2.5.2-10 shows a comparison of amplification functions developed by the staff with those developed by the applicant. The differences in site amplification functions calculated by the staff and the applicant are not significant considering that staff used Approach 3 and the applicant used Approach 2, as described in NUREG/CR-6728, for the site response calculations. The staff subsequently combined its PSHA results at the 10^{-4} and 10^{-5} exceedance frequencies with its amplification functions and calculated a site-specific GMRS. Figure 2.5.2-11 shows a comparison of the site-specific GMRS developed by the staff with that developed by the applicant. The applicant's calculations are similar to that of the staff up to the frequency of about 25 Hz, and envelope staff's calculations at higher frequencies.

Based on the applicant's response to RAIs related to the site response calculations and staff's independent confirmatory analysis that is consistent with the applicant's results, the staff considers RAI 2.5.2-2, RAI 2.5.2-3, and RAI 2.5.2-6 resolved and closed.

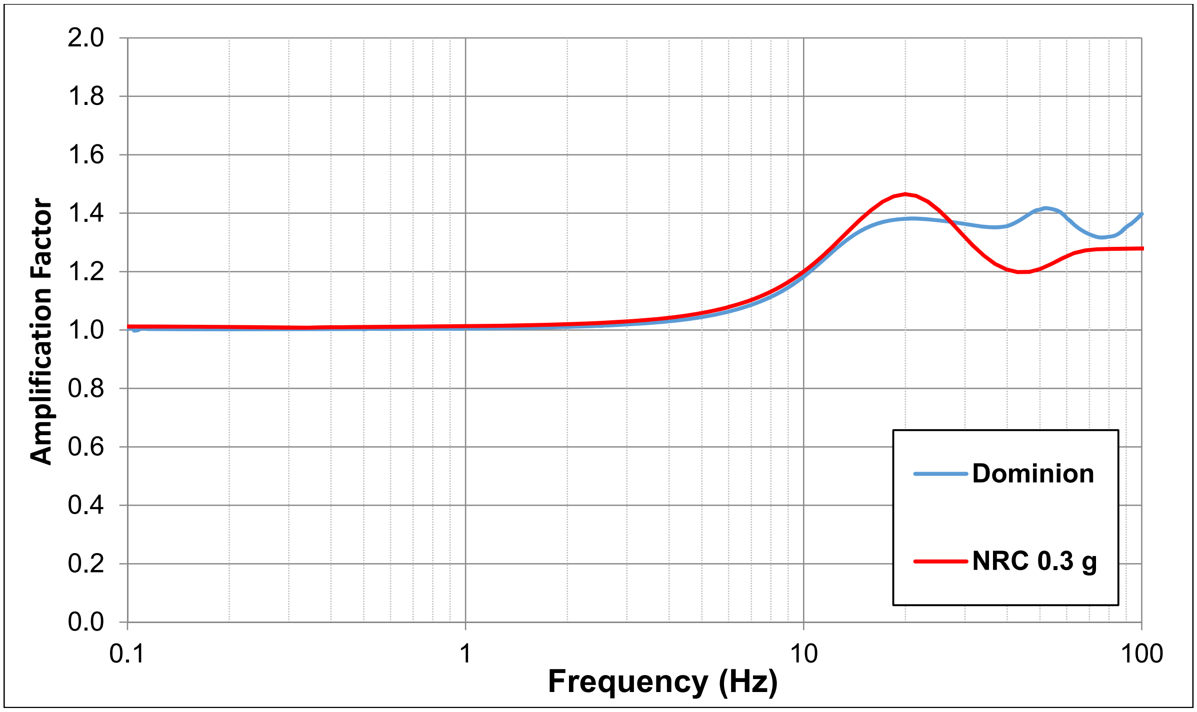


Figure 2.5.2-10. Comparison of the Applicant's Site Amplification Function with the Results of Staff's Confirmatory Analysis

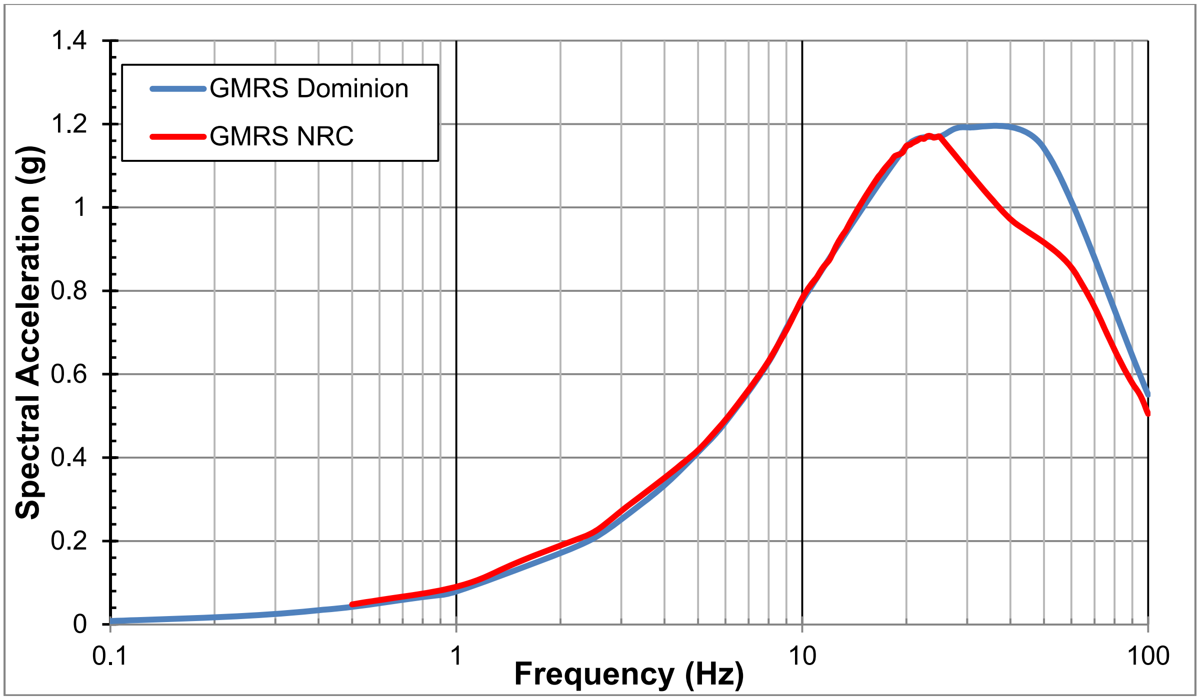


Figure 2.5.2-11. **Comparison of the Applicant's GMRS with the Results of Staff's Confirmatory Analysis at Elevation 68.3 m (224 ft).**

2.5.2.5 Post COL Activities

There are no post COL activities associated with this section.

2.5.2.6 Conclusion

The 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 section.

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. Additionally, the staff concludes that the applicant has adequately addressed new and significant information pertaining to the Mineral, Virginia earthquake, the CEUS-SSC model, and additional subsurface geologic information from the COL subsurface investigations. Finally, the staff compared the additional COL information in the application to the relevant NRC regulations and acceptance criteria defined in NUREG-0800. 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 resolved. 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 COLA. 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 RAIs, 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 the North Anna ESP SSAR, Revision 9. In addition, in FSAR Section 2.5.3, the applicant provided supplemental information on additional borehole data from North Anna 3 borings. The applicant stated that information contained in COL FSAR Section 2.5.3 is consistent with RG 1.208 and is intended to satisfy 10 CFR 100.23.

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 nontectonic faulting. The ESBWR design requires the applicant to demonstrate that there is no potential for permanent ground deformation at the site area.

Early Site Permit Variance:

- NAPS ESP VAR 2.0.4

The staff's review of the ESP VAR 2.0-4 associated with North Anna 3 COL FSAR Section 2.5.3 is addressed below in the Technical Evaluation.

Geological Evidence, or Absence of Evidence, for Surface Deformation

The COL FSAR Section 2.5.3.2.1 described recent geologic mapping at the 1:24,000 scale by Hughes and Hibbard (2014) in the Ferncliff, VA 7.5' quadrangle (southwest of North Anna site) that shows the Chopawamsic fault as un-folded, in contrast to previous mapping, and the Ellisville pluton (440 Ma) intruding and cross-cutting the Chopawamsic fault. The Ellisville pluton thus postdates the Chopawamsic fault. This mapping simplifies the geometry of the Chopawamsic fault and moves the surface trace of the fault further northwest than mapped previously.

The COL FSAR Section 2.5.3.2.2 describes the main shock and deep aftershock epicenters of the Mineral earthquake as located near the LBF. The COL applicant pointed out that the Mineral earthquake aftershock-delineated rupture plane projects to the surface several miles west of the LBF.

Ages of Most Recent Deformations

The COL FSAR Section 2.5.3.4 states that the subsurface structure defined by aftershocks of the Mineral earthquake is located outside the 5-mi (8 km) radius site area. The COL applicant concluded based on its field reconnaissance in the epicentral region on April 19 to 21, 2012, that there is no evidence of surface rupture, surface fault features, or geomorphic expression of surface rupture or co-seismic surface tectonic deformation from the Mineral earthquake. The COL applicant further concluded that the rupture plane of the Mineral earthquake does not appear to coincide with a previously mapped fault.

2.5.3.3 Regulatory Basis

The regulatory basis of the information incorporated by reference is addressed within the FSER related to the ESBWR DCD and its supplements and in ESP FSER (NUREG-1835).

The applicable regulatory requirements for reviewing the applicant's discussion of surface tectonic and non-tectonic deformation are:

- 10 CFR 52.79(a)(1)(iii), relates to identifying geologic site characteristics 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.

- 10 CFR 100.23, 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 2.5.3:

- **Geologic, Seismic, and Geophysical Investigations**: In meeting the requirements of GDC 2 in Appendix A of 10 CFR Part 50, 10 CFR 52.17(a)(1)(vi),or 10 CFR 52.79(a)(1)(iii), and 10 CFR 100.23(c) and 10 CFR 100.23(d)(2), and guidance in RGs 1.208, and 4.7, this area of review is considered acceptable if discussions of Quaternary tectonics, structural geology, stratigraphy, geochronologic methods used for age dating, paleoseismology, and geologic history of the site vicinity, site area, and site location are complete, compare reasonably with studies conducted by others in the same area, and are supported by detailed investigations performed by the applicant.

- **Geologic Evidence for Surface Deformation**: In meeting the requirements of GDC 2 in Appendix A of 10 CFR Part 50, 10 CFR 52.17(a)(1)(vi) or 10 CFR 52.79(a)(1)(iii), and 10 CFR 100.23(c) and 10 CFR 100.23(d)(2), and guidance in RGs 1.208, and 4.7, this area of review is considered acceptable if the applicant provides sufficient surface and subsurface information for the site vicinity, area, and location to confirm and characterize presence or absence of surface deformation (e.g., faulting, growth faulting, subsidence or collapse related to dissolution of limestone, salt or gypsum deposits, or salt diapirism and paleoliquefaction) features. The applicant should also take into account the potential for blind faults.

- **Timing of Deformation**: In meeting the requirements of GDC 2 in Appendix A of 10 CFR Part 50, 10 CFR 52.17(a)(1)(vi) or 10 CFR 52.79(a)(1)(iii), 10 CFR 100.23(c), and 10 CFR 100.23(d)(2), this area of review is considered acceptable if recognized surface deformation features (e.g., tectonic faults and non-tectonic features including growth faults) and features associated with a blind fault, are investigated in sufficient detail to constrain the age of the most recent surface deformation event, and, if applicable, the ages of preceding deformation events.

- **Correlation of Earthquakes with Tectonic Features**: In meeting the requirements of GDC 2 in Appendix A of 10 CFR Part 50, 10 CFR 52.17(a)(1)(vi or 10 CFR 52.79(a)(1)(iii)), and 10 CFR 100.23(c), and 10 CFR 100.23(d)(2), this area of review is considered acceptable if the applicant evaluates all reported historical earthquakes within the site vicinity with respect to accuracy of hypocenter location and source of origin, and with respect to correlation to tectonic features.

- **Relationship of Geologic Features in the Site Vicinity to Regional Geologic Features**: In meeting the requirements of GDC 2 in Appendix A of 10 CFR Part 50, 10 CFR 52.17(a)(1)(vi) or 10 CFR 52.79(a)(1)(iii), and 10 CFR 100.23(c) and 10 CFR 100.23(d)(2), this area of review is considered acceptable if the applicant evaluates the relationships between faults or other deformation features in the site vicinity and the regional framework. The application should provide an acceptable evaluation of the relationships between the regional (tectonic and non-tectonic) framework and deformation features in the site vicinity, including growths faults and growth fault systems. The applicant should show how this information is used in the evaluation of potential for future surface deformation at the site.

- **Potential for Surface Deformation at the Site:** To meet requirements of GDC 2 in Appendix A of 10 CFR Part 50, 10 CFR 52.17(a)(1)(vi) or 10 CFR 52.79(a)(1)(iii), and 10 CFR 100.23(c) and 10 CFR 100.23(d)(2), this area of review is considered acceptable if the applicant assessed the potential future tectonic and nontectonic surface deformation at the site. The applicant should provide sufficient geological, seismological, and geophysical information to clearly establish whether there is a potential for future surface deformation at the site. If the potential for future surface deformation exists at the site, the application must provide information that demonstrates the potential effects of surface deformation are within the design basis of the proposed facility. NRC regulations do not restrict building in an area with surface faulting potential, but if that potential exists, the regulations require that surface deformation must be taken into account in the design and operation of the proposed nuclear power plant. It is questionable whether it might be feasible to design for surface deformation with any degree of confidence that safety-related SSCs would maintain their safety functions if surface displacements occur in the future. Consequently, it is NRC policy (e.g., RG 1.208) to recommend that any site located on a surface or near-surface feature with a potential for future displacement be re-located to an alternate site.

Geologic characteristics should also be consistent with the related guidance from appropriate sections of RG 1.132, Revision 2, RG 1.198, “Procedures and Criteria for Assessing Seismic Soil Liquefaction at Nuclear Power Plant Sites,” RG 1.206, and 1.208.

2.5.3.4 Technical Evaluation

The staff reviewed Section 2.5.3 of the North Anna 3 COL FSAR and checked the referenced DCD, Revision 10 and the North Anna 3 ESP SSAR, Revision 9, to ensure that the combination of the DCD, the North Anna 3 ESP SSAR and the COLA represents the complete scope of information related to this review topic. The staff’s review confirms that the information in the COL FSAR and North Anna 3 ESP SSAR addresses the required information for determining the potential for tectonic and non-tectonic surface deformation. The results of the staff’s evaluation of the North Anna 3 ESP SSAR are documented in NUREG-1835.

The staff’s technical evaluation of COL FSAR Section 2.5.3 is limited to reviewing (1) the resolution of DCD COL Item 2.0-26-A, and DCD COL Item 2.0-28-A, and ESP Action 2.5-1; (2) adherence to Permit Condition Section 3(E)(6); (3) resolution of ESP Variance 2.0-4 and; (4) applicant’s responses to RAIs as addressed below.

The staff reviewed the information in the COL FSAR for conformance with DCD COL Item 2.0-26-A. Additional information on the site geologic characteristics is derived from additional subsurface investigations completed for the proposed North Anna 3 site. The staff concludes that the applicant included sufficient information from subsurface investigations to supplement SSAR Section 2.5.3 and to resolve DCD COL Item 2.0-26-A.

The staff reviewed COL Action Items in the North Anna 3 ESP. ESP Action Item 2.5-1 pertains to SER Section 2.5.1: A COL or CP applicant should perform additional borings to identify any weathered or fractured rock beneath the new foundations. Exact unit locations are not known at the ESP stage. The applicant made 93 borings for COL that were used to determine the geology characteristics and geotechnical properties of the subsurface material at the North Anna 3 site to resolve ESP Action Item 2.5-1. SER 2.5.4 provides staff’s detailed evaluation of the additional borings. The staff concludes that the applicant included sufficient information from the additional boring program to support the COL and to resolve ESP Action Item 2.5-1.

The staff reviewed the North Anna 3 ESP Permit Conditions. Permit Condition, Section 3(E)(6) pertains to SER Section 2.5.1: If the ESP holder performs an excavation for a safety-related structure, the ESP holder shall perform geologic mapping of such excavation, evaluate any unforeseen geologic features that are encountered, and notify the NRC no later than 30 days before any such excavation is open for NRC examination and evaluation. An applicant for a CP or COL referencing this ESP shall perform geologic mapping of any excavation for a safety-related structure, evaluate any unforeseen geologic features that are encountered, and notify the NRC no later than 30 days before any such excavation is open for NRC examination and evaluation. The staff proposes that this permit condition be updated to a license condition for future excavations of safety-related structures. Section 2.5.1.4 of this report addresses this license condition.

The staff reviewed the COL FSAR variances to the ESP SSAR (NAPS ESP VAR 2.0-4) for Section 2.5.3 and DCD COL Item 2.0-28-A, and submitted an RAI. The staff's evaluation of information presented by the COL applicant in COL FSAR Section 2.5.3 and of the COL applicant's responses to the RAIs are presented below.

The COL FSAR Section 2.5.3 includes new geophysical and geotechnical information from the North Anna 3 site supplemental subsurface investigation. FSAR Section 2.5.3.2.5 states that borehole data, from the supplemental subsurface investigation described in Section 2.5.4.3, were reviewed for evidence of Quaternary fault movement and no such evidence was exhibited by the borehole data. The staff asked the COL applicant in RAI 02.05.01-6c dated April 22, 2014 (ADAMS Accession No. ML14112A156), to explain how evidence or lack of evidence for Quaternary faulting was determined in borehole data targeted for geotechnical information.

In a response to RAI 02.05.01-6c dated June 23, 2014 (ADAMS Accession No. ML14177A441), the COL applicant stated that it reviewed the borehole logs for evidence of highly weathered/sheared zones that contained fault gouge, which may have represented a major shear zone or an indication of Quaternary faulting. The applicant stated that wording in FSAR Section 2.5.3.2.5 will be revised in a future revision of the COLA to more clearly indicate that there is no evidence of major shear zones in the borehole data. The COL applicant maintains that a shear zone in W-1 is entirely within felsic gneiss and does not juxtapose different lithologic units across a fault contact. The implication being that a large amount of displacement has not occurred and the feature cannot be a major shear zone. The staff examined W-1 and W-5 at the May 8, 2014, site audit, the summary of which is available in the staff audit report (ADAMS Accession No. ML14203A179), and observed that in both borings there is a shear zone characterized by rock fragments, indication of brittle deformation, mixed with yellow-brown clay and chlorite. However, staff observed that the shear zone is confined to a single, relatively thin layer within each core. The COL applicant stated that the shear zone in W-1 and W-5 is not associated with fault 'a'. In work completed for North Anna site, Dames and Moore (1973) trenched fault 'a' and determined the fault dipped 45 to 50 degrees NW. Borings W-1 and W-5, located NW of fault 'a' would intersect fault 'a' at elevations much lower than where the micro shear-zone is located. The COL applicant looked for the micro-shear zone in adjacent borings and found no indication of this feature.

The staff reviewed several Dames and Moore reports from the 1970's regarding fault 'a' (VEPCO, 1974; 1973) in addition to the findings in the ESP SER regarding fault 'a' (NUREG-1835). The shear zone observed in W-1 and W-5 has similar features to fault 'a' but at a much less significant scale. Because the micro-shear zone in W-1 and W-5 is located northwest of fault 'a' and likely also dips northwest, it is structurally higher than fault 'a' (Figure 2.5.3-1 of this report). The staff notes that significant tectonic structures such as fault 'a' typically have a zone of deformation and deformation fabric is not necessarily limited to a single fault plane so the micro-shear zone could be associated with fault 'a'. Regardless of a structural association or not, the deformation associated with fault 'a' was determined to be geologically old, greater than 1 million years old. The staff considers the shear zone in W-1 and W-5 likely to be the same age as fault 'a' and not a potential future surface deformation hazard to the site.

