2.0 SITE CHARACTERISTICS

Chapter 2, "Site Characteristics," of the Final Safety Analysis Report (FSAR) addresses the geological, seismological, hydrological, and meteorological characteristics of the site and vicinity, in conjunction with present and projected population distribution and land use, and site activities and controls.

2.0.1 Introduction

The site characteristics are reviewed by the U.S. Nuclear Regulatory Commission (NRC) 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. The review is focused on the site characteristics and site-related design characteristics needed to enable the NRC staff to reach a conclusion on all safety matters related to siting of V.C. Summer Nuclear Station (VCSNS) Units 2 and 3. Because this combined license (COL) application references a design certification (DC), this section focuses on the applicant's demonstration that the characteristics of the site fall within the site parameters specified in the DC rule or, if outside the site parameters, that the design satisfies the requirements imposed by the specific site characteristics and conforms to the design commitments and acceptance criteria described in the AP1000 Design Control Document (DCD).

2.0.2 Summary of Application

Section 2.0 of the VCSNS COL FSAR, Revision 5, incorporates by reference Chapter 2 of the AP1000 DCD, Revision 19. AP1000 DCD Chapter 2 includes Section 2. The advanced safety evaluation (ASE) with confirmatory items for Section 2.0 was based on the VCSNS COL FSAR, Revision 2 and DCD, Revision 17. After submitting DCD Revision 17 to the NRC, Westinghouse revised the AP1000 Tier 1 Table 5.0-1 and Tier 2 Table 2-1 (which revised the VCSNS COL FSAR Table 2.0-201). The revised AP1000 tables have been incorporated into Revision 18 of the DCD; however, the discussion of the COL information Item below did not change.

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

Tier 1 and 2 Departures

- VCS Departure (DEP) 2.0-1

The applicant proposed numbering Sections 2.0, 2.1, 2.2, 2.4 and 2.5 of this chapter based on Regulatory Guide (RG) 1.206, "Combined License Applications for Nuclear Power Plants (LWR Edition)," down to the X.Y.Z level, rather than following the AP1000 DCD numbering and organization. In addition, VCSNS Part 7 requests an exemption from the numbering scheme in the AP1000 DCD. The applicant also requested other portions of the FSAR be renumbered in STD DEP 1.1-1. The evaluation of STD DEP 1.1-1 can be found in Section 1.5.4 of this report.

- VCS DEP 2.0-2

The applicant proposed a departure from the maximum safety wet-bulb (noncoincident) air temperature in both Tier 1 and Tier 2 material of the AP1000 DCD. In addition, VCSNS Part 7 requests an exemption from this site parameter value.

Supplemental Information

- VCS Supplemental (SUP) 2.0-1

The applicant provided supplemental information in VCSNS COL FSAR Section 2.0, "Site Characteristics," which describes the characteristics and site-related design parameters of VCSNS.

- VCS SUP 2.0-2

The applicant provided VCSNS COL FSAR Table 2.0-201, which provides a comparison of the AP1000 DCD Site Parameters and VCSNS site parameters. In a letter dated July 2, 2010, the applicant provided a proposed revision to the VCSNS COL FSAR Table 2.0-201 to reflect the proposed changes to the AP1000 Tier 1 Table 5.0-1 and Tier 2 Table 2-1.

2.0.3 Regulatory Basis

The regulatory basis of the information incorporated by reference is addressed in NUREG-1793, "Final Safety Evaluation Report Related to Certification of the AP1000 Standard Design," and its supplements.

In addition, 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, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition."

The applicable regulatory requirements for site characteristics are as follows:

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

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

- 10 CFR Part 100, "Reactor site criteria," as it relates to the siting factors and criteria for determining an acceptable site.

The related acceptance criteria from Section 2.0 of NUREG-0800 are as follows:

- The acceptance criteria associated with specific site characteristics/parameters and site-related design characteristics/parameters are addressed in the related Chapter 2 or other referenced sections of NUREG-0800.

- Acceptance is based on the applicant's demonstration that the characteristics of the site fall within the site parameters of the certified design. If the actual site characteristics do not fall within the certified standard design site parameters, the COL applicant provides sufficient justification (e.g., by request for exemption or amendment from the DC) that the proposed facility is acceptable at the proposed site.

The regulatory requirements associated with the Tier 1 and 2 departures and the exemption request are as follows:

- 10 CFR Part 52, Appendix D, "Design Certification Rule for the AP1000 Design," Section VIII, "Processes for Changes and Departures," Item B.5.