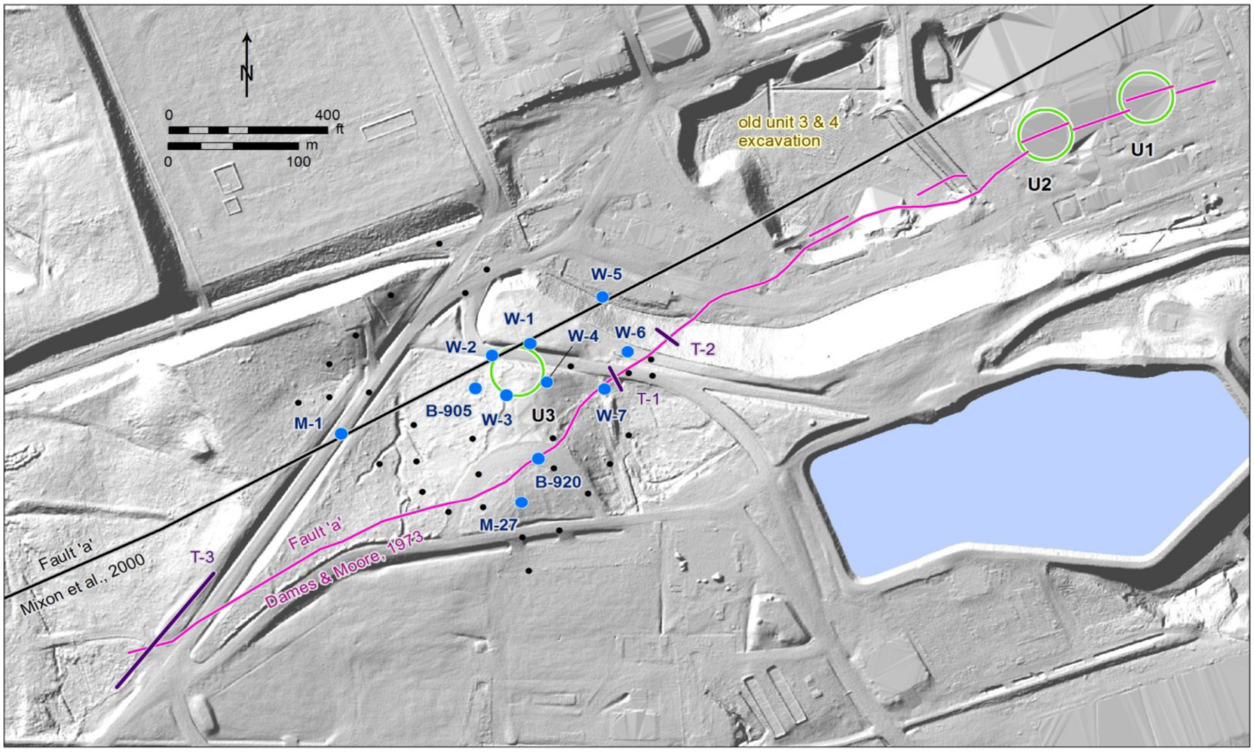


Figure 2.5.3-1. LiDAR-derived hillshade map showing locations of key North Anna 3 borings and surface mapped (Mixon et al, 2,000) and trench mapped (Dames and Moore, 1973) representations of fault 'a' (from Response to RAI 2.5.1-6d, Figure 1)

The staff reviewed DCD COL Item 2.0-28-A, which states the ESBWR design requires the applicant to demonstrate that there is no potential for permanent ground deformation at the site area. The staff concludes that the additional information from additional borings in the site area in conjunction with response to RAI 02.05.01-6c, that provides clarification regarding the possibility of finding major shear zones in the borings as opposed to determining specifically Quaternary fault movement, that there is sufficient subsurface information to resolve DCD COL Item 2.0-28-A. Accordingly and in compliance with 10 CFR 100.23 and 10 CFR 52.79, the staff considers RAI 02.05.01-6c resolved and closed.

The COL applicant proposed a future COL revision for FSAR Section 2.5.3.2.5 to more clearly indicate that there is no evidence of major shear zones in the borehole data and to remove the statement about evidence of Quaternary fault movement in borehole data. The applicant also proposed further revisions in FSAR Section 2.5.3.8 to supplement conclusions regarding tectonic and non-tectonic deformation at the site. The staff considers this to be acceptable and verified that the appropriate revisions are incorporated into the FSAR, Revision 9, and, therefore, Confirmatory Item 2.5.3-1 from the staff's advanced SER for North Anna 3 is resolved and closed.

2.5.3.5 Post Combined License Activities

There are no post COL activities related to COL FSAR Section 2.5.3. However, in Section 2.5.1.4 the staff identified a geologic mapping License Condition related to COL FSAR Section 2.5.1.2 as the responsibility of the COL licensee. Section 2.5.1.4 of this report addresses this license condition.

2.5.3.6 Conclusion

The 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 2.5.3 is within the scope of the ESP and adequately incorporates by reference Section 2.5.3 of the ESP SSAR and investigated the potential for surface deformation in the site area. For the new information provided in COL FSAR Section 2.5.3, the staff concludes that the applicant adequately followed RGs 1.208, 1.206 and 4.7 and performed appropriate field and aerial reconnaissance of the site vicinity and conducted appropriate subsurface investigations at the site, as set forth above. In addition, the staff compared the additional COL information in the application to the relevant NRC regulations and acceptance criteria defined in NUREG-0800, and concludes that the material provided by the COL applicant meets the requirements of 10 CFR 100.23 and 10 CFR 52.79 (a)(iii). 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 North Anna 3 site is suitable with respect to the tectonic and non-tectonic surface deformation criteria for new nuclear power plants.

2.5.4 Stability of Subsurface Materials and Foundations

This section of the SER addresses the North Anna 3 COL FSAR, Revision 8, site-specific information on the stability of subsurface materials and foundations for the North Anna 3 site identified in the ESBWR DCD, Revision 10.

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 3 COLA. 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 RAIs, 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.

2.5.4.1 Introduction

Section 2.5.4 of this FSAR discusses the stability of subsurface materials and foundations that relate to the North Anna 3 site. The properties and stability of the soil and rock underlying the site are important to the safe design and siting of the plant. The information in Section 2.5.4 of this FSAR addresses (1) geologic features in the site vicinity; (2) static and dynamic engineering properties of soil and rock strata underlying the site; (3) the relationship of the foundations for safety-related facilities and the engineering properties of underlying materials; (4) results of geophysical surveys, including in-hole and down-hole explorations; (5) safety-related excavation and backfill plans and engineered earthwork analyses and criteria; (6) groundwater conditions and piezometric pressure in all critical strata as they affect the loading and stability of foundation materials; (7) responses of site soils or rocks to dynamic loading; (8) liquefaction potential and consequences of liquefaction of all subsurface soils, including the settlement of foundations; (9) earthquake design bases; (10) results of investigations and analyses conducted to determine foundation material stability, deformation, and settlement under static conditions; (11) criteria, references, and design methods used in static and seismic analyses of foundation materials; (12) techniques and specifications to improve subsurface conditions, which are to be used at the site to provide suitable foundation conditions, and any additional information deemed necessary in accordance with 10 CFR Part 52.

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 proposed North Anna 3 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 North Anna 3 borings.

<u>COL Items:</u>

- NAPS COL 2.0-29-A

NAPS COL 2.0-29-A provides supplemental information and additional borehole data from the North Anna 3 borings to address the provisions listed in ESBWR DCD Table 2.0-1, regarding stability of subsurface materials and foundation requirements. The applicant provided additional information to address NAPS COL 2.0-29-A (ESBWR DCD COL Item 2.0-29-A), which requires that a COL applicant referencing the ESBWR design to provide site-specific information in accordance with SRP 2.5.4 and address: (1) localized liquefaction potential under other than seismic Category I structures, and (2) settlement and differential settlements.

- 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 COLA.

- NAPS ESP COL 2.5-4

The applicant provided additional information to address ESP COL Action Item 2.5-4, which states that the COLA 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 should 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 COLA.

- 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 COLA.

- 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 Condition 3.E(5)

The applicant provided additional information to address ESP Permit Condition 3.E(5), which states that the COL applicant should replace weathered or fractured rock at the foundation level with lean concrete before initiation of foundation construction.

- ESP Permit Conditions 3.E(6)

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 has been carried forward as a license condition for future excavations of safety-related structures (Section 2.5.1.4).

- ESP Permit Condition 3.E(7)

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 addressed in FSAR Section 2.5.4.8.

Overall Summary:

The applicant conducted additional field and laboratory tests to determine the static and dynamic properties of subsurface materials and confirmed that the associated parameters meet the design requirements defined in the ESBWR DCD, such as the minimum shear wave velocity and angle of internal friction of soil. 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 analysis results indicated that there might be localized liquefaction at certain depths at 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 COL field investigations, a supplement to the ESP investigations, included additional exploratory borings, observation wells, CPTs, packer tests, geophysical loggings, 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 that were 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 selected reactor design to better describe the foundation interfaces and developed more detailed subsurface profiles.

The applicant provided more detailed description of an excavation and backfill program compared to what was provided as part of the ESP. The applicant included the excavation plans and total depths to which excavation and backfilling would be required for the ESBWR design proposed for the North Anna 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 applicant reassessed the response of soil and rock to dynamic loading at the site presented in the ESP as part of the COLA, with the consideration of the placement of concrete 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 replaced with structural backfill. In the COLA, the applicant determined that the factor of safety (FS) against liquefaction of 1.1, which was determined during the ESP application, is still applicable.

The applicant revised the static stability evaluation for the site to incorporate the design-specific dimensions of structures in the COLA, as opposed to the assumed values used in the ESP application. The applicant also included the bearing capacity, settlement, and earth pressures in the structural fill or other load-bearing layers in the COLA, whereas the ESP had assumed that North Anna 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 specified in the ESP, and provided additional factors of safety-related to bearing capacity and lateral earth pressure. Finally, the applicant revised the description of techniques to be used to improve subsurface material 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 backfills, both concrete and granular material fills.

2.5.4.2.1 Description of Site Geologic Features

FSAR Section 2.5.4.1 refers the description of regional and site geologic features to FSAR Sections 2.5.1.1 and 2.5.1.2. Since additional North Anna 3 borings were conducted, the applicant described the integrated site geologic features in the aforementioned sections based on information from the ESP and COL site investigation 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 material and 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 North Anna 3 site investigations.

Description of Subsurface Materials

The applicant divided the subsurface materials into four zones, consistent with the site investigation findings of the ESP. FSAR Section 2.5.4.2.2 describes each zone as summarized below. The applicant also developed profiles to illustrate the subsurface across the North Anna 3 power block area. Figure 2.5.4-1 of this SER illustrated one subsurface profile, the line A-A in FSAR Figure 2.5.4-207, crossing the power block area of the North Anna 3 site. The applicant stated that the design grade elevation for North Anna 3 is at an Elevation of 88.3 m (290 ft).

<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 of 52.1 m (171 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).

Zone III Weathered Rock. 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 85.8 m (292 ft).

Zone IIA and Zone IIB Saprolites. The applicant identified the weathered rock lying above the Zone III rock as saprolite, a highly weathered rock, divided into two zones - Zones IIA and IIB. The applicant further identified the Zone IIA saprolite 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 92.0 m (302 ft).

Zone I and Fill. The applicant stated that it will excavate all Zone I soils and existing fills, and will therefore not further consider these materials for the North Anna 3 site.

Subsurface Profiles

SER Figure 2.5.4-1 (FSAR Figure 2.5.4-207) illustrates the typical subsurface profile across the North Anna 3 power block area. The applicant also illustrated the excavation in the cross section figures to show the foundations of plant structures.

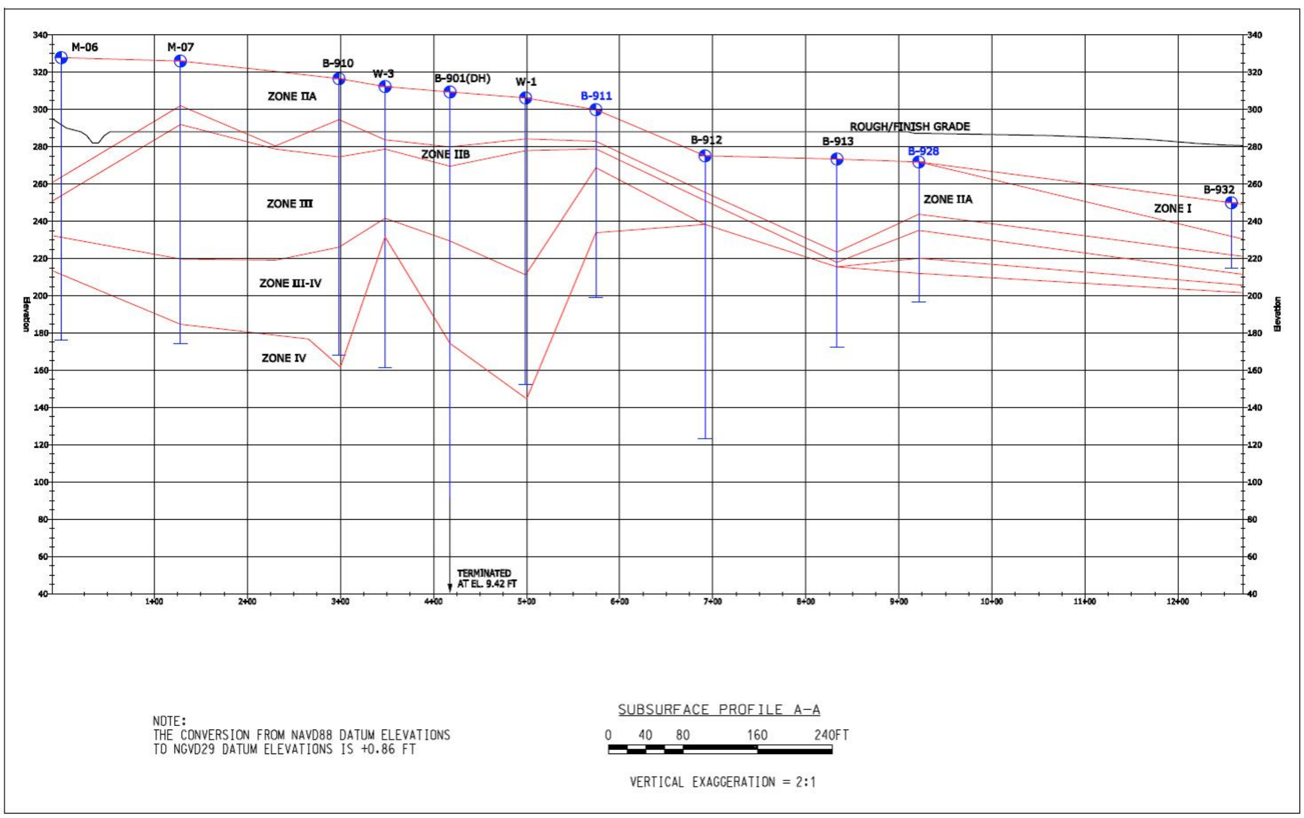


Figure 2.5.4-1. Typical Subsurface Profile across Unit 3 Power Block Area (FSAR Figure 2.5.4-207)

Field Investigations

As previously stated, the applicant performed a number of additional borings and tests in support of the COLA. 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 (ASME, 2012). FSAR Section 2.5.4.2.3 describes the additional work completed to characterize the geological, seismological, and geotechnical engineering properties of the North Anna 3 site, which included 93 borings, seven observation wells, four packer tests, 23 CPTs (including four down-hole seismic cone tests), six test pits, five sets of borehole geophysical logging, five sets of shear wave suspension logging, two sets of electrical resistivity tests, and a survey of the exploration points for all the investigations as part of the subsurface investigation program. The following paragraphs summarize the tests performed.

Borings and Samples/Cores. The applicant drilled 93 borings for the COL site investigation to 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 American Society of Testing and Materials (ASTM) International standards, including, but not limited to, ASTM D 1586 (ASTM, 2011), D 1587 (ASTM, 2012), and D 2113 (ASTM, 2014). The applicant collected the soil samples 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 made nine sets of energy measurements on the automatic SPT hammers used by the drill rigs. The applicant obtained undisturbed samples by removing disturbed portions at both ends of the sample tube and trimming the ends square. The applicant also performed pocket penetrometer tests 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 RQD. Finally, the applicant labeled and transported all samples 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. The applicant also 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 CPTs 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 0.6 to 1.3 m (2 to 4.5 ft) at the North Anna 3 site to collect soil samples for laboratory tests. It used the test results to determine the 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 that the applicant performed for the North Anna 3 site investigation. The applicant performed the laboratory tests to verify the large number of test results from previous investigations, including tests performed for existing units and ESP site investigations. The applicant focused on three areas when conducting the tests and followed the guidance of RG 1.138, "Laboratory Investigations of Soils and Rocks for Engineering Analysis and Design of Nuclear Power Plants." The applicant verified that the properties of the soil and rock beneath the North Anna 3 power block area are similar to those beneath Units 1 and 2. The applicant performed chemical tests 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 2.5.4-205 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 the North Anna 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 2.5.4-208 and related descriptions. The following sections describe the various test programs or field observations employed to derive the material properties.

<u>Rock and Concrete Properties</u>.

The applicant determined that the rock strength and stiffness values from the field and laboratory testing of the North Anna 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 North Anna 3 site, or better rock coring equipment and techniques produced better quality cores. The RQD values based on the results for each core in the boring logs are summarized in SER Table 2.5.4-1.

The applicant determined rock unconfined compressive strengths, unit weights, and elastic modulus values based on the rock strength test results. The applicant derived the shear modulus values using the elastic modulus and Poisson's ratio 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 determined the shear and compression wave velocities profiles based on suspension P-S (compression and shear wave) velocity logging and CPT down-hole seismic tests performed during the COL site investigation program.

The applicant described the concrete fill that will replace Zone II soils and Zone III weathered rock beneath the RB/FB, CB, and FWSC seismic Category I structures. The applicant stated that the concrete fill would have a minimum strength of 17.2 MPa (2,500 psi), a unit weight of 232 kg/m^3 (145 pcf), and a Poisson's ratio of 0.15. Finally, because the V_s of the in-situ rock is about 1,524 m/s (5,000 fps), the applicant concluded that the concrete fill should have a V_s equal or greater to that of the in-situ rock. The applicant noted that concrete with the given strength of 17.2 MPa (2,500 psi) will have a BE V_s of 2,134 m/s (7,000 fps).

<u>Soil Properties</u>.

The applicant presented the engineering properties of North Anna 3 site soils in FSAR Table 2.5.4-208 (SER Table 2.5.4-1) and described the methods used to determine the properties in FSAR Section 2.5.4.2.5.b. The applicant combined laboratory test and field test (SPT and CPT) to determine the undrained shear strength of soil. The V_s values were determined based on down hole seismic tests 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 V_s 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 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). The applicant plans to use crushed rock as structural fill that will conform to the gradation of Size No. 21A in the Virginia Department of Transportation (VDOT) Road and Bridge Specifications (VDOT, 2002).

RCTS Testing.

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

Table 2.5.4-1 Properties of NAPS 3 Site Subsurface Materials (FSAR Table 2.5.4-208)

STRATUM	Structural Fill	Concrete Fill	ZONE IIA	ZONE IIB	ZONE III	ZONE III-IV	ZONE IV
General description	Gravelly materials	-	Saprolite (< 10 percent core stone)	Saprolite (10 – 50 percent of core stone)	Weathered rock (> 50 percent core stone)	Moderately to slightly weathered rock	Parent rock – slightly weathered to fresh rock
Unified Soil Classification System 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)	65.5-92.0 m (215-302 ft)	62.8-89.0 m (206-292 ft)	57.0-89.0 m (187-292 ft)	52.1-84.7m (171-278 ft)
Percent fines (%)	6-12	-	25	20	-	-	-
Moisture content (%)	-	-	19	15	-	-	-
Total unit weight (kg/m^3 (pcf))	2,082 (130)	2,322 (145)	2,002 (125)	2,082 (130)	2,403 (150)	2,611 (163)	2,627 (164)
Measured SPT N-value (blows/ft)	-	-	15	75	Ref	-	
Adjusted SPT N60-value (blows/ft)	50	-	20	100	Ref	-	-
Unconfined compressive strength, q_u, MPa (ksi)	-	17.2 (2.5)	-	-	6.8 (1.0)	62.0 (9.0)	117 (17.0)
Effective cohesion, c', kPa (ksf)	0	-	6.0 (0.125)	0	-	-	-
Effective friction angle, ' (degrees)	40	-	33	40	-	-	-
Shear wave velocity, V_s, m/s (fps)	335 (1,100)	2,134 (7,000)	259 (850)	488 (1,600)	914 (3,000)	1,829 (6,000)	2,743 (9,000)
Compression wave velocity, V_p, m/s (fps)	732 (2,100)	3,322 (10,900)	549 (1,800)	1,067 (3,500)	2,225 (7,300)	3,658 (12,000)	4,877 (16,000)
Poisson's ratio, u (high strain)	0.3	0.15	0.35	0.3	0.4	0.33	0.27
Poisson's ratio, u (low strain)	0.3	0.15	0.35	0.37	0.4	0.33	0.27
Elastic modulus (high strain), E_h	86.2 MPa (1,800 ksf)	19,650 MPa (2,850 ksi)	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)	19,650 MPa (2,850 ksi)	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	8,549 MPa (1,240 ksi)	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)
Shear modulus (low strain), G_l	239 MPa (5,000 ksf)	8,549 MPa (1,240 ksi)	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, kg/m^3 (kcf)	32.03 (2,000)	-	4.16 (260)	32.03 (2,000)	-	-	-
Coefficient of sliding	0.55	0.7	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	0.50	0.36	-	-	-
Optimum Moisture Content, W_{opt} (%)	-	-	14	-	-	-	-
Maximum Dry Unit Weight, g_{max} kg/m^3 (pcf)	-	-	1,858 (116)	-	-	-	-
Rock Quality Designation, RQD (%)	-	-	-	-	20	65	95

Electrical Resistivity and Chemical Properties.

The applicant assessed corrosion potential by using field electrical resistivity and laboratory chemical tests on the Zone IIA and 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 North Anna 3 subsurface investigation, including borings, observation wells, CPTs, electrical resistivity tests, and test pits made in the power block area. While FSAR Figure 2.5.4-217 illustrates these locations, FSAR Figure 2.5.4-206 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 subsurface material contours under the plant structures on 10 subsurface profiles (see FSAR Figures 2.5.4-207 through 2.5.4-216). Finally, the applicant presented cross sections of the structure foundations with the proposed excavation and backfilling limits superimposed (see FSAR Figures 2.5.4-225 through 2.5.4-234).