- 10 CFR Part 52, Appendix D, "Design Certification Rule for the AP1000 Design," Section IV.A.2.d.

  > An applicant for a combined license that wishes to reference this appendix shall…comply with the following requirements: Include, as part of its application…Information demonstrating compliance with the site parameters and interface requirements.

- 10 CFR Part 52, Appendix D, Section VIII.A.4. This section states that exemptions from Tier 1 material are governed by 10 CFR 52.63(b)(1). 10 CFR 52.63(b)(1) references 10 CFR 52.7.

- 10 CFR 52.7 – "Specific Exemptions." This section states that the Commission may grant exemptions from the requirements of the regulations of this part as governed by 10 CFR 50.12 of this chapter.

- 10 CFR 50.12(a) – Specific Exemptions

  > (a) The Commission may, upon application by any interested person or upon its own initiative, grant exemptions from the requirements of the regulations of this part, which are authorized by law, will not present an undue risk to the public health and safety, and are consistent with the common defense and security. The Commission will not consider granting an exemption unless special circumstances are present.

- 10 CFR 52.93(a) –Exemptions and variances

  > (a) Applicants for a combined license under this subpart, or any amendment to a combined license, may include in the application a request for an exemption from one or more of the Commission's regulations.

2.0.4 Technical Evaluation

The NRC staff reviewed Section 2.0 of the VCSNS COL FSAR and checked the referenced DCD to ensure that the combination of the DCD and the COL application represents the complete scope of information relating to this review topic.[1] The NRC staff's review confirmed that the information in the application and incorporated by reference addresses the required information relating to site characteristics. The results of the NRC staff's evaluation of the information incorporated by reference in the VCSNS COL application are documented in NUREG-1793 and its supplements.

The staff reviewed the information in the VCSNS COL FSAR:

Tier 1 and 2 Departures and Exemptions

- VCS DEP 2.0-1

The applicant's evaluation, in accordance with 10 CFR Part 52, Appendix D, Section VIII, Item B.5, determined that this departure did not require prior NRC approval. The numbering of VCSNS COL FSAR Chapter 2 is based on RG 1.206, down to the X.Y.Z level rather than following the AP1000 DCD organization for Chapter 2. The staff finds the FSAR Chapter 2 numbering system proposed by the applicant to be acceptable because it provides for a logical presentation and review of the information in accordance with the guidance in RG 1.206.

The applicant renumbered the FSAR Sections 2.0, 2.1, 2.2, 2.4 and 2.5 to include content consistent with RG 1.206, and NUREG-0800. The applicant identified the affected FSAR sections in Part 7 of the COL application. The departure and the exemption associated with the numbering scheme of the FSAR are closely related. The departure provided in Part 7 of the COL application provides the specific sections of the VCSNS COL FSAR that deviate from the DCD numbering scheme.

Pursuant to 10 CFR 52.7, "Specific Exemptions," and 10 CFR 52.93, "Exemptions and Variances," the applicant requested an exemption from 10 CFR Part 52, Appendix D, Section IV.A.2.a, to include "a plant-specific DCD containing the same type of information and using the same organization and numbering as the generic DCD for the AP1000 design…." In Part 7, "Departures and Exemptions," of the VCSNS COL application, the applicant states that the exemption will not result in any significant departures from the expected organization and numbering of a typical FSAR, and the information is readily identifiable to facilitate NRC review. The applicant states that the subject deviations are considered to be purely administrative to support a logical construction of the document. Further, the revised organization and numbering generally follows the guidance provided in RG 1.206, and NUREG-0800.

Pursuant to 10 CFR 52.7, "Specific Exemptions," the Commission may, upon application by any interested person or upon its own initiative, grant exemptions from the requirements of 10 CFR Part 52. 10 CFR 52.7 further states that the Commission's consideration will be governed by 10 CFR 50.12, which states that an exemption may be granted when: (1) the exemptions are authorized by law, will not present an undue risk to public health or safety, and are consistent with the common defense and security; and (2) special circumstances are present. Special circumstances are present whenever, according to 10 CFR 50.12(a)(2)(ii), "Application of the regulation in the particular circumstances would not serve the underlying purpose of the rule or is not necessary to achieve the underlying purpose of the rule."

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[1] See Section 1.2.2 for a discussion of the staff's review related to verification of the scope of information to be included in a COL application that references a DC.