2.5.4.2.4 Geophysical Surveys

FSAR Section 2.5.4.4 describes the geophysical testing conducted for North Anna 3, including field electrical resistivity testing, geophysical down hole testing, and seismic CPTs. The following subsections summarize these survey programs and investigations.

Field Electrical Resistivity Testing

FSAR Section 2.5.4.4.1 describes the field electrical resistivity tests performed along two crossing lines in the North Anna 3 site area. The applicant used four electrodes equidistant from a central point and inserted approximately 0.3 m (1 ft) into the ground to measure the voltage recorded at two inner electrodes after sending a current through two outer electrodes. The applicant used these results, included in FSAR Appendix 2.5.4AA, to evaluate corrosion potential in FSAR Section 2.5.4.2.5.

Geophysical Down-Hole Testing

For the North Anna 3 site geophysical investigation, the applicant performed geophysical down-hole tests in three borings (B-901, B-907 and B-909) within the footprint of Seismic Category 1 structures 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. The applicant described this probe 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 3.0 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 applicant used the data 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 3.0 m (10 ft) per minute.

Acoustic Televiewer and Borehole Deviation Measurement.

The applicant used a High Resolution Acoustic Televiewer probe to measure boring inclination and deviation based on acoustic images and boring deviation data collected at 0.24 cm (0.096 in.) intervals. The images generated by processing acoustic pulses reflection data transmitted by an ultrasonic beam sensor to the borehole wall show the borehole wall at different depths. 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 suspension P-S velocity logging tests to directly determine the average in-situ horizontal V_s and V_p of a 1.0 m high (3.3 ft) segment of the soil and rock column surrounding the borehole. This method involves dropping a source and two receivers 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 North Anna 3 site investigation. The applicant performed seismic CPTs to measure shear wave velocity at 1.5 m (5 ft) intervals in four CPTs and provided test results in Appendix 2.5.4AA.

Results of Shear and Compression Wave Velocity Tests

FSAR Section 2.5.4.4.4 presents the results of V_s and V_p tests for soil and rock at the North Anna 3 site. For soil, the applicant determined the V_s from suspension P-S velocity logging and seismic CPTs in saprolite. The applicant concluded that for Zone IIA saprolite, the average V_s increases with depth from 152.4 to 365.7 m/s (500 to 1,200 fps) with a median value of 259 m/s (850 fps), comparable to the median value of 289 m/s (950 fps) in the ESP SSAR. The low strain Poisson's ratio for Zone IIA saprolite is 0.35. For Zone IIB saprolite, the applicant noted that the average V_s ranges from 365.7 to 762 m/s (1,200 to 2,500 fps) with a median value of 487 m/s (1,600 fps), the same as the ESP SSAR, and with a low strain Poisson's ratio of 0.37.

For rock, the applicant illustrated the V_s measurements from suspension P-S velocity logging. The applicant noted that the V_s determined at the North Anna 3 site as part of the COL investigations are slightly higher than those determined in the ESP SSAR. The BE V_s was 914 m/s (3,000 fps) for Zone III weathered rock, 1,829 m/s (6,000 fps) for Zone III-IV partially weathered rock, and 2,743 m/s (9,000 fps) for Zone IV fresh rock.

2.5.4.2.5 Excavation and Backfill

FSAR Section 2.5.4.5, “Excavation and Backfill,” describes the extent of seismic Category I structure related excavations, fills and slopes; methods to be used for excavation and stability control; and sources of backfill including quantities, compaction specifications, and quality control.

Extent of Excavations, Fills, and Slopes

FSAR Section 2.5.4.5.1 describes the extent of excavations, fills, and slopes at the North Anna 3 site. In this section, the applicant included numerous figures to illustrate this information, including FSAR Figure 2.5.4-206 showing the extent of excavations, fills, and slopes for North Anna 3 and FSAR Figures 2.5.4-225 through 2.5.4-234 showing cross sections of the excavations. The applicant indicated that it will excavate up to 12.2 m (40 ft) to reach the design plant grade of elevation 88.2 m (290 ft), but some lower areas may need to be backfilled. The applicant estimated the total cut at about 478,140 cubic meters (625,380 cubic yards), while the amount of backfilling with compacted structural fill about 184,830 cubic meters (241,750 cubic yards) and concrete fill about 83,810 cubic meters (109,620 cubic yards). The applicant described the excavation plan as having 3-horizontal to 1-vertical (3H:1V) slopes extending up from the plant grade around the southern and eastern perimeters of the area. To the northeast of the TB, going towards the existing Units 1 and 2, ground surface elevation reduces at an approximately 5 percent slope down to elevation 85.3 m (280 ft) at the SW Building. As existing grade falls off from the power block area northeast towards Units 1 and 2, the applicant stated that it may need an additional 9.14 m (30 ft) of backfill to bring the ground level currently at elevation 76.2 m (250 ft) in the area of the originally planned Units 3 and 4 to achieve the designed finish grade.

Excavation Methods and Stability

FSAR Section 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 North Anna 3 site. The following subsections summarize these excavation methods.

<u>Excavation in Soil</u>.

The applicant stated that it will use conventional equipment for excavation in soil Zones IIA and IIB and in any existing fills. For excavation of less than 6.1 m (20 ft) in height, the applicant stated that it will follow U.S. Office of Safety and Health Administration (OSHA) regulations. The applicant further described plans to use a temporary vertical wall system to stabilize the power block excavation, and the slopes around the perimeter of the power block area will be no steeper than 3H:1V, with a bench at approximately 7.5 m (25 ft) height. Due to the erosive potential of the saprolitic soils, the applicant concluded that it will need to seal and protect even temporary slopes cut into the saprolite.

<u>Excavation in Rock</u>.

Based on lessons learned from the construction of Units 1 and 2, the applicant stated that it will use techniques to reduce vibrations during rock excavation, including a temporary vertical wall system to support the excavation where necessary during North Anna 3 excavation. Because North Anna 3 is about 457.2 m (1,500 ft) from the center of the Unit 2 containment building, not

91.44 m (300 ft) as originally planned, the applicant concluded that the initially planned excavation methods would be effective for the new North Anna 3. These methods include controlled blasting techniques, preservation of the rock integrity outside of the excavations, and reinforcing the rock to ensure adequate support and safety. The applicant also stated that it would geologically map the excavations for safety-related structures and notify the NRC no later than 30 days before any safety-related excavations are open to allow for staff examination or evaluation. Finally, the applicant stated that it will not monitor the excavation in rock because there is no measurable rebound or heave of the sound rock subgrade.

Structural Fill Sources, Compaction and Quality Control

FSAR Section 2.5.4.5.3 describes the sources of backfill, compaction requirements, and quality controls for the North Anna 3 site. The applicant illustrated the anticipated extent of structural fills on the foundation cross-section plots (see FSAR Figures 2.5.4-225 through 2.5.4-234). The applicant described plans to replace moderately to severely weathered Zone III rock exposed at the bottom of the excavations for the seismic Category I RB/FB, CB, and FWSC foundation mats with concrete fill. The FSAR states that saprolitic soil material found onsite will not be used as structural fill to support or backfill seismic Category I and II structures. 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 described the fill as well-graded, angular or sub-angular sand and gravel-sized particles conforming to the gradation of Size No. 21A in the "Virginia Department of Transportation Road and Bridge Specifications (VDOT, 2002)", and it will confirm the soundness through sulfate soundness and Los Angeles abrasion tests. The applicant stated that it plans to place the structural fill in lifts of no more than 30.48 cm (12 in.) loose thickness and compacted to at least 95 percent of the maximum dry density from the modified Proctor Test (ASTM D1557) and within 3 percent of its optimum moisture content. The applicant assumed that a N_{60} value of 50 blows per foot and an internal friction angle of 40 degrees were reasonable and conservative. The applicant stated that it plans to perform confirmatory gradation tests, modified Proctor compaction tests, and CU triaxial compression tests to ensure that the structural fill meets the selected criteria.

The applicant also referred to TSs that addresses fill placement and compaction control procedures. The applicant stated that it plans to perform at least one field density test per lift of fill and at least one test for every 191 cubic meters (250 cubic yards) of fill placed. Finally, the planned test fill program will determine the optimum size roller, number of passes, lift thickness, and other data to achieve the specified compaction.

Control of Groundwater during Excavation

Although FSAR Section 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 more details. The applicant described plans to slope back the tops of excavations to prevent runoff down the excavated slopes during heavy rainfall and to construct lined dewatering sumps and ditches due to the erosive nature of the saprolitic soil.

2.5.4.2.6 Groundwater Conditions

In FSAR Section 2.5.4.6, the applicant briefly described the groundwater conditions at the North Anna 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 North Anna 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 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 observation wells during the COL site investigation. The applicant stated that the groundwater level in the observation wells 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 ground water in the North Anna 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. For rock, the values ranged 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. The applicant also stated that ground water 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 North Anna 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 groundwater level in the power block area of North Anna 3 is presented in FSAR Section 2.4.12.4 and ranges from about an elevation of 82.6 m (271 ft) at the north end of the TB to about an elevation of 86.1 m (282.5 ft) at the south end of the RB/FB.

Construction Dewatering and Seepage

FSAR Section 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 stated that it plans to use sump-pumping to collect water from relief drains installed in the major rock excavation walls to prevent the buildup of hydrostatic pressure. Although the applicant noted a head of approximately 12.2 m (40 ft) between the excavation grade and Lake Anna during the final excavation stages for abandoned Units 3 and 4, the applicant did not encounter any dewatering difficulties. 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 anticipated negligible seepage effects from the lake since the excavation for North Anna 3 is at least 305 m (1,000 ft) from Lake Anna.

Effects of Groundwater Conditions on Foundation Stability

FSAR Section 2.5.4.6.3 refers to FSAR Section 2.5.4.10 for a description of the maximum groundwater level below plant grade. The applicant concluded that there are no buoyancy issues at the North Anna 3 site; therefore a permanent dewatering system is not necessary.

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 V_s profiles of the subsurface materials, the variation of shear modulus and damping with strain, and the site-specific acceleration-time histories. The applicant stated that it will found the seismic Category I structures on Zone III-IV rock, Zone IV rock, or on concrete placed on the bedrock.

Shear Wave Velocity Profile

FSAR Section 2.5.4.7.1 describes the development of the V_s profiles for the soil and bedrock at the North Anna 3 site. To develop the profiles, the applicant compiled various measurements to determine the V_s in the soil and rock at the North Anna 3 site, as described in FSAR Section 2.5.4.4. The applicant developed the BE V_s profiles beneath the seismic Category I RB/FB, CB, and Firewater Service Complex (FWSC) based on shear wave velocity data collected from borings B-901, B-907, and B-909. The bottom of foundation elevation for these structures is Elevation 68.3 m (224 ft), Elevation 73.5 m (241 ft) and Elevation 86.0 m (282 ft), respectively. SER Figure 2.5.4-2 shows the BE V_s profiles for the RB/FB and CB, and SER Figure 2.5.4-3 presents the BE V_s profiles for the FWSC.

In addition to the V_s profiles considered for the seismic Category I structures, the applicant also developed a V_s profile beyond the excavation for the power block. The applicant developed this profile based on the V_s measured in C-916, the N-values measured in B-947, the average V_s values derived from site-wide V_s measurements in saprolite, and data collected from borings B-901, B-907 and B-909. SER Figure 2.5.4-4 shows the V_s profile which the applicant used to determine the PGAs in the free-field for use in liquefaction potential and slope stability analyses.

For the structural fill to be used as backfill around the seismic Category I structures, the applicant developed a V_s profile based on the relationships between the N-value (adjusted for overburden pressure) and V_s developed by Seed, et al. (1983) and Imai and Tonoucchi (1982). The applicant averaged this profile in 1.5 m (5 ft) intervals vertically to produce the average V_s profile shown in SER Figure 2.5.4-5. The upper and lower bound values shown in this figure are 1.414 and 0.707 times the mean value of shear wave velocity, respectively. The applicant used this profile as input in the seismic response analyses.

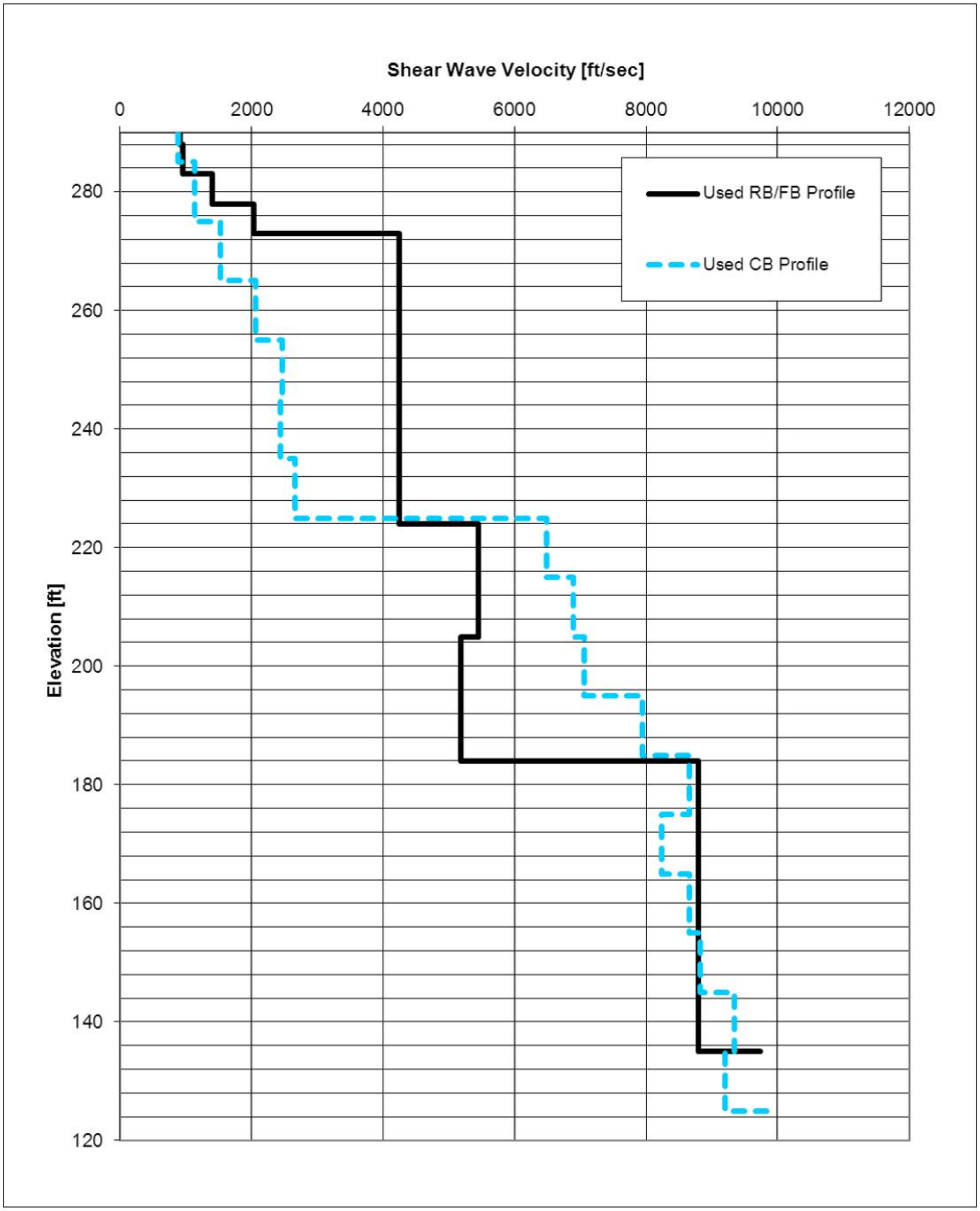


Figure 2.5.4-2. Best Estimate Shear Wave Velocity Profiles for RB/FB and CB (FSAR Figure 2.5.4-242)

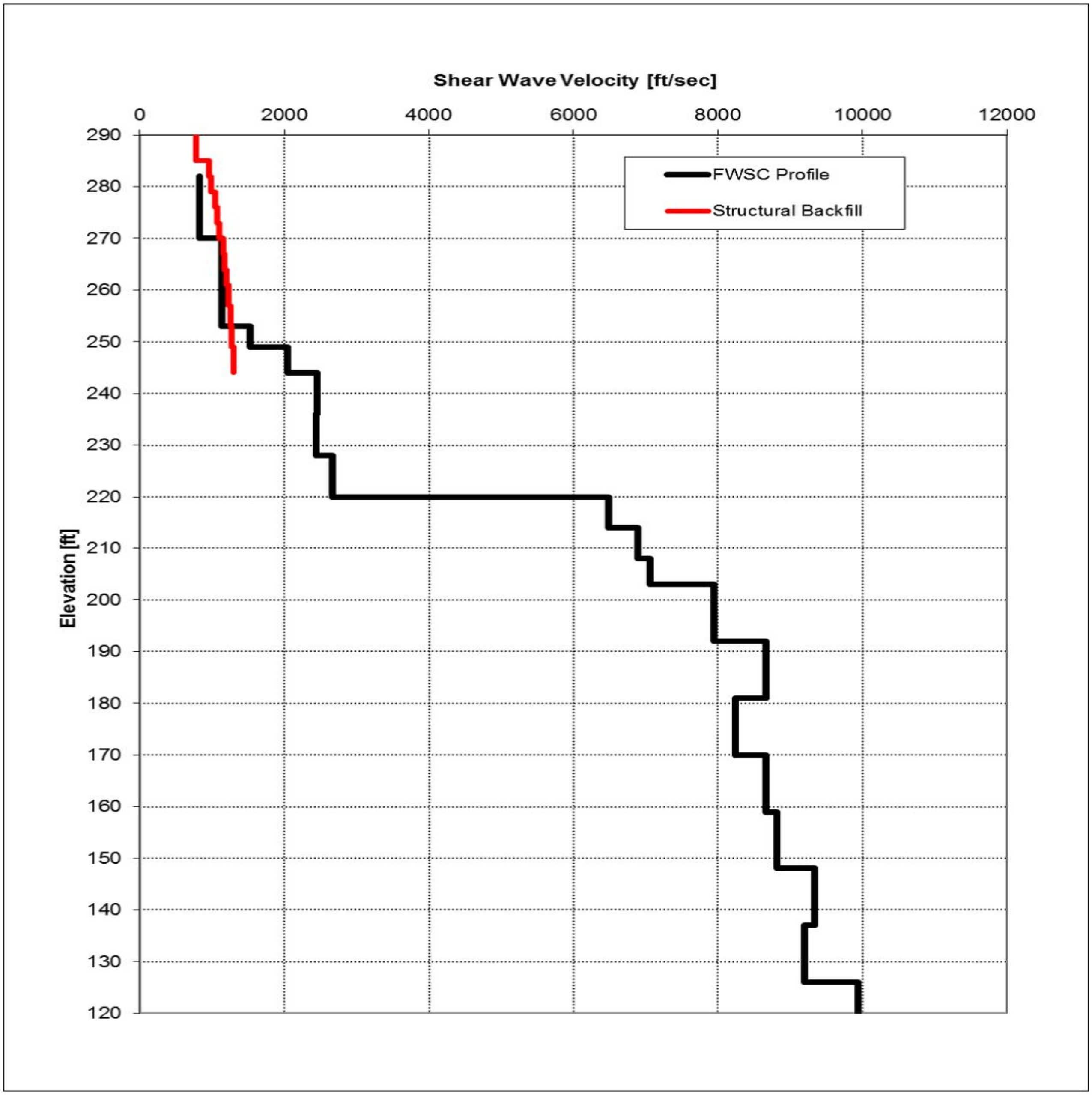


Figure 2.5.4-3. Best Estimate Shear Wave Velocity Profiles for FWSC (FSAR Figure 2.5.4-243)