Before considering whether this numbering exemption should be granted, the staff needed to address a threshold question regarding the review standard applicable to the request. Under 10 CFR 52.93(a)(1), if a request for an exemption is from any part of a design certification rule, then the Commission may grant the exemption if the exemption complies with the appropriate change provision in the referenced design certification rule, or if there is no applicable change provision, if the exemption complies with 10 CFR 52.63, “Finality of standard design certifications.” Here, there is no applicable change provision in the referenced design certification rule, so according to section 52.93(a)(1), the exemption must meet 10 CFR 52.63. However, the standards of the appropriate provision of 10 CFR 52.63 applicable to requests for exemptions from a design certification rule in section 52.63(b)(1), by their terms, also do not apply to this change. Specifically, section 52.63(b)(1) applies to changes to “certification information,” and not administrative or procedural design certification rule provisions such as this one under consideration. In the Statements of Consideration for 10 CFR 52.63, the Commission stated that it used the “phrase ‘certification information’ in order to distinguish the rule language in the DCRs from the design certification information (e.g., Tier 1 and Tier 2) that is incorporated by reference in the DCRs.” 72 Fed. Reg. 49,444. The exemption requested from the AP1000 DCD numbering scheme is an exemption from rule language, not Tier 1 or Tier 2 information; therefore, 10 CFR 52.63 should not be used to analyze this exemption.

Because there is not an applicable change provision in the referenced design certification, and because 10 CFR 52.63(b)(1) does not apply to this exemption, the exemption cannot comply with the plain language of 10 CFR 52.93(a)(1). In this situation, the language of 10 CFR 52.93(a)(1) does not appear to serve the underlying purpose of the regulation as described by the Commission in the Statements of Consideration to the rule, in which the Commission stated that only changes to certification information must meet 10 CFR 52.63. Instead, this exemption should have fallen under 10 CFR 52.93(a)(2), and, thus, be analyzed under the requirements in 10 CFR 52.7. Therefore, the staff finds that, pursuant to 10 CFR 52.7, an exemption to section 52.93(a)(1) should be granted. This exemption is warranted because it meets the requirements in 10 CFR 50.12. First, because this is an administrative change regarding what exemption regulation applies, the exemption to 10 CFR 52.93(a)(1) is authorized by law, will not present an undue risk to public health or safety, and is consistent with the common defense and security. Additionally, application of the regulation in this case is not necessary to achieve the underlying purpose of the rule. The underlying purpose of the rule is to maintain the safety benefits of standardization by requiring any exemption from certification information to meet the requirements in 10 CFR 52.63(b)(1). This underlying purpose does not apply to this exemption, because the form and organization of the application does not affect the safety benefits of standardization of the certification information. Therefore, for the purpose of determining the standards applicable to the exemption related to VCS DEP 2.0-1, the staff finds an exemption to section 52.93(a)(1) to be acceptable for the review of the exemption related to VCS DEP 2.0-1.

Pursuant to the exemption described above, the NRC staff has reviewed the exemption related to VCS DEP 2.0-1 to determine whether it meets the requirements in 10 CFR 52.7. This exemption would allow the applicant to provide an FSAR with numbering and topics more closely related to NUREG-0800 and RG 1.206. The staff finds that this administrative change of minor renumbering will not present an undue risk to the public health and safety and is consistent with the common defense and security. In addition, this exemption is consistent with the Atomic Energy Act and is, therefore, authorized by law. Further, the application of the regulation in these particular circumstances is not necessary to achieve the underlying purpose of the rule. Therefore, the staff finds that the exemption to 10 CFR Part 52, Appendix D, Section IV.A.2.a is justified. Finally for the same reasons the staff is granting the exemption request, the staff also finds the departure from the numbering scheme in the VCSNS COL FSAR to be acceptable.

- VCS DEP 2.0-2

The NRC staff reviewed VCS DEP 2.0-2 in VCSNS COL FSAR Section 2.0, “Site Characteristics,” describing the maximum safety wet-bulb (noncoincident) air temperature. The maximum safety wet-bulb (noncoincident) air temperature in AP1000 DCD Tier 1, Table 5.0-1 and DCD Tier 2, Table 2-1 is compared to the site-specific maximum safety wet-bulb (noncoincident) air temperature in VCSNS COL FSAR Table 2.0-201.

Pursuant to 10 CFR Part 52, Appendix D, Section VIII.A.4 and 10 CFR 52.93, the applicant requested an exemption from 10 CFR Part 52, Appendix D, Section IV.A.2.d, to include “information demonstrating compliance with the site parameters and interface requirements,” related to the maximum safety wet-bulb (noncoincident) air temperature. In Part 7, “Departures and Exemptions,” of the VCSNS COL application, the applicant states that the exemption was evaluated in accordance with Section VIII.A.4 of the design certification rule which requires that: 1) the change will not result in a significant decrease in the level of safety otherwise provided by the design; 2) the exemption is authorized by law, will not present an undue risk to the public health and safety, and is consistent with the common defense and security; 3) special circumstances are present as specified in 10 CFR 50.12(a)(2); and 4) the special circumstances outweigh any decrease in safety that may result from the reduction in standardization caused by the exemption. The applicant's bases for satisfying each of these four criteria are shown below:

1. As described above [in Section B.3 of Part 7 of the COL application], the exemption does not have an adverse impact on the AP1000 Standard Plant design and therefore will not result in a significant decrease in the level of safety otherwise provided by the design.

2. The exemption is not inconsistent with the Atomic Energy Act or any other statute and therefore is authorized by law. As discussed above, the exemption does not have an adverse impact on the AP1000 Standard Plant design and therefore will not present an undue risk to the public health and safety. The exemption does not relate to security and does not otherwise pertain to the common defense and security.

3. Special circumstances are present as specified in 10 CFR 50.12(a)(2). Specifically, application of 10 CFR Part 52, Appendix D, Section IV.A.2.d and the site parameters in Tier 1 of the DCD are not necessary to achieve the underlying purpose of the rules. The analysis described above shows that the increase in the maximum safety temperature does not affect the AP1000 Standard Plant design. Consequently, granting relief from the maximum safety air temperature in the DCD would maintain the level of safety in the design, which is the underlying purpose of the rule.

4. The special circumstances outweigh any decrease in safety that may result from the reduction in standardization (due to the increase in the maximum safety temperature) caused by the exemption. Specifically, the exemption does not change the AP1000 Standard Plant design and does not affect the configuration of the plant or the manner in which the plant is operated.

The staff's evaluation of the appropriateness of the 87.3 °Fahrenheit (F) value for the VCSNS site is in Section 2.3 of this SER. The staff's evaluation of the effects that this higher temperature has on the operation of the AP1000 design is addressed in Sections 2.3.1, 5.4, 6.2, 6.4, 9.1.3, 9.2.2 and 9.2.7 of this SER.

Based on these evaluations, the staff has determined that the proposed increase in maximum safety wet-bulb (noncoincident) air temperature will not result in a significant decrease in the level of safety otherwise provided by the design as required by 10 CFR Part 52, Appendix D, Section VIII.A.4 and will not present an undue risk to the public health and safety as required by 10 CFR 50.12(a). Granting this exemption will not adversely affect the common defense and security. Further, the application of the regulation in these particular circumstances is not necessary to achieve the underlying purpose of the rule as required by 10 CFR 50.12(a)(2) and the special circumstances outweigh any decrease in safety that may result from the reduction in standardization (due to the increase in the maximum safety wet-bulb (noncoincident) air temperature) caused by the exemption as required by 10 CFR Part 52, Appendix D, Section VIII.A.4. Specifically, the exemption does not change the AP1000 standard plant design and does not affect the configuration of the plant or the manner in which the plant is operated.

Therefore, the staff finds that the exemption to 10 CFR Part 52, Appendix D, Section IV.A.2.b is justified and meets the requirements of 10 CFR Part 52, Appendix D, Section VIII.A.4.

Supplemental Information

- VCS SUP 2.0-1 and VCS SUP 2.0-2

The NRC staff reviewed supplemental information VCS SUP 2.0-1 and VCS SUP 2.0-2 in VCSNS COL FSAR Section 2.0 describing the characteristics and site-related design parameters of VCSNS Units 2 and 3. The AP1000 DCD site parameters in DCD Table 2-1 are compared to the site-specific site characteristics in VCSNS COL FSAR Table 2.0-201. In addition, control room atmospheric dispersion factors for accident dose analysis are presented in VCSNS COL FSAR Table 2.0-201.

The NRC staff reviewed and compared the site-specific characteristics included in VCSNS COL FSAR Tables 2.0-201 against AP1000 DCD Table 2-1. The staff's evaluation of the site characteristics associated with air temperature, precipitation, wind speed, atmospheric dispersion values, and control room atmospheric dispersion values is addressed in Section 2.3 of this SER. The staff's evaluation of site characteristics associated with flood level, ground water level, and plant grade elevation is addressed in Section 2.4 of this SER. The staff's evaluation of seismic and soil site characteristics is addressed in Section 2.5 of this SER. The staff's evaluation of site characteristics associated with missiles is addressed in Section 3.5 of this SER.