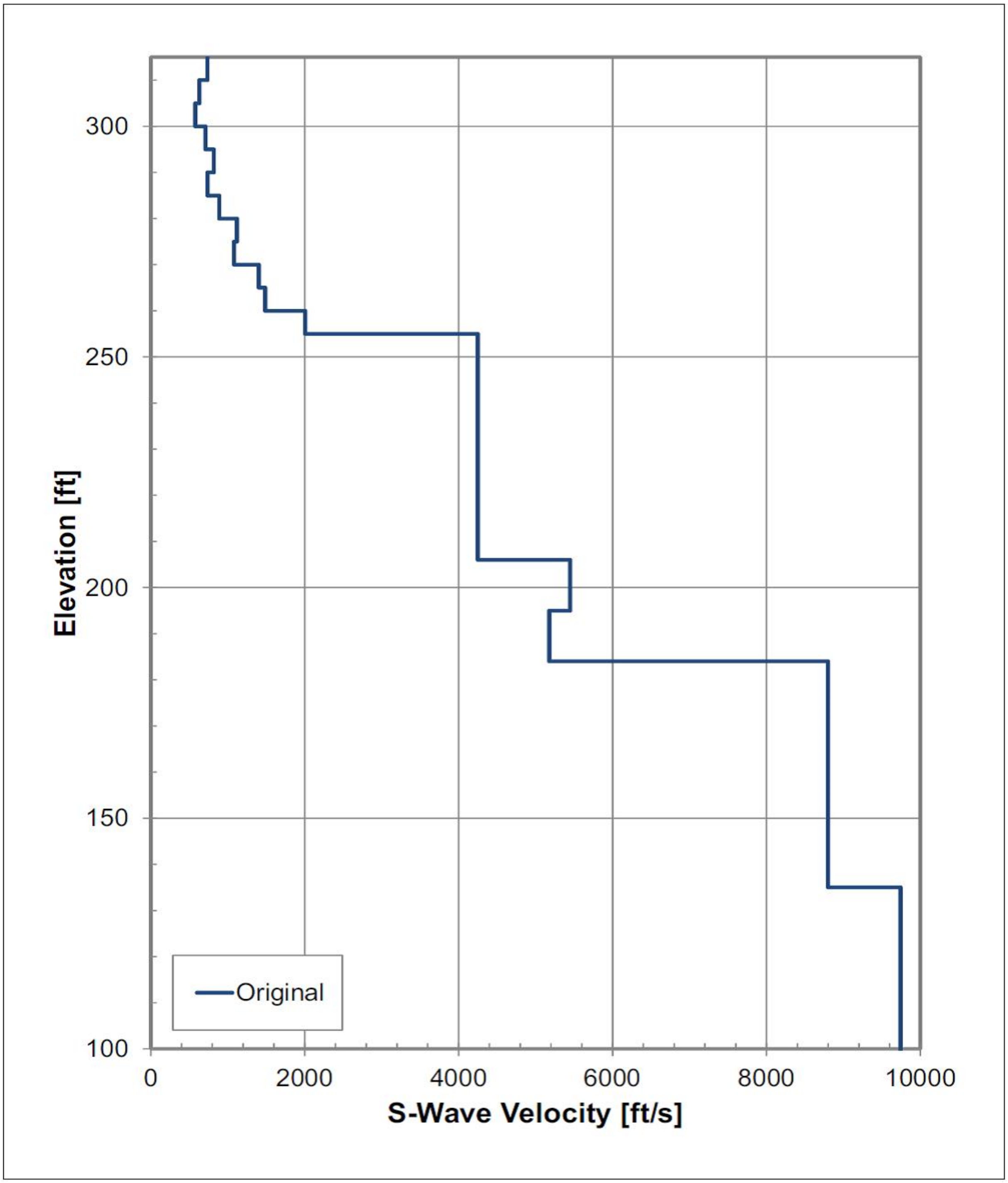


Figure 2.5.4-4. Best Estimate Shear Wave Velocity Profiles for Free-Field Slope (FSAR Figure 2.5.4-244)

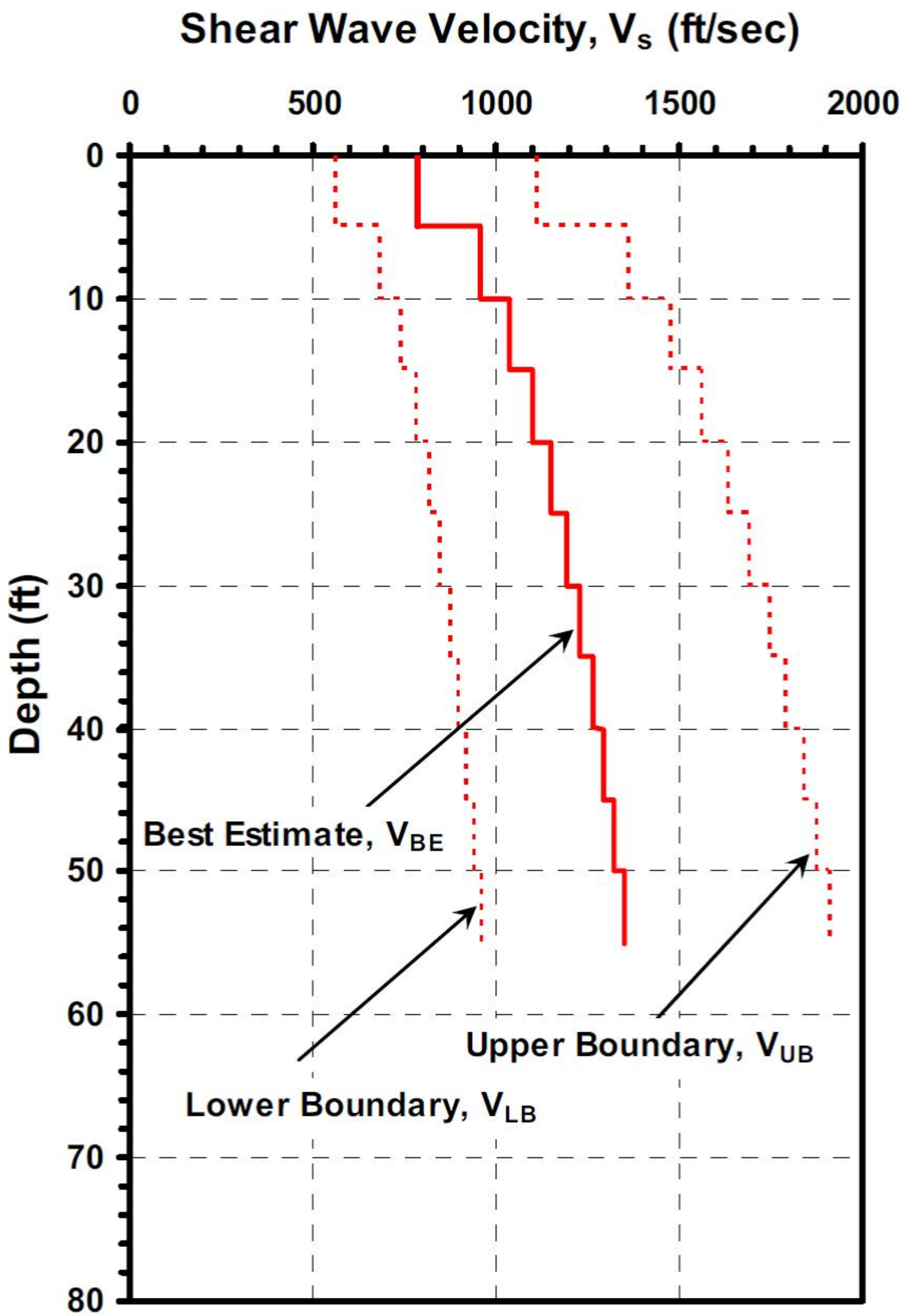


Figure 2.5.4-5. Best Estimate Shear Wave Velocity Profile for Structural Fill in 5-Foot Intervals (FSAR Figure 2.5.4-246)

Variation of Shear Modulus and Damping with Strain

FSAR Section 2.5.4.7.2 describes the effect of varying shear strain on both the shear modulus and damping. The soil degradation properties, specifically the variations of soil shear modulus and damping ratio with shear strain levels, are important inputs 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 two curves from a 1993 EPRI report.

In combining these studies, the applicant took into account of several factors, including reference strain and effective vertical stress. Unlike the 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 as shown on SER Figure 2.5.4-6.

The applicant compared the RCTS test results with a shear modulus reduction curve that represents the Zone IIA and IIB soils and it showed that the test data points are very close to that curve, which confirmed that the recommended shear modulus curve can reasonably represent the soil condition in the field. The applicant selected Curve 2 and Curve 3 from ESP SSAR Figure 2.5-63 as the shear modulus reduction curve for the structural backfill, and for the Zone III weathered rock, respectively. Finally, the applicant stated that the shear modulus of the Zone IV and Zone III-IV weathered rock was non-strain dependent.

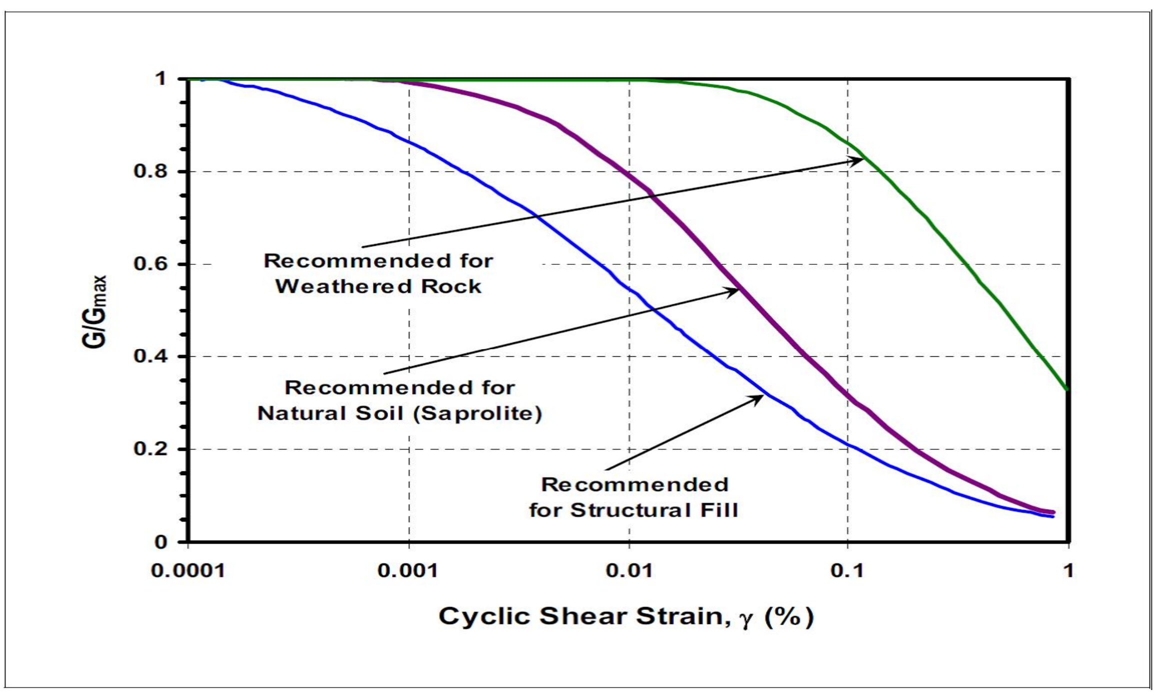


Figure 2.5.4-6. Shear Modulus Reduction Design Curves (FSAR Figure 2.5.4-247)

Damping Ratio.

SER Figure 2.5.4-7 illustrates the EPRI curves for depths of 0 to 6.09 m (0 to 20 ft) and 6.09 to 15.24 m (20 to 50 ft) selected for Zone IIA and IIB saprolite and structural backfill, and Curve 3 from ESP SSAR Figure 2.5-64 used for Zone III weathered rock. The applicant compared the results of the RCTS tests with the curve selected for granular soils and concluded that the results show reasonable agreement. The applicant also concluded that the damping ratio of the Zone III-IV and Zone IV rock does not vary with cyclic shear strain; however, the applicant selected a damping ratio of 1 percent with a ±0.5 percent variation.

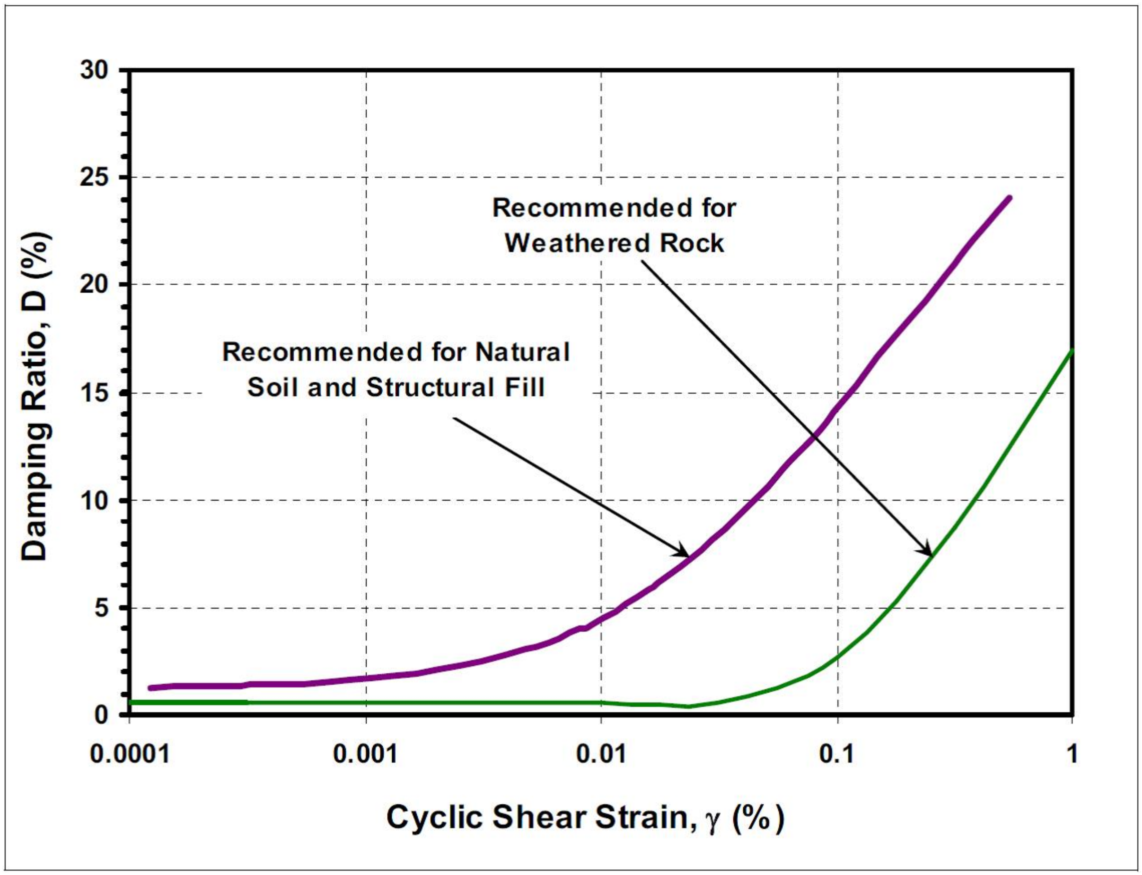


Figure 2.5.4-7. Damping Ratio versus Cyclic Shear Strain (FSAR Figure 2.5.4-249)

Site-Specific Acceleration-Time Histories

FSAR Section 2.5.4.7.3 states that the P-SHAKE program does not need acceleration-time histories as an input.

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 North Anna 3 site. The applicant referred to FSAR Section 3.7.1 for the acceleration response spectra as derived from the P-SHAKE analyses for seismic Category I structures. The applicant used the P-SHAKE program to obtain PGAs in the free-field for use in slope stability and liquefaction analysis with the V_s profile described in FSAR Section 2.5.4.7.1.d. The results show that the PGA occurs at about 12.8 m (42 ft) depth and the values of the PGA are about 0.56g for the HF earthquake and about 0.31g for the LF earthquake.

2.5.4.2.8 Liquefaction Potential

FSAR Section 2.5.4.8 describes the liquefaction potential evaluation of the soil at the North Anna 3 site, including the analyses performed and the conclusions reached. The applicant concluded that due to the density and high percentage of core stone in Zone III weathered rock, it is not prone to liquefaction. The applicant further concluded that the structural fill was not liquefiable because of its angularity and degree of compaction under the given seismic loading condition. The applicant identified slopes whose failure due to liquefaction could impact adjacent safety-related structures, and performed the liquefaction potential analysis for those slopes.

Liquefaction Analyses Performed for North Anna 3

FSAR Section 2.5.4.8.2 describes the liquefaction analyses performed for North Anna 3 site. The applicant first determined the magnitude and acceleration values for North Anna 3 liquefaction analyses, then performed seismic margin assessments, and analyzed samples and CPT results to estimate the liquefaction potential. The applicant followed the guidelines in RG 1.198, regarding the acceptable FS against liquefaction.

Based on rock and soil column analyses described in the previous section, the applicant obtained the peak accelerations at the natural ground surface of 0.31g and 0.56g for the LF (M= 7.4) and HF (M = 6.0) earthquake, respectively. The applicant used these values as the PGAs for the liquefaction analyses.

Because Zone IIA saprolitic soil in the power block area where the seismic Category I structures are located will be excavated, there is no need to analyze the liquefaction potential of these soils prior to excavation. Therefore, the applicant performed liquefaction analysis focused on slopes whose failure could impact safety-related structures.

The applicant used six SPT borings, two CPT borings and two V_s measurements taken from two borings to assess the liquefaction potential of the slope soils. The analysis followed the method proposed by Youd, et al. (2001) based on the evolution of the Seed and Idriss “Simplified Procedure” (1983). The analysis of the SPT results gave FS values against liquefaction greater than 1.1 for the approximately 80 Zone IIA saprolite samples, except for eight samples. The liquefaction analysis using CPT data yielded FS against liquefaction greater than 1.1 for all data points. For analysis using V_s measurements, only eight data points gave FS of less than 1.1 against liquefaction.

The applicant used the method outlined in Tokimatsu and Seed (1997) to estimate dynamic settlement of the Zone IIA saprolite due to earthquake shaking obtaining less than 12.7 cm (5 in) of the maximum dynamic settlement.

Applicant's Conclusions about Liquefaction

The applicant stated that the aforementioned liquefaction analyses showed that a very small percentage of the Zone IIA saprolitic soils have a potential for liquefaction based on the LF and HF North Anna 3 site seismic characteristics. The liquefaction analysis did not consider the beneficial effects of age, structure, fabric, and mineralogy; the applicant therefore concluded that the probability of any liquefaction occurring in the North Anna 3 site area is very low. Furthermore, the applicant concluded that any liquefaction of the Zone IIA saprolite will not impact the stability of any North Anna 3 seismic Category I 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 and 3.7.1 for a discussion of the GMRS and FIRS for the North Anna 3 site, respectively.

2.5.4.2.10 Static Stability

FSAR Section 2.5.4.10 states that the applicant will found the North Anna 3 RB/FB structures on Zone III-IV or Zone IV bedrock. The applicant will remove and replace Zone III weathered rock or fractured rock encountered at the foundation subgrade level with concrete fill for all seismic Category I structures. For seismic Category II structures, depending on the elevation and location, there can be more than one material beneath the foundation of larger structures because of variable stratigraphy. FSAR Table 2.5.4-209 summarizes the dimensions, foundation elevation, embedment depth and design static and dynamic loads of structures including seismic Category I and II structures and the RW.

Bearing Capacity

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

<u>Allowable Bearing Capacity of Rock and Concrete Fill</u>.

FSAR Table 2.5.4-210 gives the allowable static bearing capacity values for each bedrock zone. The applicant determined the dynamic allowable bearing capacity as 957 kPa (20 ksf), that is less than 20 percent of the ultimate rock crushing strength of 6,896 kPa (144 ksf), using various building codes for moderately weathered to freshly foliated rock (D'Appolonia et al., 1975). Because the RB/FB will not be directly founded on Zone III weathered rock, the applicant stated that if excavation during construction for this foundation reveals any weathered or fractured zones at foundation level, it will be over-excavated and replaced with concrete fill. The applicant stated that the Zone III-IV and Zone IV bedrock have a design unconfined compressive strength of 62 MPa (1,296 ksf) and 117 MPa (2,448 ksf) with allowable static values of the bearing capacity of 3,830 kPa (80 ksf) and 7,660 kPa (160 ksf), respectively. The applicant selected 20 percent of the ultimate crushing strength, 12,400 kPa (259 ksf) for Zone III-IV and 23,460 kPa (490 ksf) for Zone IV, as dynamic bearing capacity. Finally, the applicant determined that the allowable bearing capacity for 17.2 MPa (2,500 psi) concrete fill is 9,528 kPa (199 ksf) for both static and dynamic loading.

Allowable Bearing Capacity for Structures.

FSAR Table 2.5.4-211 provides the estimated and selected allowable static and dynamic bearing capacity values for the seismic Category I and II structures at the North Anna 3 site. The applicant noted that there is concrete fill beneath each structure underlain by Zone III-IV bedrock. For the static case, the applicant noted that the bearing capacity of the Zone III-IV bedrock is less than that of concrete, but for the dynamic case, the bearing capacity of the concrete is less than half of that of the Zone III-IV materials. The applicant assumed the lesser bearing capacity in each case, selecting the bearing capacity of the Zone III weathered rock for both the static and dynamic cases. The applicant also limited the allowable bearing capacity to 191 kPa (4 ksf) for the Zone IIA saprolite due to settlement considerations, but noted that the actual allowable bearing capacity may be less, especially based on settlement considerations for larger foundations.

Buoyancy Effects.

The applicant predicted that the maximum groundwater level in the power block area of North Anna 3 would increase from about elevation 82.6 m (271 ft) at the north end of the TB to about elevation 86.1 m (282.5 ft) at the south end of the RB/FB and concluded that it is possible for a hydrostatic uplift force to act on the structures founded below grade. However, the applicant also concluded that the below-ground structures have sufficient applied foundation loads such that there are no net uplift forces at the maximum ground water level. The applicant indicated that uplift forces can be significant in the design of buried piping, particularly empty pipes. The applicant used a FS of 3 in its analysis of the weight and strength of the backfill above the pipe to ensure satisfactory resistance to uplift forces.

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. SER Table 2.5.4-2 summarizes the estimated settlements for major structures. Based on the analysis, the applicant expected that the estimated average settlement for seismic Category I structures is about 2.54 mm (0.1 in) or less.

Table 2.5.4-2 Estimated Settlements Structures (FSAR Table 2.5.4-212)

STRUCTURE	APPLIED LOAD kPa (ksf)	CALCULATED SETTLEMENT Mm (in.)			
		CENTER	EDGE	AVERAGE[1]	CORNER
Reactor/Fuel Building	669 (14.6)	3.0 (0.12)	1.9 (0.075)	2.5 (0.10)	1.3 (0.05)
Control Building	292 (6.1)	0.6 (0.022)	0.4 (0.014)	0.5 (0.02)	0.3 (0.010)
Fire Water Service Complex	165 (3.45)	0.3 (0.011)	0.2 (0.008)	0.3 (0.010)	0.13 (0.005)
Turbine Building	287 (6)	56.6 (2.23)	29.0 (1.14)	42.9 (1.69)	14.7 (0.58)
Radwaste Building	287 (6)	19 (0.75)	10 (0.38)	14.5 (0.57)	6.9 (0.27)
Service Building	192 (4)	17.3 (0.68)	8.9 (0.35)	13.2 (0.52)	6.9 (0.27)
Ancillary Diesel Building	192 (4)	3.3 (0.13)	1.7 (0.065)	(0.10)	0.9 (0.034)

Notes: (1) Average is average of center and edge settlements.

Earth Pressures

FSAR Section 2.5.4.10.3 describes the estimates 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 Mononobe-Okabe method (Mononobe, 1929 and Okabe, 1926) to estimate the active lateral earth pressure. The applicant used peak LF acceleration of 0.31g as the seismic force that develops seismic active earth pressure, because it considered that using the peak HF acceleration was overly conservative given the low magnitude (energy) of this earthquake. The applicant used the method described in ASCE 4-98, “Seismic Analysis of Safety-Related Nuclear Structures,” Section 3.5.3.2 (ASCE, 1998) to estimate the dynamic component of seismic at-rest lateral earth pressure for the below-grade walls of the power block structures and provided an elastic solution demonstrated in a nomograph. The applicant developed the nomograph for a dimensionless normalized in-situ lateral stress at 1.0g horizontal earthquake acceleration for a normalized depth at a given Poisson’s ratio. The applicant calculated the site-specific at-rest pressure from the nomograph at various depth intervals using the site-specific acceleration and Poisson’s ratio.

The applicant illustrated lateral earth pressure diagrams for the active and at-rest cases in FSAR Figures 2.5.4-253 and 2.5.4-254, respectively, and indicated that the lateral pressures in the figures are BEs with an FS of 1. The applicant concluded that the FS against a gravity wall or structure foundation sliding, as well as for a wall overturning, is normally 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 equal or greater than 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 provides lateral earth pressure values versus depth with FS=1.0 and notes that FS=1.1 is normally used for sliding and overturning due to these lateral loads when the seismic component is included. 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 and IIB saprolite beneath or within the zone of influence of seismic Category I or II structures and replace the saprolite with structural fill. Furthermore, the applicant described plans to remove zones of weathered or fractured rock immediately beneath the RB/FB, CB, and FWSC foundations and replace the rock with concrete fill. Finally, for non-seismic 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:

- 10 CFR 50.55a, requires that SSCs be designed, fabricated, erected, constructed, tested, and inspected in accordance with the requirements of applicable codes and standards commensurate with the importance of the safety function to be performed.

- 10 CFR Part 50, Appendix A, GDC 1, "Quality Standards and Records," requires that SSCs 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 SSCs important to safety be maintained by or under the control of the nuclear power unit licensee throughout the life of the unit.

- 10 CFR Part 50, Appendix A, GDC 2, relates to 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.

- 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 SSCs 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.

- 10 CFR Part 50, Appendix S, "Earthquake Engineering Criteria for Nuclear Power Plants," applies to the design of nuclear power plant SSCs important to safety to withstand the effects of earthquakes.

- 10 CFR 100.23, 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:

- **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 that are sufficiently detailed to obtain an unambiguous representation of the geology.

- **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 to sufficient depth that impact behavior during construction and over the life of the facility, including during postulated seismic events.

- **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.

- **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.

- **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); long-term solubility properties and dissolution behavior during the life of the facility have been determined; and this data is included, interpreted, and summarized; (2) the extent (horizontally and vertically) of all seismic 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 over the life of the plant; (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. If backfill is to be placed under safety-related structures, proper ITAAC should be specified in the applicant's technical submittal to ensure that the static and dynamic properties of in-place backfill material will be the same as, or better than the design parameters. In case cementitious construction material is to be placed under safety -related structures, proper ITAAC should be specified in the applicant technical submittal to ensure that the cementitious backfill placed underneath any seismic Category I structures to a thickness greater than 5 ft, meets the design, construction and testing of applicable American Concrete Institute (ACI) standards. In addition, the long-term behavior of the backfill subjected to any aggressive groundwater characteristics is evaluated; (7) For sites where deeply embedded structures are involved, deep excavation techniques will likely utilize wall retaining systems rather than a sloped excavation of the soil. Also, a description of the planned excavation technique(s) and design of the wall retention system with sufficient details is provided and it should be able to demonstrate that the excavation technique used will not significantly affect the surrounding soil properties that are relied upon in the analysis and design of the foundation and plant structures.

- **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 applicant's technical submittal: (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. This includes consideration of the potential for substantial head and volume of water due to the deep excavation for the plant 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 as determined by periodic monitoring of an adequate number of local wells and piezometers. Flood conditions should also be considered; (6) Evaluation of chemical properties of the groundwater that may impact long-term behavior of the rock/soil/fill materials as well as structural elements (concrete and steel materials).

- **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. Evidence of liquefaction and sand cone formation should be included; (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. If generic soil degradation properties are used in the related preliminary analyses (e.g., site seismic response and SSI analyses), then reconciliation of the generic properties and laboratory testing results should be performed. The section should be cross-referenced with Section 2.5.2.5.

- **Liquefaction Potential**: In meeting the requirements of 10 CFR Parts 50 and 100, if the foundation materials at the site adjacent to and under seismic 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.

- **Static and Dynamic Stability**: In meeting the requirements of 10 CFR Parts 50 and 100, the discussions of static and dynamic analyses are acceptable if the stability of all safety-related facilities has been analyzed from a static and dynamic stability standpoint including bearing capacity, rebound, settlement, and differential settlements under deadloads of fills and plant facilities, dynamic loads including "live" and seismic loads with consideration of loading sequences and combinations, and lateral loading conditions.

- **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.

- **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, bridging mats, dental work, rock bolting, or anchors).

In addition, the geotechnical engineering characteristics should be consistent with appropriate sections from: RG 1.27, RG 1.28, "Quality Assurance Program Requirements (Design and Construction)"; RG 1.132, RG 1.138, RG 1.198, and RG 1.206.

2.5.4.4 Technical Evaluation

This section provides the staff's evaluation of the geophysical and geotechnical investigations including field and laboratory tests carried out by the applicant to determine the static and dynamic engineering properties of the materials that underlie the North Anna 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. 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 evaluated the information provided to resolve DCD COL Item 2.0-29-A and ESP Permit Conditions 3.E(4) to 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 is resolved in Section 2.5.4.4.3 of this SER. Permit Condition 3.E(4) requires that an applicant for a CP or COL referencing this ESP shall excavate weathered or fractured rock at the foundation level and replace it with lean concrete before the commencement of foundation construction for safety-related structures. This was addressed in North Anna 3 FSAR Section 2.5.1 and evaluated in Section 2.5.1.4 of this SER. More detailed discussion regarding the resolution of this permit condition was presented in Sections 2.5.4.5.2 and 2.5.4.5.3 of the North Anna 3 FSAR, and additional staff evaluation was presented in Section 2.5.4.4.5 of this SER. Permit Condition 3.E(5) requires the applicant not to use an engineered fill with high compressibility and low maximum density, such as saprolite, this is resolved in Section 2.5.4.4.5 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 is resolved in Section 2.5.4.4.5, in conjunction with Sections 2.5.1 and 2.5.3 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 is 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 North Anna 3 site. The staff reviewed the applicant's description of the four zones of subsurface materials and the methods used to determine the engineering properties of those materials and to develop the subsurface profile as shown on SER Figure 2.5.4-1. The staff also reviewed the applicant's use of the latest field and laboratory methods, including boring sample analysis, observation wells, SPT, P-S suspension logger, and CPTs, to determine the properties of the subsurface materials.

To clarify how the properties of Zone IIA soil were determined, the staff issued RAI 02.05.04-1 (ADAMS Accession Number No. ML081690661) dated June 17, 2008, requesting that the applicant justify the use of an effective cohesion value (c') of 6.0 kPa (125 psf) for Zone IIA soil, given that the SPT and C-U test results imply very little effective cohesion (interpreted as c' = 0). In the applicant's response to RAI 02.05.04.-1 (ADAMS Accession No. ML082050558) dated July 14, 2008, the applicant stated that it derived the effective cohesion value from various data sources. The applicant assumed some effective cohesion due to the mineralogy, texture, and fabric of the Zone IIA saprolite. 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 6.0 kPa (125 psf) for the Zone IIA saprolite.

The staff reviewed the applicant's response, and concluded that although it is not a conservative approach to use a small effective cohesion value, it was reasonable as detailed below. 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 foundation stability analyses with relatively large internal friction angles of soil. The results of the staff's confirmatory analyses also noted that with a decrease of c' value from 6.4 to 5.5 kPa (135 to 115 psf), the FS 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 of determining the effective cohesion value is reasonable, the staff concludes that the applicant provided adequate information to resolve RAI 02.05.04-1.

During the review of FSAR Section 2.5.4.2.5, the staff noted that the applicant stated that it will place concrete fill with an average thickness of 3.0 m (10 ft) and a maximum thickness of 15.2 m (50 ft) below the base of the RB/FB, CB and FWSC foundations. Because thermal cracking can be an issue for a large concrete mass, the staff issued RAI 02.05.04-22 dated February 09, 2011 (ADAMS Accession No. ML110400770). The staff asked the applicant to describe how it will place the concrete fill in the field to reduce thermal cracking distress and how it will ensure the long-term strength and stability of the concrete fill.

In the applicant's response to RAI 02.05.04-22 dated April 04, 2011 (ADAMS Accession No. ML110950474), the applicant stated that in order to minimize thermal cracking distress for large concrete masses, the general objective is to limit volume changes and the temperature differential across the concrete as much as practical by properly controlling and/or limiting the heat generated by hydration of the mass of concrete. The applicant committed to follow ACI 349, Code Requirements for Nuclear Safety-Related Structures, which provides provisions and guidelines regarding concrete material properties, quality, mixing and placing requirements, durability requirements to ensure long-term strength and stability of the concrete, and requirement to reduce thermal cracking distress. The applicant also stated that it will follow additional standards referenced in ACI 349, such as ASTM standards and publications of ACI Committees 201 and 207, in the detailed concrete fill design. The applicant also committed to revise FSAR Section 2.5.4.2.5 to include a statement referencing ACI 349 with regard to concrete fill durability, design, construction, and quality assurance.

The staff reviewed this RAI response and relevant chapters of ACI 349 and ACI 207, and finds that the applicant identified appropriate industrial standards that it will follow to address the thermal cracking distress issue in mass concrete fill. The staff noted that the applicant committed to develop construction specifications in accordance with the applicable standards to provide controls on the construction process, including placement techniques, material properties (including mix design and concrete properties during placement such as slump, air content, and mix temperature), and proposed a revision to FSAR Section 2.5.4.2.5 to reflect those focus areas of staff concern. The staff later confirmed that the latest version of the FSAR incorporated the proposed changes. Accordingly, the staff concludes that the applicant adequately addressed the long-term strength and stability of the concrete fill and provided necessary specification in its application. Therefore, the staff considers RAI 02.05.04-22 resolved and closed.

Based on the acceptable determination of the subsurface properties and the resolution of related RAIs, the staff concludes that the field investigations and laboratory testing performed by the applicant to determine the subsurface material properties were performed in accordance with RGs 1.132 and 1.138 and are sufficient to meet the relevant criteria of 10 CFR Parts 50 and 100.

2.5.4.4.3 Foundation Interfaces

FSAR Section 2.5.4.3 describes and illustrates the location of site exploration points for the North Anna 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 ten 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 SSCs. As part of this review, the staff also examined the site exploration points for the North Anna 3 subsurface investigations, including SER Figure 2.5.4-8 (FSAR Figure 2.5.4-217), which shows the locations of additional boreholes, observation wells, CPTs, electrical resistivity tests, and test pits. The staff considered this information along with the exploration points outside of the power block area and 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 North Anna 3 site. The staff reviewed the subsurface profiles and cross sections and plot plans and concludes that the relevant information provided by the applicant is acceptable and satisfies the previously mentioned requirements.

Finally, the staff reviewed the future excavation and backfill plans for the North Anna 3 site as illustrated in SER Figure 2.5.4-9 (FSAR Figure 2.5.4-225). The staff concludes that the information presented 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.

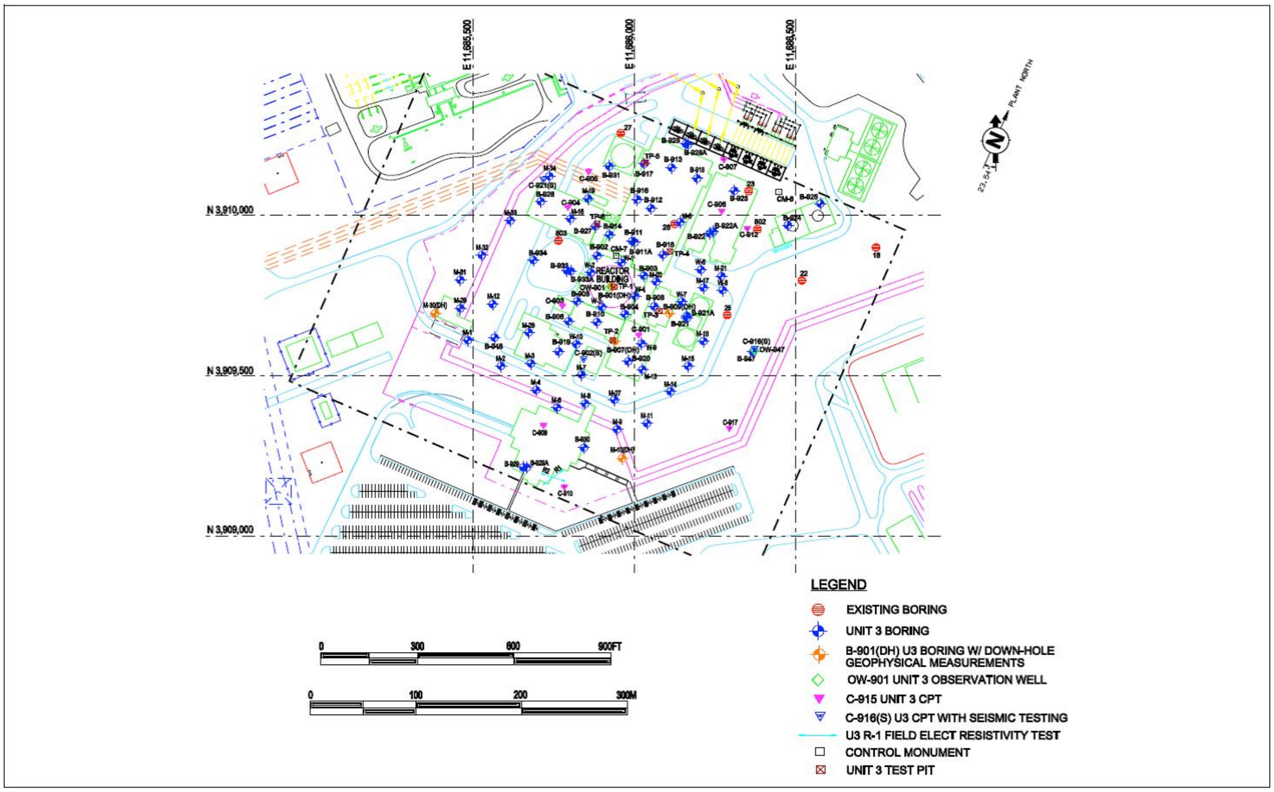


Figure 2.5.4-8. Unit 3 Boring Locations (FSAR Figure 2.5.4-217)

Resolution of ESP COL Action Items 2.5-1 to 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 seismic Category I structures, plan dimensions, and bottom of foundation elevations for those structures.

The applicant included several figures that show the subsurface profiles with the cross sections of foundation structures superimposed for comparison. SER Figure 2.5.4-8 shows the locations of the exploration points at the North Anna 3 site. Because the applicant included the plot plans and profiles that compare the foundations of seismic Category I structures to the subsurface profiles at the North Anna 3 site, the staff concludes that the applicant 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 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 North Anna 3 site. In FSAR Section 2.5.4.3, the applicant provided the plot plans and comparison figures of the excavation, subsurface profiles, and seismic Category I foundations. SER Figure 2.5.4-9 presents a representative plot plan and excavation and backfill plan. In FSAR Section 2.5.4.5.3, the applicant described details such as the source, type and material properties 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 it will employ to ensure that the backfill meets the design values. The staff concludes that the applicant provided adequate information to describe the excavation and backfill plans for the North Anna 3 site as required by ESP COL Action Item 2.5-3. Accordingly, the staff considers ESP COL Action Item 2.5-3 resolved.

Based on the information and findings above, the staff concludes that the discussion of the foundation interfaces, including the subsurface investigations at the North Anna 3 site, is acceptable and meets the relevant requirements of 10 CFR Parts 50 and 100.

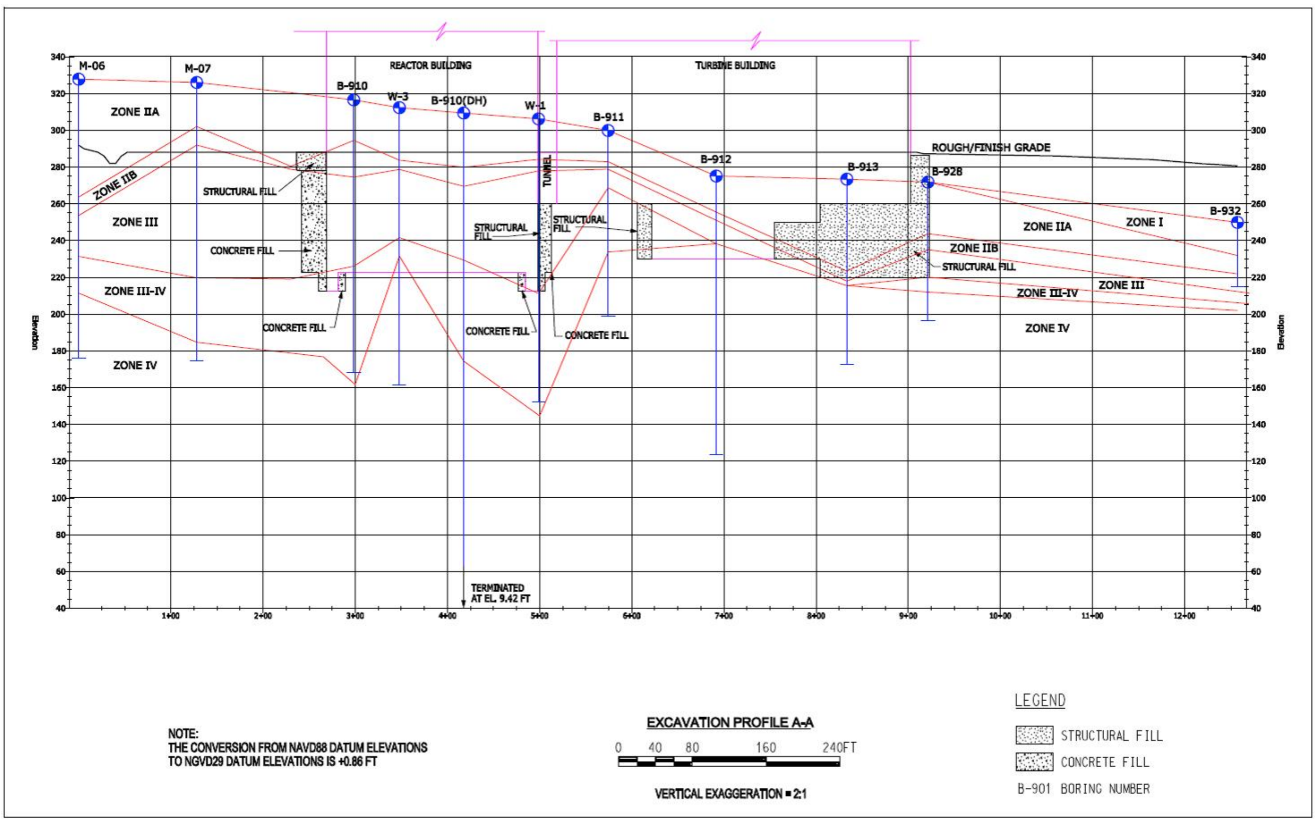


Figure 2.5.4-9. Excavation and Backfill Plan for Cross Section A-A'
(FSAR Figure 2.5.4-225)

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 testing 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 concludes that the applicant used acceptable methods commonly used in current engineering practices to determine shear wave velocity for each of the soil and rock zones at the North Anna 3 site. The staff further concludes that the applicant adequately described the results of laboratory analyses to confirm the validity of the dynamic properties obtained from field explorations and tests.