With the exception of the maximum safety wet-bulb (noncoincident) air temperature value, the site-specific parameters listed in VCSNS COL FSAR Table 2.0-201 are enveloped by the AP1000 DCD values addressed in DCD Table 2-1. In Revision 2 of the application, the applicant requested an exemption to this parameter. The staff's evaluation of this exemption request is addressed above. The updating of the VCSNS COL FSAR to include the changes to FSAR Table 2.0-201 discussed in the applicant's letter dated July 2, 2010, is **Confirmatory Item 2.0-1**.

Resolution of Confirmatory Item 2.0-1

Confirmatory Item 2.0-1 is an applicant commitment to update its FSAR to include the changes to FSAR Table 2.0-201 discussed in the applicant's letter dated July 2, 2010. The staff verified that the VCSNS COL FSAR was appropriately updated. As a result, Confirmatory Item 2.0-1 is now closed.

2.0.5 Post Combined License Activities

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

2.0.6 Conclusion

The NRC staff reviewed the application and checked the referenced DCD. The NRC staff's review confirmed that the applicant addressed the required information relating to site characteristics, and there is no outstanding information expected to be addressed in the VCSNS COL FSAR related to this section. The results of the NRC staff's technical evaluation of the information incorporated by reference in the VCSNS COL application are documented in NUREG-1793 and its supplements.

As set forth above, the NRC staff reviewed the application to ensure that sufficient information was presented in VCS SUP 2.0-1, VCS SUP 2.0-2, and VCS DEP 2.0-2 to demonstrate that the characteristics of the site fall within the site parameters specified in the DC and adequate justification has been provided for the maximum safety wet-bulb (noncoincident) air temperature value falling outside the DC site parameter. The staff concludes that the applicant has demonstrated that the requirements of 10 CFR 52.79(d)(1) have been met. The staff also concludes that VCS DEP 2.0-2 meets the requirements for departures in 10 CFR Part 52, Appendix D and is, therefore, acceptable.

Regarding VCS DEP 2.0-1, the staff concludes that the exemption meets the requirements in 10 CFR Part 52, Appendix D and 10 CFR 50.12 and is, therefore, acceptable.

2.1 <u>Geography and Demography</u>

2.1.1 Site Location and Description

2.1.1.1 *Introduction*

The descriptions of the site area and reactor location are used to assess the acceptability of the reactor site. The review covers the following specific areas: (1) specification of reactor location with respect to latitude and longitude, political subdivisions; and prominent natural and manmade features of the area; (2) site area map to determine the distance from the reactor to the boundary lines of the exclusion area, including consideration of the location, distance, and orientation of plant structures with respect to highways, railroads, and waterways that traverse or lie adjacent to the exclusion area; and (3) any additional information requirements prescribed in 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.

2.1.1.2 *Summary of Application*

Section 2.1 of the VCSNS COL FSAR, Revision 5, incorporates by reference Section 2.1 of the AP1000 DCD, Revision 19.

In addition, in VCSNS COL FSAR Section 2.1, the applicant provided the following:

Tier 2 Departure

- VCS DEP 2.0-1

Evaluation of this departure is in Section 2.0 of this SER.

AP1000 COL Information Item

- VCS COL 2.1-1

The applicant provided additional information in VCS COL 2.1-1 to resolve COL Information Item 2.1-1 (COL Action Item 2.1.1-1), which addresses the provision of site-specific information related to site location and description, including political subdivisions, natural and man-made features, population, highways, railways, waterways, and other significant features of the area.

2.1.1.3 *Regulatory Basis*

The regulatory basis of the information incorporated by reference is addressed in NUREG-1793 and its supplements.

In addition, the acceptance criteria associated with the relevant requirements of the Commission regulations for the site location and description are given in Section 2.1.1 of NUREG-0800.

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

- 10 CFR 50.34(a)(1) and 10 CFR 52.79(a)(1),as they relate to the 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 Part 100, as it relates to the following: (1) defining an exclusion area and setting forth requirements regarding activities in that area (10 CFR 100.3); (2) addressing and evaluating factors that are used in determining the acceptability of the site as identified in 10 CFR 100.20(b); (3) determining an exclusion area such that 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, would ensure a low risk of public exposure.

The related acceptance criteria from Section 2.1.1 of NUREG-0800 are as follows:

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

2.1.1.4 *Technical Evaluation*

The NRC staff reviewed Section 2.1 of the VCSNS COL FSAR and checked the referenced DCD to ensure that the combination of the DCD and the COL application represents the complete scope of information relating to this review topic.[1] The NRC staff's review confirmed that the information in the application and incorporated by reference addresses the required information relating to the site location and description. The results of the NRC staff's evaluation of the information incorporated by reference in the VCSNS COL application are documented in NUREG-1793 and its supplements.

The staff reviewed the information in the VCSNS COL FSAR:

AP 1000 COL Information Item

- VCS COL 2.1-1

The NRC staff reviewed VCS COL 2.1-1 related to site location and description, including political subdivisions, natural and man-made features, population, highways, railways, waterways, and other significant features of the area included in Section 2.1.1 of the VCSNS COL FSAR. COL Information Item 2.1-1 in Section 2.1.1 of the AP1000 DCD states:

> Combined License applicants referencing the AP1000 certified design will provide site-specific information related to site location and description, exclusion area authority and control, and population distribution. Site-specific information on the site and its location will include political subdivisions, natural and man-made features, population, highways, railways, waterways, and other significant features of the area.

The NRC staff, using maps publically available, has independently estimated and used this estimate to verify the applicant supplied latitude and longitude. The NRC staff then converted this latitude and longitude to universal transverse Mercator (UTM) coordinates for the proposed VCSNS Units 2 and 3 and used the calculated values to verify the UTM coordinates provided in the FSAR.

The NRC staff reviewed the site area map provided in the FSAR for the proposed Units 2 and 3 to verify that the distance from the reactor to the boundary line of the exclusion area meets the guidance in NUREG-0800 Section 2.1.1. On the basis of the NRC staff's review of the information in the VCSNS COL FSAR, and also the NRC staff's confirmatory review of the political subdivisions, and prominent natural and manmade features of the area as described in publically available documentation, the NRC staff determined the information provided by the applicant with regard to the site location and description is considered adequate and acceptable.

2.1.1.5 *Post Combined License Activities*

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

2.1.1.6 *Conclusion*

The NRC staff reviewed the application and checked the referenced DCD. The NRC staff's review confirmed that the applicant addressed the required information relating to site location and description, and there is no outstanding information expected to be addressed in the VCSNS COL FSAR related to this section. The results of the NRC staff's technical evaluation of the information incorporated by reference in the VCSNS COL application are documented in NUREG-1793 and its supplements.

As set forth above, the applicant has presented and substantiated information to establish the site location and description. The staff has reviewed VCS COL 2.1-1, and for the reasons given above, concludes that it is sufficient for the staff to evaluate compliance with the siting evaluation factors in 10 CFR Part 100.3, as well as with the radiological consequence evaluation factors in 10 CFR 52.79(a)(1). The staff further concludes that the applicant provided sufficient details about the site location and site description to allow the staff to evaluate, as documented in Sections 2.1.2, 2.1.3, and 13.3 and Chapters 11 and 15 of this SER, whether the applicant has met the relevant requirements of 10 CFR 52.79(a)(1) and 10 CFR Part 100 with respect to determining the acceptability of the site.

2.1.2 Exclusion Area Authority and Control

2.1.2.1 *Introduction*

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

2.1.2.2 *Summary of Application*

Section 2.1 of the VCSNS COL FSAR, Revision 5, incorporates by reference Section 2.1 of the AP1000 DCD, Revision 19.

In addition, in VCSNS COL FSAR Section 2.1.2, the applicant provided the following:

<u>AP1000 COL Information Item</u>

- VCS COL 2.1-1

The applicant provided additional information in VCS COL 2.1-1 to resolve COL Information Item 2.1-1 (COL Action Item 2.1.2-1), which addresses the provision of site-specific information related to exclusion area authority and control, including size of the area, exclusion area authority and control, and activities that may be permitted within the designated exclusion area.

2.1.2.3 *Regulatory Basis*

The regulatory basis of the information incorporated by reference is addressed in NUREG-1793 and its supplements.

In addition, the acceptance criteria associated with the relevant requirements of the Commission regulations for the exclusion area authority and control are given in Section 2.1.2 of NUREG-0800.