The staff concludes that the results of the geophysical surveys completed as part of the COLA and presented in the FSAR are in accordance with 10 CFR 100.23, and therefore are acceptable. However, the staff noted a discrepancy between the previous ESP site investigations and those completed in support of the COLA. The staff issued RAI 02.05.04-2 dated June 17, 2008 (ADAMS Accession No. ML081690661), requesting the applicant explain the difference in the North Anna 3 site median V_s values presented in the ESP SSAR versus the 36 to 50 percent higher median V_s in the COL FSAR.

The applicant's response to RAI 02.05.04.-2 dated July 14, 2008 (ADAMS Accession No. ML082050558), stated that the reasons for the difference in median V_s values between the ESP SSAR and COL FSAR are two-fold. First, the applicant stated that it took the V_s values in the ESP SSAR across a widely spaced area that does not reflect the conditions of the North Anna 3 specific location. Also, the applicant pointed out that it took the V_s measurements in rock presented in the COL FSAR from closely spaced boreholes at the specific location of North Anna 3 seismic Category I structures. Second, the applicant stated that there was a difference in the equipment used to measure the V_s values during ESP and COL site investigations. The applicant used suspension P-S velocity logging equipment to measure and determine the median V_s during the COL site investigation, which is a more sophisticated and advanced method than the crosshole and downhole testing methods used during the ESP site investigations and reported in the ESP SSAR.

The staff reviewed the RAI response and agrees that the P-S suspension logging equipment will yield a better constrained measurement of median V_s. The staff also considered the refined locations of boreholes used to measure V_s values and agrees that a broader distribution of boreholes, coupled with a less sophisticated testing method, would explain the variance in median V_s values between the ESP SSAR and COL FSAR. Accordingly, the staff considers RAI 02.05.04-2 resolved and closed.

Based on the review of FSAR Section 2.5.4.4, the acceptability of the results of geophysical surveys performed in support of the COLA and the applicant's response to RAI 02.05.04-2, the staff concludes that the applicant adequately determined the dynamic properties of soil and rock through the geophysical surveys of the North Anna 3 site to satisfy the relevant requirements 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 structure foundation 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. 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 structure foundation excavations, fills, and slopes, as illustrated in FSAR Figure 2.5.4-206, 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 concludes that the description of the extent of the excavations, fills, and slopes is acceptable. The staff also concludes that this information, with additional information provided in FSAR Sections 2.5.1 and 2.5.3, satisfies Permit Condition 3.E(6). The staff then reviewed the excavation methods and stability for the North Anna 3 site, which included a review of the soil excavation methods as well as the blasting techniques to be used for rock excavations, against the requirements of 10 CFR 100.23 and guidance contained in RG 1.132. The staff concludes that the methods of excavation and stability are acceptable because the applicant 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 concludes that the applicant's plans to monitor blasting, including the use of controlled blasting techniques as part of the excavation into rock, are acceptable as it will reduce vibrations and ensure the integrity of the rock mass at the site during the excavation.

The staff also reviewed the descriptions of backfill the applicant proposed to be used 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 under the seismic Category I foundation building mats. The staff issued RAI 02.05.04-3 dated June 17, 2008 (ADAMS Accession No. ML081690661), requesting the applicant to provide additional material and engineering properties of the concrete fill that will replace weathered rock exposed at the bottom of the excavation for seismic Category I building foundation mats. The applicant's initial response to RAI 02.05.04.-3 dated July 14, 2008 (ADAMS Accession No. ML082050558), stated that the properties of the concrete fill were yet to be determined. However, the applicant stated that it will design the concrete mix to have a V_s within the same range as the Zone III-IV rock at the North Anna 3 site. The applicant revised the FSAR to include a statement that the V_s of the concrete fill will be within the range of Zone III-IV rock.

In order for the staff to fully evaluate and determine the acceptability of the engineering properties of the concrete fill, the staff issued RAI 02.05.04-12 dated March 26, 2009 (ADAMS Accession No. ML090840271), and RAI 02.05.04-19 dated March 26, 2009 (ADAMS Accession No. ML090840271), in which the staff asked the applicant to provide the engineering properties of concrete fill, and, if the properties are assumed, to clarify how to ensure that the in-place concrete fill will have the same engineering properties as that used in stability analyses. The staff issued RAI 02.05.04-13 dated March 26, 2009 (ADAMS Accession No. ML090840271), in which the staff further asked the applicant to: (1) provide a detailed description of how the applicant planned to ensure that the static and dynamic properties of the backfill 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 the applicant plans to confirm that the design criteria of the ESBWR DCD and the parameter values related to backfill will be met during and after construction.

In North Anna 3 Revision 8 of FSAR Section 2.5.4.2.5a, the applicant described the detailed properties of the concrete fill: the minimum strength of 17.2 MPa (2,500 psi), the unit weight of 2,322 kg/m^3 (145 pcf), and a Poisson's ratio of 0.15. FSAR Section 2.5.4.10.1 states that the bearing capacity of the concrete fill is designed as 9,528 kPa (199 ksf) under both static and dynamic loading conditions. The applicant also provided ITAAC in Table 2.4.1-1, "ITAAC for Fill

Concrete Under and Around the Sides of Seismic Category I Structures," in COLA Part 10, "Tier 1/ITAAC," Section 2.4, "Site-Specific ITAAC," of its COLA.

Because structural soil will be backfilled surrounding the seismic Category I structures and the specific backfill soil properties were used in structural stability analyses, the applicant proposed an additional ITAAC for structural fill to ensure the in-place backfill will have the same, or better, engineering properties as designed. Table 2.4.1-2, "ITAAC for Structural Fill Surrounding Seismic Category I Structures," in COLA Part 10, "Tier 1/ITAAC," Section 2.4, "Site-Specific ITAAC" of its COLA presents the proposed ITAAC for structural fill. The staff verified that the appropriate change is incorporated in the FSAR, Revision 9, and, therefore, Confirmatory Item 2.5.4-1 from the staff's advanced SER for North Anna 3 is resolved and closed.

The staff reviewed the additional information regarding concrete fill including the minimum strength and bearing capacity, and the ITAACs for concrete fill and structural fill to be used for seismic Category I structure foundations. The specified ITAACs describe the inspection and testing required to ensure the properties of concrete fill and structural fill placed in the field meet the design requirements. Based on the staff's review of the latest FSAR Section 2.5.4.5 and the ITAACs for concrete fill and structural fill presented in the COLA, the staff concludes that the additional information related to excavation and backfill meets the relevant requirements of 10 CFR 100.23 and is acceptable. Accordingly, RAI 02.05.04-12, 02.05.04-13, and 02.05.04-19 are resolved and closed.

During the review of the SSI analysis results for FWSC, the staff noted that the analysis results indicated that although the shear stress capacity of the monolithic concrete fill material is sufficient to withstand the seismic demands for concrete fill under the FWSC foundation, the shear resistance of the construction joints, if needed as part of the detailed design, may not be sufficient to resist the sliding demands under the seismic loading. Because the FWSC is a seismic Category I structure and the stability of the concrete fill beneath it will directly affect the stability of the FWSC, in RAI 02.05.04-26 dated January 12, 2016 (ADAMS Accession No. ML16012A520), the staff requested the applicant to specify which code/standard(s)/procedure(s) will be followed in the construction of the in-place monolithic concrete fill. The staff also requested that the applicant explain under what conditions the construction joints may exceed the shear resistance requirement, and specify necessary ITAAC if shear reinforcements are to be used to ensure the bonding condition of the concrete fill construction joints in consideration of long-term effects in order to meet the required shear resistance capacity.

In its February 02, 2016, response to RAI 02.05.04-26 (ADAMS Accession No. ML16042A247), the applicant confirmed that the maximum seismic shear demand in the horizontal planes of the concrete fill is only about 12 percent of the nominal shear strength (0.39 MPa (56.3 psi) versus 3.26 MPa (473 psi)) even if conservatively neglecting the friction resistance of the mass concrete and using the lowest measured ratio of cohesion to compressive strength based on ACI 207.1R. The applicant then stated that the friction resistance alone is insufficient to achieve a minimum FS of 1.1 against sliding for the FWSC along the unbounded horizontal construction joints. To prevent this undesirable situation from happening in the field, the applicant stated that bonded construction joints will be used by following ACI 207.1R and other standards to ensure the monolithic integration of the concrete fill block under the FWSC.

The applicant proposed a revision to FSAR Section 2.5.4.2.5 to provide further details regarding the concrete fill below the FWSC, and clarify that the provisions of ACI 207.1R and the associated requirements in Part III, Section 1, of the North Anna 3 Quality Assurance Program Description (FSAR Appendix 17AA) will be applied to the concrete fill placed around and below the FWSC, as well as the RB/FB, and CB. The applicant also clarified that no shear reinforcements to the concrete fill will be used. The staff verified that the appropriate clarification is incorporated into the FSAR, Revision 9, and, therefore, Confirmatory Item 2.5.4-2 from the staff's advanced SER for North Anna 3 is resolved and closed.

The staff reviewed the RAI response and related industrial standards, such as ACI 207.1R and USACE EM 1110-2-2200, and concludes the following:

- The shear strength of the monolithic concrete fill under the FWSC foundation is sufficient to withstand the seismic demands with adequate margin; the maximum seismic shear demand of 0.39 MPa (56.3 psi) versus allowable shear strength of 0.54 MPa (7 8.8 psi) that used a proper FS.

- ACI 207.1R states that for bonded joints, the coefficient of internal friction can be taken as 1.0 and the cohesion resistance may approach that of the parent concrete. Therefore, the staff determined that the design concrete fill shear strength can be reached in the field if the ACI 207.1R standard is followed to ensure the construction of the monolithic concrete fill.

- The applicant committed to perform necessary testing during the concrete fill construction to ensure and verify that the as-built concrete compressive strength is equal to or greater than the required design strength. The ITAAC 1 on Table 2.4.1-1 of the North Anna 3 COLA, Part 10 will enforce this planned action to ensure that in-place concrete fill will meet all design requirements.

Based on the staff's review and verification of the proposed revision of the North Anna 3 COLA being incorporated in the FSAR, Revision 9, the staff considers the RAI 02.05.04-26 resolved and Confirmatory Item 2.5.4-3 from the staff's advanced SER for North Anna 3 closed.

Resolution of Permit Conditions 3.E(4) and 3.E(5)

Permit Condition 3.E(4) requires that an applicant for a CP or COL referencing this ESP shall excavate weathered or fractured rock at the foundation level and replace it with lean concrete before the commencement of foundation construction for safety-related structures.
Permit Condition 3.E(5) requires that the permit holder and an applicant for a CP or COL referencing this ESP shall not use an engineered fill with high compressibility and low maximum density, such as saprolite.

The applicant is planning to remove weathered or fractured rock at the foundation level and place concrete fill underneath all seismic Category I structures. The applicant will also place well-graded, highly compacted, angular to sub-angular gravel-sized particles of crushed rock as structural fill surrounding foundations, the concrete and structural materials will have adequate engineering properties to support structures and are non-liquefiable under the given site-specific seismic loading condition. In addition, the applicant proposed ITAACs (Tables 2.4.1-1 and 2.4.1-2 in Section 2.4 of North Anna COLA Part 10) specifically for the concrete and structural fills to ensure its in-place properties. In conjunction with staff's evaluation in Section 2.5.1 of this SER, the staff considers the requirements of Permit Conditions 3.E(4), and 3.E(5) are met.

Because the applicant adequately addressed North Anna 3 site excavation and backfill considerations for seismic Category I structure foundations, the staff concludes that the applicant provided sufficient information to satisfy the relevant requirements of 10 CFR 100.23 and guidance contained in RG 1.132.

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 North Anna 3 site. The staff reviewed the groundwater information provided 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 concludes 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, for staff to evaluate the stability of foundations and structures to be built 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 evaluated the effects of groundwater conditions on foundation stability. The applicant concluded that the maximum design allowable groundwater level was at least 0.6 m (2 ft) below the final plant grade, while the maximum predicted groundwater level in the power block area of North Anna 3 is at least 2.3 m (7.5 ft) below design 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 concludes that the applicant 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 resolved.

The staff also considered the groundwater condition related requirements specified in 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 concludes that the applicant's assessment of groundwater conditions is acceptable and meets the relevant requirements 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 V_s design profiles to determine the response of the soil and rock underlying the North Anna 3 site to seismic loading. The applicant also described shear modulus and damping variations with shear strain, and amplification/attenuation analyses performed for rock and soil.

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 selected for each of the soil and rock zones to determine whether the applicant used the appropriate criteria, such as grain size, cohesiveness, confining pressure, and V_s. The staff concludes that the applicant selected shear modulus and damping degradation curves based on appropriate criteria and are suitable for Zone IIA, IIB, and III soil and rock. The staff further concludes that the damping ratio of 1 percent with a variation of about ± 0.5 percent for the Zone III-IV and Zone IV rock is acceptable because this is a conservative value for this type of rock.

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 for the specific selected locations for the nuclear power plant structures. FSAR Section 2.5.4.7.4 describes the rock and soil column amplification/attenuation analyses conducted for North Anna 3 using the P-SHAKE computer program. The applicant illustrated the maximum acceleration versus depth and noted that the peak acceleration was 0.31g and 0.56g for the LF and HF earthquake, respectively. The PGAs occurred about 12.8 m (42 ft) below natural ground surface. The staff concludes that the applicant provided sufficiently detailed descriptions of the amplification/ attenuation analyses for use in the staff's evaluation of the applicant's site seismic response, as discussed in Section 2.5.2.4 of this SER, which also meet the requirements of ESP COL Action Item 2.5-5. Therefore, the staff considers ESP COL Action Item 2.5-5 resolved.

ESP COL Action Item 2.5-9 requires the applicant referencing the North Anna ESP to ensure that the average V_s 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 V_s determinations that the applicant made for soil, rock, and backfill at the North Anna 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 V_s values at North Anna 3 were greater than the minimum V_s design values. The ESBWR DCD requires a COL applicant to use the lower bound shear wave velocity value after taking into account uncertainties of soil properties under site-specific seismic loading conditions to determine the equivalent uniform shear wave velocity. Because the applicant initially combined rock layers with soil layers when determining the average soil shear wave velocity within certain depth, in RAI 02.05.04-14 dated March 26, 2009 (ADAMS Accession No. ML090840271), the staff requested the applicant to properly determine the design required soil shear wave velocity.

The applicant's response to RAI 02.05.04-14 dated June 17, 2009 (ADAMS Accession No. ML091700117), revised its calculation by not mixing rock and soil layers and following the design requirement when determining average shear wave velocity. The staff reviewed the information provided in the latest revision of FSAR Section 2.5.4.7 regarding the average V_s of subsurface materials and confirmed that the revised subsurface material properties followed the ESBWR design guide and are presented in the latest revision of the FSAR. The staff therefore concludes that the applicant adequately determined shear wave velocity of subsurface materials and addressed the issue of the RAI 02.05.04-14, as well as the ESP COL Action Item 2.5-9. Accordingly, the staff considers ESP COL Action Item 2.5-9 is resolved and RAI 02.05.04-14 is resolved closed.

Because the applicant adequately addressed the response of the soil and rock to dynamic loading at the North Anna 3 site and resolved ESP COL Action Items 2.5-5 and 2.5-9, the staff concludes that the applicant provided sufficient information to satisfy the relevant requirements of 10 CFR Parts 50 and 100.

2.5.4.4.8 Liquefaction Potential

The staff reviewed FSAR Section 2.5.4.8 and evaluated the applicant's liquefaction analyses for the North Anna 3 site to ensure conformance with the criteria described in RG 1.198. The staff focused its review on the applicant's conclusion that only the Zone IIA saprolite is susceptible to liquefaction, and the applicant's liquefaction analyses for Zone IIA saprolites outside of the power block area for soils that it will not excavate, as well as the parameters used in these analyses.

The staff reviewed the applicant's liquefaction potential assessment for the North Anna 3 site based on SPT data, CPT data, and shear wave velocity data analyses. For each analysis, the applicant used the method proposed by Youd et al. (2001). The staff determined that the applicant used the latest empirical method for the liquefaction analyses in accordance with RG 1.198, and therefore concludes that the North Anna 3 liquefaction potential analysis is acceptable.

The staff reviewed the liquefaction analyses that the applicant performed for the engineered backfill designed to be granular material and possibly saturated due to the design maximum groundwater level being above the bottom of the backfill layer. In RAI 02.05.04-7a dated June 17, 2008 (ADAMS Accession No. ML081690661), the staff asked why the applicant did not perform a liquefaction analysis for the backfill soil in accordance with the recommendations of RGs 1.206 and 1.198. The applicant's response to RAI 02.05.04-7a dated July 14, 2008 (ADAMS Accession No. ML082050558), stated that the analyses for backfill soil at the North Anna 3 site showed that the soil was non-liquefiable. The applicant further stated that the non-liquefiable nature of the soil was attributable to the fill beneath the FWSC being both dense and gravelly. The applicant cited the results of liquefaction potential analyses based on SPT, CPT and V_s data 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 application to be sufficient to conclude that the applicant provided adequate information to demonstrate that the backfill soil is non-liquefiable. Accordingly, the staff considers RAI 02.05.04-7a resolved and closed.

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 02.05.04-10 dated June 19, 2008 (ADAMS Accession No. ML081710161), the staff asked the applicant to explain why this value is significantly smaller than the value determined in the ESP SSAR (127 mm [5 in]). In the applicant's response to RAI 02.05.04-10 dated August 4, 2008 (ADAMS Accession No. ML082200626), the applicant stated that the maximum settlements estimated in the FSAR differed significantly from the ESP SSAR for two reasons: first, the CPT test data, which formed the basis for the FSAR settlements, was collected at some distance apart from the locations where the applicant collected the CPT test data for the ESP SSAR; second, due to the distance separating the locations, the underlying saprolitic soils do not have identical properties, which also contributed to the difference. The applicant also stated that the PGAs used in the FSAR analysis were about 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 also reviewed this information and considered that although the applicant performed the CPT tests at different locations where soil properties may be different during ESP and COL site investigations, the soil property variation was not significant. The staff compared the strength parameters for the saprolite soil in the FSAR to those in the ESP SSAR and noted that the values presented in the ESP SSAR were higher. The applicant also indicated that "the value of cyclic stress ratio used as input to the dynamic settlement analysis is directly proportional to the peak ground acceleration." However, the staff determined that even though the PGAs 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 almost 3 times that presented in the FSAR. Therefore, in RAI 02.05.04-18 dated March 26, 2008 (ADAMS Accession No. ML090840271), a supplement to RAI 02.05.04-10, the staff asked the applicant to explain why the estimated dynamic settlement in the ESP SSAR was almost 3 times of that estimated in the FSAR while there is only a 40 percent difference for PGAs used in these two calculations.

In the applicant's response to RAI 02.05.04-18 dated June 17, 2009 (ADAMS Accession No. ML091700117), and in a later version of the FSAR, the applicant explained that for the estimated maximum dynamic settlement of the Zone IIA saprolite due to earthquake induced seismic loading, a significantly smaller value was obtained for the COLA than that calculated in the ESP SSAR is because in the ESP SSAR the dynamic settlement was estimated based on soil encountered in one of the CPTs performed for the ESP investigation, while the new estimate was based on overall site investigation data. Nonetheless, since the applicant chose to use the maximum dynamic settlement of 12.7 cm (5 in) in the FSAR (the same as that presented in the ESP SSAR), which is a conservative approach, the staff concludes that it is acceptable. Accordingly, RAI 02.05.04-18 is resolved and closed.

Resolution of Permit Condition 3.E(7)

This Permit Condition 3.E(7) requires the applicant to improve Zone II saprolitic soils and reduce any liquefaction potential if it will remain under any safety-related structures. Because FSAR Section 2.5.4.8 states that all safety-related structures would be founded on rock or concrete fill placed on rock, and the applicant planned to remove Zone II saprolite and replace it with engineering fills for all safety-related and/or seismic Category I structure foundations at the North Anna 3 site, the staff concludes that the requirements of Permit Condition 3.E(7) are met.

In summary, the staff reviewed FSAR Section 2.5.4.8 and the applicant's response to RAI 02.05.04-7a, regarding the non-liquefiable nature of the backfill, and finds that the applicant's conclusion of liquefaction potential at the site is acceptable because there will be no liquefiable material underneath or surrounding the seismic Category I structures and the methods used in liquefaction potential analyses for soil outside the power block are commonly used methods in engineering practices. The staff further concludes that the removal of potentially liquefiable soil from all seismic Category I structure foundations at the site is sufficient to satisfy Permit Condition 3.E(7).

Therefore, the staff concluded that the assessment of the liquefaction potential at the planned North Anna 3 site is adequate and satisfies the requirements of 10 CFR Part 50, Appendix A; 10 CFR Part 50, Appendix S; GDC 2, and 10 CFR 100.23.

2.5.4.4.9 Earthquake Design Basis

FSAR Section 2.5.2.6 presents the applicant's derivation of the SSE and Operating Basis Earthquake (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 it obtained those results.

Bearing Capacity

The staff reviewed the initial bearing capacity calculations and identified several concerns. One area of concern was the difference in dynamic bearing capacity for the RB and FB, which was initially stated as 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 02.05.04-6 dated June 17, 2008 (ADAMS Accession No. ML081690661), the staff asked the applicant to clarify the values of allowable dynamic bearing capacity for the RB/FB. The applicant's response to RAI 02.05.04-6 dated July 14, 2008 (ADAMS Accession No. ML082050558), stated that the computed dynamic bearing capacity value for concrete was 10,200 kPa (214 ksf) and for Zone III-IV bedrock was 12,401 kPa (259 ksf). The applicant also stated that since the value for the concrete was lower, it will revise FSAR Table 2.0-201 to reflect the concrete dynamic bearing capacity. The applicant also estimated the allowable dynamic bearing capacity as the least value of the allowable bearing capacity of the underlying strata, regardless of thickness. In the case of the RB/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 concludes that it is acceptable. However, the staff had additional concerns for how the applicant determined the properties of the concrete fill to be used in the analyses, because there is no three dimensional information available about the concrete fill to be placed in the field, nor has the applicant finalized the design of the concrete fill. Therefore, in follow-up RAI 02.05.04-15 dated March 26, 2009 (ADAMS Accession No. ML090840271), the staff asked the applicant to clarify how it determined the properties of the concrete fill, such as engineering properties and thickness underneath the foundation in all directions, and used the results in the allowable bearing capacity calculation without knowing the actual concrete fill design and placement at foundation.

The applicant stated that local failure would not occur in the concrete mat foundation of the FWSC; however, the local failure not occurring in the concrete mat does not exclude the possibility of local failure in the backfill layers beneath the concrete mat. Therefore, in RAI 02.05.04-16 dated March 26, 2009 (ADAMS Accession No. ML090840271), 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.

As another foundation bearing capacity related issue, in RAI 02.05.04-19 dated March 26, 2009 (ADAMS Accession No. ML090840271), the staff asked the applicant to provide details on what load combinations it used in the dynamic bearing capacity estimate and why it used one and one-third of static bearing capacity as dynamic bearing capacity for this site without actual analysis.

To address the issues identified above, the applicant's response to RAI 02.05.04-15 dated August 20, 2009 (ADAMS Accession No. ML092360773) and in the revised FSAR, the applicant specified that the concrete fill will have a minimum strength of 17,240 kPa (2,500 psi, or 360 ksf), with a unit weight of 2.32 g/cm^3 (145 pcf) and Poisson's ratio of 0.15. The applicant also stated that for the specified concrete fill, it will use 10,244 kPa (214 ksf) (the final design value is specified as 9,528 kPA (199 ksf) as the allowable bearing capacity for both static and dynamic loading conditions, in accordance with the guidelines of ACI 349-01 (2001). Therefore, this issue and RAIs are resolved and closed.

To further address the issues identified by RAI 02.05.04-16, in a response dated June 17, 2009 (ADAMS Accession No. ML091700117), the applicant stated that the large, thick, heavily-reinforced concrete mat used to support the FWSC provides the most stable kind of soil-supported foundation. This type of mat foundation has two distinct advantages: (1) the confinement of the foundation provided to a loaded granular (cohesionless) soil will increase the soil's bearing capacity; and (2) the structural integrity and resulting stiffness of the mat itself. Normally the local failure cannot occur beneath a mat foundation as long as the foundation itself does not fail structurally.

In the applicant's response to RAI 02.05.04-19 dated June 17, 2009 (ADAMS Accession No. ML091700117), the applicant stated that it will build the RB/FB and the CB on bedrock or on concrete fill above bedrock, and thus the increase in bearing capacity for dynamic loads for soils is no longer applicable. Other structures, such as RW and TB, will be supported on either structural fill or on weathered rock and sound rock or on a combination of structural fill and weathered and sound rock. The allowable bearing capacity for those buildings was conservatively determined based on the lowest allowable bearing capacity of any stratum underlying those structures (the Zone III weathered rock). Because the applicant did not use the allowable bearing pressure for soil and the increase in allowable bearing pressure as noted in the International Building Code (IBC) for any of the structures, no IBC-related load combinations are considered.

The staff reviewed the additional information and concludes that there is adequate margin by using 9,528 kPa (199 ksf) as allowable bearing capacity for the 17,240 kPa (360 ksf, or 2,500 psi) concrete fill, and all other rock layers underlying the foundation have higher bearing capacity. The staff, therefore, concludes that this is a conservative approach and acceptable. The staff also concludes that the probability of localized foundation failure at this site is negligible because no safety-related structure will be founded on a soil layer; therefore, there is no mechanism for large local settlements below the FWSC mat or other seismic Category I structures. Finally, the staff agrees with the applicant that because the revised allowable bearing capacity values did not use the IBC code to increase the bearing capacity by one-third, no IBC-related load combination needs to be considered when determine the dynamic bearing capacity.

Based on the review of the bearing capacity calculations provided in the revised FSAR referencing the ESBWR DCD, the staff noted that the applicant calculated the allowable static bearing capacity values for each bedrock zone and concrete fill following the industrial standards. The applicant used values less than 20 percent of the ultimate crushing strength of the rock as allowable static bearing capacity and allowable dynamic bearing capacity, which results in a conservative estimate of the bearing capacity for rock layers. The applicant also used a much smaller than designed concrete fill strength value as bearing capacity for concrete fill. By comparing the estimated bearing capacity values with standard design requirements, the staff finds that the minimum FS is greater than 3.3 for static loading condition; and greater than 7.9 for dynamic loading condition for all structures. The staff further concludes that the applicant conservatively selected bearing capacity values, and these parameters are enveloped by the standard design; therefore, the subsurface materials underneath the safety-related structures at the site are capable of meeting the design bearing capability requirements. The staff also verified that the latest version of the FSAR presents all revised calculation results, accordingly, Open Items previously identified by the staff are closed and the associated RAIs are resolved and closed.

Because the coefficient of friction is one of the engineering properties used for foundation stability evaluation, in RAI 02.05.04-17 dated March 26, 2009 (ADAMS Accession No. ML090840271), the staff asked the applicant to justify the site-specific coefficient of friction used to calculate the site-specific FS against sliding between the basemat and underlying material.

In the applicant's response to RAI 02.05.04-17 dated June 17, 2009 (ADAMS Accession No. ML091700117), the applicant provided the coefficient of friction used for this site. Because all seismic Category I structures will be founded on subgrade materials including Zone IV bedrock, Zone III-IV bedrock or concrete fill; and some buildings will be on compacted structural fill, different values of the coefficient of sliding for a poured concrete foundation on the site subgrade materials were specified with range from 0.55 to 0.7. The staff considers that the applicant specified coefficient of friction values based on typical material properties, and the friction angles corresponding to those coefficients, from 23 to 33 degrees, are normal values for the materials involved. The staff confirmed that the applicant specified coefficients of friction used in foundation stability analyses in Table 2.5.4-208 of the latest revised FSAR; accordingly this RAI is resolved and is closed.

Settlement Analysis

During the review of the settlement analyses performed by the applicant, the staff identified three areas requiring additional information. In FSAR Section 2.5.4.10.2, the applicant estimated settlement using a formula that included the layer elastic modulus E. In RAI 02.05.04-7c dated June 17, 2008 (ADAMS Accession No. ML081690661) and RAI 02.05.04-23, dated February 09, 2011 (ADAMS Accession No. ML110400770), the staff asked the applicant to clarify the types of E values used in the settlement calculations whether they were corresponding to small or large strains. In the July 14, 2008, and March 7, 2011, responses (ADAMS Accession Nos. ML082050558 and ML110680412), the applicant clarified that it used the high-strain elastic modulus in the settlement calculations for the North Anna 3 Seismic Category 1 structure foundations. Because the applicant used an elastic modulus in settlement calculation that would not result in underestimating the settlement at the site, the staff concludes that this approach yielded an adequate settlement estimate. Accordingly, the staff considers RAI 02.05.04-7c and RAI 02.05.04-23 resolved and closed.

Also in FSAR Section 2.5.4.10.2, the applicant initially estimated the differential settlement for the FWSC excluding the weight of the basemat. In RAI 02.05.04-7d dated June 17, 2008 (ADAMS Accession No. ML081690661), the staff sought justification as to why the weight of the basemat was not included in the settlement calculation. In a July 14, 2008 response (ADAMS Accession No. ML082050558) to this RAI, the applicant stated that it excluded the weight of the basemat 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, the applicant provided estimated settlements that include the basemat to take all possible loads into consideration. The staff reviewed this response, including the information presented in ESBWR DCD Table 2.0-1 and the latest revision of FSAR Table 2.5.4-212, and concludes that although the DCD does not include the basemat in the settlement calculations, the applicant included the basemat in the settlement calculations and showed that the estimated site-specific settlement of FWSC meets the design requirement; therefore, the applicant provided sufficient information to resolve RAI 02.05.04-7d and the staff considers it closed.

In RAI 02.05.04-7e dated June 17, 2008 (ADAMS Accession No. ML081690661), the staff asked the applicant to explain why it did not consider the seismic settlement of the FWSC foundation in the settlement analysis. The applicant's response referred to its July 14, 2008 response to RAI 02.05.04-7a (ADAMS Accession No. ML082050558), 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 structural fill would be compacted to a high degree of density 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. Moreover, in the latest revision of the FSAR, the applicant stated that it will replace structural fill with concrete fill under the FWSC, and therefore seismic settlement is no longer an issue. Accordingly, the staff concludes that the applicant adequately addressed RAI 02.05.04-7e and considers the RAI resolved and closed.

Resolution of NAPS COL 2.0-29-A

NAPS COL 2.0-29-A (ESBWR DCD COL Item 2.0-29-A) requires that a COL applicant referring to the ESBWR design to provide site-specific information in accordance with SRP 2.5.4 and address: (1) localized liquefaction potential under other than seismic Category I structures, and (2) settlement and differential settlements. In FSAR Section 2.5.4.8 and Section 2.5.4.10.2, the staff concludes that the applicant provided sufficient information to address liquefaction potential under all structures, both seismic Category I structures and non-seismic Category I structures, and estimated the settlement of those structures using adequate methods to satisfy the requirements specified in NAPS COL 2.0-29-A. Therefore, the staff considers NAPS COL 2.0-29-A (ESBWR DCD COL Item 2.0-29-A) resolved.

Earth Pressures

The staff reviewed FSAR Sections 2.5.4.10.3 and 3.7.2.4.1, and related calculations, and finds that the methods used to estimate dynamic (seismic) and static lateral earth pressure on below-grade walls of the power block structures is consistent with the methodology used in ESBWR DCD. The staff also noted that in the static lateral earth pressure calculation, the applicant considered earth pressures induced by hydrostatic pressure and lateral loads on below-grade walls due to embedment and surcharge loading. In the calculations, the key site characteristics that the applicant used, such as unit weight of structural fill, at-rest pressure coefficient, and groundwater level, are the same as or enveloped by the parameters used for the ESBWR design, which ensures that the design plant static lateral earth pressure loading envelopes the North Anna 3 static lateral earth pressure loading. In the dynamic lateral earth pressure calculation, the applicant considered the active lateral earth pressure generated by earthquake-induced horizontal ground accelerations. For at-rest lateral earth pressure under seismic loading, the applicant used the Wood's soil pressure distributions model as described in ASCE 4-98. Because the lateral earth pressure induced by vertical ground accelerations is very small, the applicant did not consider this component in accordance with common engineering practices. The applicant used a peak acceleration of 0.31g, corresponding to higher magnitude but LF dominated earthquake, to develop the seismic active earth pressure diagram.

Based on the above findings, the staff concludes that the applicant considered all possible loadings, including the site SSE loading that can contribute to lateral earth pressure on plant below-ground walls in this analysis, which follows the guidance of industrial standards and RGs. The staff further concludes that the use of the peak acceleration of 0.31g for LF earthquake when developing the seismic active earth pressure is adequate because it considered higher magnitude of the corresponding earthquake that has higher energy and greater potential for moving the subsurface materials and causing damage. Finally, the staff concludes that the applicant used methods endorsed by industrial standards and commonly used in engineering practices to adequately determine the static and dynamic lateral earth pressure on below-ground walls of the power block structures.

The comparison of estimated site-specific and ESBWR design total (static and dynamic) lateral earth pressure confirms that the design lateral earth pressure diagram envelopes the site-specific estimate; therefore, the staff concludes that the site-specific lateral earth pressure will not affect the stability of foundations and structures.

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 COLA. FSAR Section 2.5.4.10 describes the static stability of the North Anna 3 site, including the bearing capacity, rebound, settlement, and differential settlement. The applicant also discussed lateral earth pressures at the North Anna 3 site. The staff reviewed this information and concludes 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 resolved.

The staff reviewed FSAR Section 2.5.4.10 and applicant's responses to related RAIs, and concludes that the bearing capacity, settlement and earth pressure analyses and results for the North Anna 3 site are acceptable for satisfying the ESBWR design requirements and meeting the relevant 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 and NAPS COL 2.0-29-A.

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 COLA, such as wall rotation, sliding, and overturning. FSAR Section 2.5.4.11 describes the design criteria that apply to North Anna 3. These criteria include a minimum FS against sliding and overturning of 1.1, as well as an FS against liquefaction, bearing capacity failure and slope stability failure, among others. The staff reviewed this information and concludes that the applicant provided the applicable FS against sliding and overturning, as well as other design criteria, sufficient to satisfy the requirements of ESP COL Action Item 2.5-7. Therefore, the staff considers ESP COL Action Item 2.5-7 resolved.

The staff reviewed the FS used by the applicant and compared these values with those of RG 1.198, the related SRP sections and industry codes and standards, and concludes that those factors of safety are acceptable. The staff reviewed this information, including the resolution of ESP COL Action Item 2.5-7, and concludes that the applicant provided adequate design criteria for the North Anna 3 site, such as estimated settlement and earth pressure values, the factors of safety against liquefaction, bearing capacity failure, slope stability failure, sliding, and overturning to meet the relevant requirements of 10 CFR Parts 50 and 100.

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 structural fill for North Anna 3 site. The staff reviewed the plans to improve the Zone IIA saprolite 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 used, for the staff to 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 it will use to improve the subsurface conditions at the North Anna 3 site. The applicant described plans to remove the Zone IIA saprolitic soil, the only potentially liquefiable material identified at the site, and replace the excavated material with concrete fill and/or structural fill. The applicant stated that it will also remove zones of fractured or weathered rock from the areas immediately beneath the RB/FB, and FWSC basemat and replace it with concrete. The staff concludes that the applicant described the techniques it will use to improve the site, including the removal of the potentially liquefiable material from the foundation areas of the North Anna 3 structures, which meets the requirements of ESP COL Action Item 2.5-8. Accordingly, the staff considers ESP COL Action Item 2.5-8 resolved.

The staff further concludes that the methods described for subsurface improvements in FSAR Sections 2.5.4.12 and 2.5.4.5 are sufficiently detailed regarding the removal of the potentially liquefiable material and replacement with suitable structural fills at the North Anna 3 site to be acceptable and to satisfy the relevant requirements of 10 CFR Parts 50 and 100.

2.5.4.5 Post Combined License Activities

To ensure the quality of the backfills, either underneath or surrounding the seismic Category I structures, the applicant provided ITAACs in Table 2.4.1-1, “ITAAC for Fill Concrete Under and Around the Sides of Seismic Category I Structures,” Table 2.4.2-1, “ITAAC for Structural Fill Surrounding Seismic Category I Structures,” and Section 2.4, “Site Specific ITAAC,” in NAPS COLA Part 10; “Tier 1/ITAAC/Proposed License Conditions.”

The staff identified a License Condition relating to geologic mapping of both tectonic and non-tectonic surface deformation features at the site. The geologic license condition replaces ESP Permit Condition 3(E)(6) and is described in detail in Section 2.5.1.5 of this SER.

2.5.4.6 Conclusion

The staff reviewed the North Anna 3 COLA and cross checked the referenced ESP SSAR, ESBWR DCD and staff’s ESP SER. The staff’s review confirmed that the applicant addressed the relevant COL items, ESP COL Action items and ESP Permit Conditions, specifically, NAPS COL 2.0-29-A, NAPS ESP COL 2.5-2 through NAPS ESP COL 2.5-9 and ESP Permit Conditions 3.E(4) to 3.E(7). There are no outstanding issues that need to be addressed in the COL FSAR related to this section.

Based on its review, the staff concludes that the applicant conducted sufficient site investigations and performed adequate field and laboratory tests and associated analyses to provide sufficient information describing soil and rock conditions underlying the COL site of North Anna 3; provided sufficient information to characterize the subsurface materials at the site; and presented and substantiated information to assess the stability of subsurface materials and foundations. The staff reviewed the engineering properties of subsurface materials at the proposed site and backfill materials to be used during construction, the assessment of bearing capacity, liquefaction potential, settlement, and lateral earth pressure, as well as the development of a shear wave velocity profile through the site, and concludes that the applicant adequately addressed the related COL items and ESP permit conditions.

Accordingly, the staff concludes that the applicant provided sufficient information to meet the relevant requirements of ESBWR standard design and 10 CFR Part 50, Appendix A (GDC 2); Appendix S of 10 CFR Part 50; and 10 CFR 100.23, and therefore Section 2.5.4 of the North Anna 3 FSAR is acceptable.

2.5.5 Stability of Slopes

2.5.5.1 Introduction

Section 2.5.5 of this SER addresses 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 COLA. 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 staff's conclusions, restates any bases covered in the application, and confirms that the application 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:

COL Items:

- NAPS COL 2.0-30-A

NAPS COL 2.0-30-A addresses the provision in COL Item 2.0-30-A listed in the 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 North Anna 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

The slope stability analyses for the North Anna 3 site is presented in this FSAR section, 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 North Anna 3 subsurface investigation, and gave results that 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 COLA. In this request, the applicant asked that the information presented in North Anna 3 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 North Anna 3 from the anticipated slopes in the ESP SSAR. Due to these differences, the applicant stated that for the seismic slope stability analysis, the PGA applied at North Anna 3 is also different from the ESP, although the method of analysis remains the same. The main differences are smaller PGA used in the seismic slope stability analysis than that used in ESP SSAR Section 2.5.5 and differences in the changed slope 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 FS against failure under both long-term static and short-term seismic conditions.

North Anna 3 FSAR Figure 2.5.5-201 presents the grading plan for North Anna 3. The applicant noted that the design plant grade for the power block area is at an elevation of 88.4 m (290 ft) sloping down to an elevation of 87.7 to 86.6 m (288 to 284 ft) around the perimeter. From the south and southwest of the TB toward the existing Units 1 and 2, the applicant noted that the slope reduces at 5 percent down to elevation 85.3 m (280 ft) at the SW Building. To attain the North Anna 3 elevations, the applicant noted that up to 9.1 m (30 ft) of fill is needed to bring the ground surface up to plant grade, where ground level is presently at around elevation 76.2 m (250 ft).

The applicant stated that there are no slopes that contribute to the support of any seismic Category I or II structures and only instability of the cut slopes at the northern and western edges of the plant could affect North Anna 3. The applicant described the southwesterly-oriented existing slopes to the west of Units 1 and 2 that were originally excavated during construction of the existing units. Additional details of the existing slopes are provided in Section 2.5.5.1.1 of the FSAR. The new slopes in the site area are cut slopes north of the power block that merge into the existing slopes to the west. The applicant noted that these new slopes reach a maximum height of 11.9 m (39 ft).

The applicant also discussed the impact of slope instability as part of ESP VAR 2.5-1, noting that the instability of the slopes surrounding the storm water management pond, as well as the temporary slopes in the site area, do not affect the safety of the plant or any of its structures. The applicant also noted that the nearest point of the existing slopes is more than 30.5 m (100 ft) from the new diesel tanks and even farther from the closest point on the SW cooling tower. The applicant also considered instability of the new 3-horizontal to 1-vertical (3h:1v) slope, but concluded it does not impact the foundation stability because the facilities are founded on concrete fill on top of bedrock.

To address NAPS ESP COL 2.5-11, the applicant discussed the stability of the existing and new slopes at the North Anna 3 site in the following subsections.

2.5.5.2.1 Slope Characteristics

North Anna 3 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 North Anna 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. 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

Figure 2.5.5-1 of this report also shows the location and direction of the existing slopes, including Slope ES, a 2.4h:1v slope with a maximum height of 13.7 m (45 ft) to the southeast of the service water reservoir (SWR) for Units 1 and 2.

New Slope Characteristics

FSAR Section 2.5.5.1.2 describes the location of the new 11.9 m (39 ft) Slope SS, a 3h:1v slope to the east of the FWSC shown in plan view in SER Figure 2.5.5-1. The applicant noted that boring B-947 was drilled relatively close to the final location of the top of the slope during the North Anna 3 subsurface investigation. The stability analysis performed for Slope DD conservatively neglected a 4.6 m (15 ft) wide berm in the slope.