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

- 10 CFR 50.34(a)(1), and 10 CFR 52.79(a)(1), as it relates to the inclusion in the SAR of a detailed description and safety assessment of the site on which the facility is to be located, with appropriate attention to features affecting facility design (10 CFR 50.34(a)(1), 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); (2) addressing and evaluating factors that are used in determining the acceptability of the site as identified in 10 CFR 100.20(b); and (3) determining an exclusion area such that 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.

The related acceptance criteria from Section 2.1.2 of NUREG-0800 are as follows:

- Establishment of Authority for the 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.

2.1.2.4 *Technical Evaluation*

The NRC staff reviewed Section 2.1.2 of the VCSNS COL FSAR and checked the referenced DCD to ensure that the combination of the DCD and the COL application represents the complete scope of information relating to this review topic.[1] The NRC staff's review confirmed that the information in the application and incorporated by reference addresses the required information relating to the exclusion area authority and control. The results of the NRC staff's evaluation of the information incorporated by reference in the VCSNS COL application are documented in NUREG-1793 and its supplements.

The staff reviewed the information in the VCSNS COL FSAR:

<u>*AP1000 COL Information Item*</u>

- VCS COL 2.1-1

The NRC staff reviewed VCS COL 2.1-1 related to the exclusion area authority and control, including size of the area, exclusion area authority and control, and activities that may be permitted within the designated exclusion area included in Section 2.1.2 of the VCSNS COL FSAR. COL Information Item in Section 2.1.1 of the AP1000 DCD states:

> Combined License applicants referencing the AP1000 certified design will provide site-specific information related to site location and description, exclusion area authority and control, and population distribution. Site-specific information on the exclusion area will include the size of the area and the exclusion area authority and control. Activity that may be permitted within the exclusion area will be included in the discussion.

The applicant supplied the following information: There are no residences, unauthorized commercial activities, or recreational activities within the Unit 2 and 3 exclusion area. No public highways or active railroads not owned and controlled by the applicant traverse the exclusion area. There are no residents in the exclusion area. No unrestricted areas within the site boundary area are accessible to members of the public. The acceptance criteria for NUREG-0800, Section 2.1.2 states that, "Absolute ownership of all lands, including mineral rights, is considered to carry with it the required authority to determine all activities on this land and is acceptable." The NRC staff verified ownership of the lands within the site boundary, including mineral rights, and thus concur that the applicant has authority to determine all activities on this land.

The NRC staff verified that the applicant owns all the land in the exclusion area including mineral rights. The NRC staff also verified for consistency that the exclusion area boundary (EAB) is the same as being considered for the radiological consequences in Chapter 15 and Section 13.3 of the FSAR by the applicant. The acceptance criteria of NUREG-0800, Section 2.1.2 states "Absolute ownership of all lands within the exclusion area, including mineral rights, is considered to carry with it the required authority to determine all activities on this land and is acceptable. Thus the staff concludes that the applicant has the required authority to control all activities within the designated exclusion area.

The NRC staff used publically available maps and satellite pictures, a site visit, and the area map provided in the Unit 2 and 3 FSAR to verify that no publicly used transportation mode crosses the EAB; therefore, arrangements for the control of traffic in the event of an emergency are not required.

The NRC staff, using maps, satellite pictures and the area map provided in the Unit 2 and 3 FSAR verified that no public roads cross the exclusion area; therefore, neither relocation nor abandonment of roads is needed.

2.1.2.5 *Post Combined License Activities*

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

2.1.2.6 *Conclusion*

The NRC staff reviewed the application and checked the referenced DCD. The NRC staff's review confirmed that the applicant addressed the required information relating to the exclusion area authority and control, and there is no outstanding information expected to be addressed in the VCSNS COL FSAR related to this section. The results of the NRC staff's technical evaluation of the information incorporated by reference in the VCSNS COL application are documented in NUREG-1793 and its supplements.

As set forth above, the applicant has provided and substantiated information concerning its legal authority and control of all activities within the designated exclusion area. The staff has reviewed VCS COL 2.1-1, and for the reasons given above, concludes that the applicant's exclusion area is acceptable to meet the requirements of 10 CFR 50.34(a)(1), 10 CFR 52.79(a)(1), 10 CFR Part 100, and 10 CFR 100.3 with respect to determining the acceptability of the site. This conclusion is based on the applicant having appropriately described the plant exclusion area, the authority under which all activities within the exclusion area can be controlled, the methods by which the relocation or abandonment of public roads that lie within the proposed exclusion area can be accomplished, if necessary, and the methods by which access and occupancy of the exclusion area can be controlled during normal operation and in the event of an emergency situation. In addition, the applicant has the required authority to control activities within the designated exclusion area, including the exclusion and removal of persons and property, and has established acceptable methods for control of the designated exclusion area.