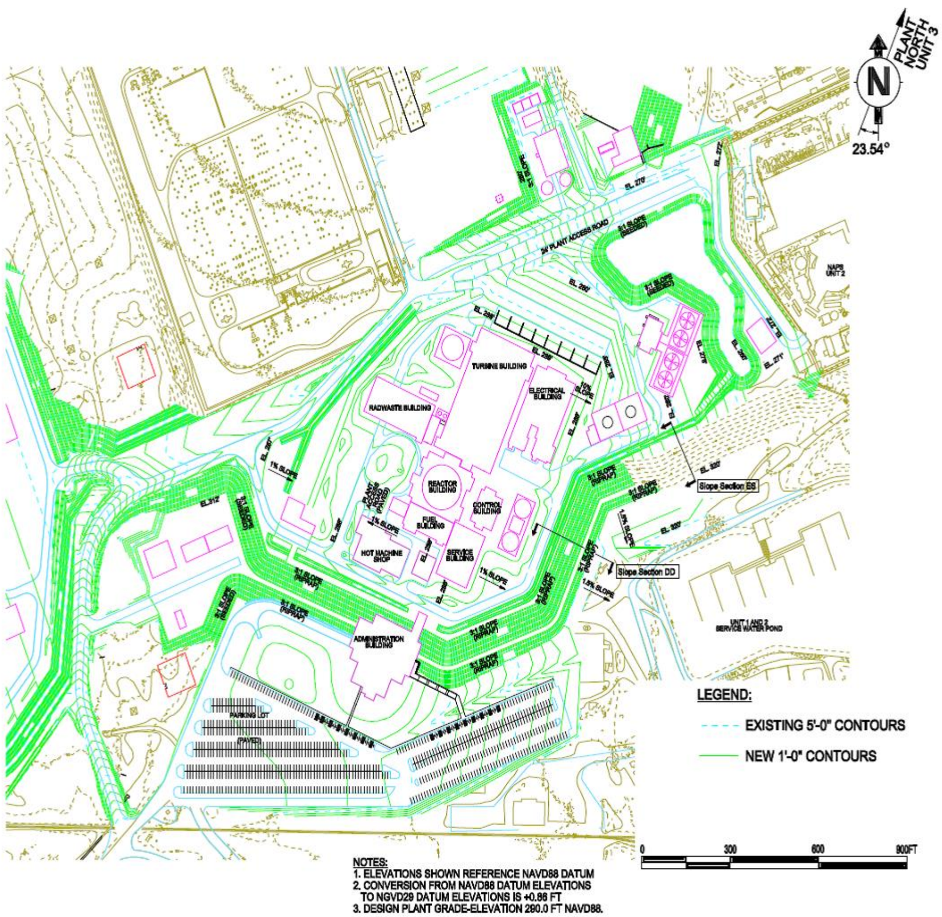


Figure 2.5.5-1. Location of Elevated Slopes (FSAR Figure 2.5.5-201)

Slope Subsurface Conditions

FSAR Section 2.5.5.1.3 describes the slope subsurface conditions at the North Anna 3 site and refers to Section 2.5.4.2.2 for details of the site soils and bedrock. Based on the site investigation data, the applicant determined that the soils in the slope consisted mostly of Zone IIA saprolites and were classified as silty sands. The applicant summarized the engineering properties of the site soils and bedrock, as well as the liquefaction characteristics of all of the Zone IIA saprolites estimated in FSAR Section 2.5.4.8.

New Slope Subsurface Conditions. The applicant also discussed the subsurface conditions of the new slopes in the site area. For the purposes of the stability analyses, the applicant noted that in B-929 Zone IIA saprolite is present down to about 14.2 m (46 ft) below the existing ground level with the remaining 5.4 m (18 ft) being Zone IIB saprolite.

Existing Slope Subsurface Conditions. The applicant summarized boring B-947 which provides information on the subsurface materials on the top of the existing slope and CPT C-916 which is adjacent to B-947. The applicant confirmed that the existing slope materials have the properties of the Zone IIA saprolite down to about 10.7 to 15.2 m (35 to 50 ft) below the existing ground level and the bottom 3.0 m (10 ft) of saprolite above weathered rock has the Zone IIB saprolite properties.

Slope Phreatic Surface

The applicant illustrated the phreatic, or groundwater, surfaces for existing and new slopes in FSAR Figures 2.5.5-202 and 2.5.5-203. The applicant developed these surfaces using water table levels measured in observation well 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 Slope

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 existing slope ES. The properties of soil and rock are provided in FSAR Table 2.5.4-208.

<u>Long-Term Static Analysis</u>. 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 2.29, 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 0.26g and a vertical acceleration of 0.130g in the slope for a LF earthquake, resulting in an FS of 1.30, more than the minimum 1.1 required. For the HF earthquake, the equivalent peak horizontal acceleration used was 0.42g with a vertical acceleration of 0.21g yielding an FS of about 1.04, 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 1.61 and 1.41 for the LF and HF earthquake inputs, respectively.

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 0.10g and 0.15g for HF and LF earthquake inputs with a vertical acceleration of zero. From these inputs, the applicant computed an FS of 1.76 and 1.57 for HF and LF 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 FS lower than the required minimum was the pseudo-static analysis using the HF peak acceleration. However, the applicant considered that to be an overly conservative approach and concluded that the existing 2.4h:1v slope to the southeast of the SWR will remain stable under long-term static and design seismic conditions.

Analysis of the New Slope

FSAR Section 2.5.5.2.4 analyzes the static and dynamic stability of the new 11.9 m (39 ft) high 3h:1v slope (Slope D-D) to the east of the FWSC, using the same methods as the existing slope analysis.

Long-Term Static Analysis

FSAR Figure 2.5.5-211 presents the input into the SLOPE/W program used in the analysis and the results. For long-term static stability, the applicant concluded that the calculated FS of 2.27 was well above the minimum FS of 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 for the new 11.9 m (39 ft) high slope that incorporated an average PGA of 0.25g with a vertical acceleration of about 0.125g, the applicant determined the FS for the LF earthquake of 1.24. The applicant used an average peak horizontal acceleration of about 0.41g with a vertical acceleration of about 0.205g for the HF earthquake resulting in a FS of 1.00, less than the required minimum of 1.1. The applicant also used Seed's (1979) reduced peak acceleration and determined the FS for LF and HF earthquakes of 1.64 and 1.43, respectively. Finally, the applicant utilized the reduced peak acceleration of Kramer (1996) and determined an FS of 1.59 for the LF earthquake and 1.34 for the HF earthquake. Based on the stability analysis results and the considerations used for the existing slope, the applicant concluded that the new 3h:1v slope to the east 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 summarizes the boring logs, CPT logs, observation wells, and laboratory test results for two borings, two CPTs, and one groundwater observation well in the area of the existing and new slopes. The applicant stated that borehole B-18 was 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-915 and 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 size 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 and the new 3h:1v slope are cut slopes and do not contain fill materials in any significant quantity.

2.5.5.2.5 Applicant Conclusion

North Anna 3 FSAR Section 2.5.5.5 describes the applicant's conclusions regarding stability of the slopes at the North Anna 3 site. The applicant concluded that the existing slopes and embankments and the new slopes, such as storm water management Pond No. 1 or the temporary slopes and excavations, do not affect the stability of plant structures at North Anna 3, and therefore do not require slope stability analysis. However, the applicant noted that the only existing slope whose failure could adversely affect the safety of North Anna 3 is the 2.4h:1v slope that descends from the north of the SWR down to the southeast of the excavation made for abandoned Units 3 and 4. The applicant indicated the only analysis that gave a FS lower than the required minimum was the pseudo-static analysis, which was overly conservative. The applicant concluded that the 2.4h:1v slope would remain stable under long-term static and design seismic conditions. Based on the results of the stability analyses for the new 3h:1v slope, the applicant also concluded that the slope would remain stable under both 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:

- 10 CFR 50.55a, requires that SSCs shall be designed, fabricated, erected, constructed, tested, and inspected in accordance with the requirements of applicable codes and standards commensurate with the importance of the safety function to be performed.

- 10 CFR Part 50, Appendix A, GDC 1, requires that SSCs 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 SSCs important to safety be maintained by or under the control of the nuclear power unit licensee throughout the life of the unit.

- 10 CFR Part 50, Appendix A, GDC 2, 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.

- 10 CFR Part 50, Appendix A, GDC 44, "Cooling Water," requires that a system be provided with the safety function of transferring the combined heat load from SSCs important to safety to an UHS under normal operating and accidental conditions.

- 10 CFR Part 50, Appendix B, establishes quality assurance requirements for the design, construction, and operation of those SSCs 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.

- 10 CFR Part 50, Appendix S, applies to the design of nuclear power plant SSCs important to safety to withstand the effects of earthquakes.

- 10 CFR Part 100, provides the criteria which guide the evaluation of the suitability of proposed sites for nuclear power and testing reactors.

- 10 CFR 100.23, 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:

- 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 ground water, seepage, and high and low ground water conditions.

- 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.

- 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.

- 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, RG 1.28, RG 1.132, RG 1.138, RG 1.198, and 1.206.

2.5.5.4 Technical Evaluation

As documented in NUREG–1966, the staff reviewed and approved Section 2.5.5 of the ESBWR DCD Revision 10. The staff reviewed Section 2.5.5 of the North Anna 3 COL FSAR, Revision 8, and checked the referenced DCD to ensure that the combination of the information in the ESBWR DCD and the information in the COL FSAR represents the complete scope of information relating to this review topic[1].

The 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

The 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 relates to the stability of slopes. Because of the shallower slopes and a smaller applied seismic acceleration for the North Anna 3 site, as described in the FSAR based on updated information, which results in an increased FS against slope failure, the staff concludes that the use of North Anna 3 FSAR Section 2.5.5 in place of North Anna 3 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 slope instability on the seismic Category I structures at the North Anna 3 site. The staff reviewed this information as well as the characterizations of the phreatic surfaces for new and existing slopes. As discussed below, the staff found that the information provided by the applicant meets the minimum requirements for slope characterization in 10 CFR Part 100. The staff further determined that the subsurface investigations adhered to the criteria of RG 1.132.

Resolution of ESP COL Action Item 2.5-11

ESP COL Action Item 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 described the location of the new 3h:1v slope to the southeast of the FWSC. FSAR Figure 2.5.5-201 illustrates the plan view, while FSAR Figures 2.5.5-202 and 2.5.5-203 show cross-section of those slopes. 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 concludes that the failure of the slope would not affect the safety-related structures at the site. The staff also concludes that the applicant 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 resolved.

The staff also considered the results and interpretations of the borings, CPTs, and observation wells conducted at the site. During the review of FSAR Section 2.5.5.1.3, the staff noted that the applicant identified two different lithologies in the same CPT and borehole analyses. In RAI 02.05.05-1 dated June 17, 2008 (ADAMS Accession No. ML081690661), 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, clays, and silty sand saprolite. In the response to RAI 02.05.05-1 dated July 14, 2008 (ADAMS Accession No. ML082050558) the applicant 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 concurs 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 02.05.05-1 resolved and closed.

Based on the slope characterization provided and the response to the RAI, the staff concludes that the applicant's characterization of the slopes at the North Anna 3 site area is acceptable for meeting the relevant requirements of 10 CFR Parts 50 and 100.

2.5.5.4.2 Design Criteria and Analyses

FSAR Section 2.5.5.2 describes the design criteria and analyses performed for the North Anna 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 North Anna 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 (non-seismic) 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 02.05.05-2 dated June 17, 2008 (ADAMS Accession No. ML081690661), 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 July 14, 2008, 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. In the response to RAI 02.05.05-2 dated July 14, 2008 (ADAMS Accession No. ML082050558), the applicant also stated that a more accurate model will give a higher FS, 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 (Bishop, 1955) 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 was previously reviewed and approved in the North Anna ESP.

The staff considered the applicant's statement regarding the Bishop method. However, the reality is 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 for a specific slope. Accordingly, the staff conducted an independent confirmatory analysis for a selected slope using the information provided in the FSAR. The results from the confirmatory analysis show that there is little variation among the factors of safety for the slope stability—about 7 percent among all six methods used—but higher than the applicant's estimate (about 1 percent); and all FS values are greater than the minimum requirement under the given seismic loads (i.e., the slope will not fail under the given conditions); therefore, the applicant's conclusion regarding the stability of the slopes is acceptable. Accordingly, the staff considers RAI 02.05.05-2 resolved and closed.

The staff also reviewed the assumptions used for the seismic stability analysis of slopes in the North Anna 3 area. Some of the assumptions the applicant stated 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 02.05.05-3 dated June 17, 2008 (ADAMS Accession No. ML081690661), 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.

In the response to RAI 02.05.05-3 dated July 14, 2008 (ADAMS Accession No. ML082050558), the applicant stated that the possible maximum dynamic settlement of 41 mm (1.6 in.) calculated for this site, 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 for slope failure during a seismic event normally is not a slip failure, but instead 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 with maximum slope height of 13.7 m (45 ft). In addition, the applicant concluded that, based on the LF and HF seismic characteristics, the chance of any liquefaction occurring in the Zone IIA saprolitic soils is 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 basis earthquake at the North Anna 3 site.

The staff also conducted reliability analyses by assigning probability distributions (uncertainties) to each input parameter and examined how the uncertainties affect the reliability of the calculated FS. During the reliability analysis, the staff used different values of coefficients-of-variation, 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 FS can represent the actual site conditions, therefore, when determining FS using deterministic methods, soil parameters should be conservatively 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 for seismic loading input will increase the probability of FS greater than 1.0, or the confidence level from about 42 to 70 percent, although the mean values of FS remain the same at 1.128 as shown in SER Figure 2.5.5-2. 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 concludes that seismic loading has high uncertainty that has been considered when conducting site specific seismic hazard evaluation.

Based on the staff's independent confirmatory analysis, and the applicant's response to RAI 02.05.05-3, particularly the use of the pseudo-static methods to determine the seismic slope stability at the North Anna 3 site, the staff concurs with the applicant that the use of the pseudo-static method was appropriate for the North Anna 3 site. The staff also concurs with the applicant's assessment of the liquefaction potential and slope stability at the North Anna 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 02.05.05-3 resolved and closed.

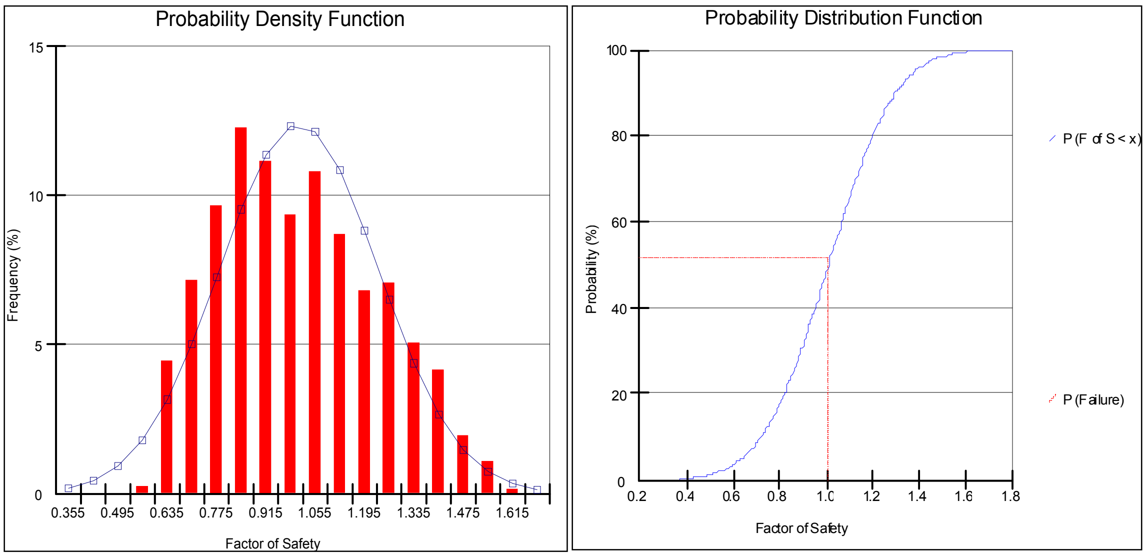


Figure 2.5.5-2. Probability Density and Distribution Functions of FS. Probabilistic Seismic Loading of a_h=0.25g and a_v = 0.125g with COV = 1.0

Resolution of NAPS COL 2.0-30-A and ESP COL Action Item 2.5-10

NAPS COL 2.0-30-A (ESBWR COL 2.0-30-A) requires the COL applicant to provide site-specific information in accordance with SRP 2.5.5 to evaluate stability of slopes at the site.

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.

North Anna 3 FSAR Section 2.5.5.2 describes the design criteria and analyses of slope stability performed for the North Anna 3 site. In addition to static slope stability analyses, 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 North Anna 3 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. Based on the analysis results, the applicant concluded that the new slope would also remain stable under long-term static and design seismic conditions. Because the applicant conducted static and dynamic stability analyses for both the new and existing slopes, and the results demonstrated that the slopes meet stability requirements under the design static and seismic loading conditions, the staff concludes that the applicant provided sufficient information to satisfy the requirements of NAPS COL 2.0-30-A and ESP COL Action Item 2.5-10. Accordingly, the staff considers NAPS COL 2.0-30-A and ESP COL Action Item 2.5-10 resolved.

Based on the information provided in the FSAR and the applicant's response to the RAIs listed above, the staff concludes that the applicant's assessments of the design criteria and analyses of the slopes at the North Anna 3 site area are acceptable and meet the criteria of 10 CFR Parts 50 and 100.

2.5.5.4.3 Boring Logs

The applicant provided boring logs, CPT logs, observation wells, and laboratory test results for two borings, two CPTs, and one groundwater observation wells in the existing and new slopes at the North Anna 3 site area, as well as laboratory test results related to the slope materials. The staff reviewed this information to confirm that that the applicant provided sufficient data and used appropriate material and engineering properties of slope materials in slope stability analysis, and concludes that the information provided satisfies the relevant 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 top of the new 3h:1v slope will contain re-compacted backfill derived from the saprolite on the site. The staff reviewed the applicant's intent to apply the properties of the saprolite to the compacted fill and concluded that this is an acceptable approach because the compacted fill will have better engineering properties than the in-situ saprolite.

2.5.5.4.5 Conclusion

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 noted that this section states that "[e]xisting slopes and embankments that are not impacted by North Anna 3 (such as the SWR embankments) do not require analysis for North Anna 3 and are not addressed here." However, although the SWR embankments were built for Units 1 and 2 and the construction of North Anna 3 will not impact those embankments, the reevaluation of the site seismic hazard for Unit 1 and 2 based on the lessons learned from the Fukushima event determined that the updated site-specific GMRS will exceed the original design basis. Because any breach of the SWR embankment might have an impact on the North Anna 3 site. In RAI 02.05.05-4 dated April 8, 2014 (ADAMS Accession No. ML14098A297), the staff asked for an evaluation of the impact of possible failure of the SWR embankment on the stability of slopes at the North Anna 3 site.

In the response to RAI 02.05.05-4 dated May 9, 2014 (ADAMS Accession No. ML14140A087), the applicant stated that there will be no impact from a possible failure of the SWR embankment on the stability of slopes at the North Anna 3 site because: 1) at the western end of the SWR and the western portion of the northern end of the SWR, a failure of the inside slope would not result in a release of water; 2) an embankment breach of the east portion of the SWR may result in a release of water but it would flow down gradient to the east and away from North Anna 3. The staff reviewed the RAI response and conducted a site audit (ADAMS Accession No. ML14203A179) to confirm the geographic characteristics of the North Anna 3 site, the SWR and Units 1 and 2. The staff also noted that the design plant grade elevation of North Anna 3 is 88.3 m (290 ft) while for Units 1 and 2, this elevation is 82.6 m (271 ft), or about 6.3 m (19 ft) below the North Anna 3; therefore water will flow to Units 1 and 2 site if the SWR embankment fails. Based on the above, the staff concludes that there will be no impact from a possible failure of the SWR embankment on the stability of slopes at the North Anna 3 site, and accordingly, the staff considers RAI 02.05.05-4 resolved and closed.

The staff considered applicant’s conclusions and additional information regarding the stability of SWR embankment, along with the criteria and requirements of 10 CFR Parts 50 and 100. The staff concluded that the information provided in FSAR Section 2.5.5 is sufficient and acceptable for meeting relevant requirements of the ESBWR DCD and 10 CFR Parts 50 and 100.

2.5.5.5 Post Combined License Activities

There are no post COL activities related to this section.

2.5.5.6 Conclusion

The staff reviewed the application with related RAI responses, and checked the referenced ESBWR DCD and North Anna ESP SSAR. The staff’s review confirmed that the applicant addressed the relevant information and there is no outstanding information expected to be addressed in the COL FSAR related to this section.

As set forth above, the applicant presented and substantiated information to establish the stability of all earth and rock slopes - natural or 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 both static and dynamic (seismic) loading 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 and results 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 NAPS COL Item 2.0-30-A. In conclusion, the applicant provided sufficient information for resolving NAPS COL Item 2.0-30-A, 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 concludes that the North Anna 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 existing unit. 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 2.5.6, the applicant added that no embankments and dams were analyzed because Lake Anna is only used as a source of makeup water for North Anna 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 be used only as a source of makeup water for North Anna 3. 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, "Processing Applications for Early Site Permits," provide similar information and guidance.

2.5.6.4 Technical Evaluation

As documented in NUREG–1966, the staff reviewed and approved Section 2.5.6 of the ESBWR DCD, Revision 10. The staff reviewed Section 2.5.6 of the North Anna 3 COL FSAR, Revision 8, and checked the referenced DCD to ensure that the combination of the information in the ESBWR DCD and the information in the COL FSAR represents the complete scope of information relating to this review topic[1].

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 Conclusion

Section 2.4.4 and 2.5.5 of this SER present the staff's conclusions regarding dam failures and slope stability, respectively.

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