2.1.3 Population Distribution

2.1.3.1 *Introduction*

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

2.1.3.2 *Summary of Application*

Section 2.1 of the VCSNS COL FSAR, Revision 5, incorporates by reference Section 2.1 of the AP1000 DCD, Revision 19.

In addition, in VCSNS COL FSAR Section 2.1.3, the applicant provided the following:

AP1000 COL Information Item

- VCS COL 2.1-1

The applicant provided additional information in VCS COL 2.1-1 to resolve COL Information Item 2.1-1 (COL Action Item 2.1.3-1), which addresses the provision of site-specific information related to population distribution for the site environs.

2.1.3.3 *Regulatory Basis*

The regulatory basis of the information incorporated by reference is addressed in NUREG-1793 and its supplements.

In addition, the acceptance criteria associated with the relevant requirements of the Commission regulations for population distribution are given in Section 2.1.3 of NUREG-0800.

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

- 10 CFR 50.34(a)(1), as it relates to consideration of the site evaluation factors identified in 10 CFR 100.3, 10 CFR Part 100 (including consideration of population density), 10 CFR 52.79, as they relate to provision by the applicant in the SAR of the existing and projected future population profile of the area surrounding the site.

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

The related acceptance criteria from Section 2.1.3 of NUREG-0800 are as follows:

- Population Data: The population data supplied by the applicant in the SAR is acceptable under the following conditions: (1) the FSAR includes 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),” Revision 3, and in accordance with Draft Regulatory Guide DG-1145, “Combined License Applications for Nuclear Power Plants (LWR Edition)”; (2) the FSAR describes the methodology and sources used to obtain the population data, including the projections; and (3) the FSAR includes information on transient populations in the site vicinity.

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

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

- 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 given in Regulatory Position C.4 of RG 4.7, the applicant must give special attention to the consideration of alternative sites with lower population densities.

2.1.3.4 *Technical Evaluation*

The NRC staff reviewed Section 2.1.3 of the VCSNS COL FSAR and checked the referenced DCD to ensure that the combination of the DCD and the COL application represents the complete scope of information relating to this review topic.[1] The NRC staff's review confirmed that the information in the application and incorporated by reference addresses the required information relating to population distribution. The results of the NRC staff's evaluation of the information incorporated by reference in the VCSNS COL application are documented in NUREG-1793 and its supplements.

The staff reviewed the information in the VCSNS COL FSAR:

AP1000 COL Information Item

- VCS COL 2.1-1

The NRC staff reviewed VCS COL 2.1-1 related to the population distribution around the site environs included in Section 2.1.3 of the VCSNS COL FSAR. COL Information Item in Section 2.1.1 of the AP1000 DCD states:

> Combined License applicants referencing the AP1000 certified design will provide site-specific information related to site location and description, exclusion area authority and control, and population distribution. Site-specific information will be included on population distribution.

The staff reviewed the data on the population in the site environs, as presented in VCSNS COL FSAR, Sections 2.1.1, 2.1.2, and 2.1.3, to determine whether the exclusion area, LPZ, and nearest population center distance for the proposed site comply with the requirements of 10 CFR Part 100. The staff also evaluated whether, consistent with Regulatory Position C.4 of RG 4.7, the applicant should consider alternative sites with lower population densities. Further, the staff reviewed whether appropriate protective measures could be taken on behalf of the enclosed populace within the emergency planning zone (EPZ), which encompasses the LPZ, in the event of a serious accident. The NRC staff, using U.S. Census Bureau and state population estimates, calculated estimates of the projected populations including weighted transient populations for the years 2010, 2020, 2030, 2040, 2050, and 2060. The staff reviewed the projected population data provided by the applicant, including the weighted transient population for 2010, 2020, 2030, 2040, 2050 and 2060. The staff reviewed the extensive transient population data provided by the applicant, and compared the estimates the staff calculated with those calculated by the applicant. Since the applicant's calculated values for each year were within a few percent of the NRC determined values, the staff finds the applicant's estimate of the normal and transient population acceptable.

The nearest population center to the VCSNS site, with more than 25,000 residents, is the city of Columbia, South Carolina, with a 2000 population of 116,278. The closest point of Columbia's corporate limit to the VCSNS site is approximately 14.5 miles (mi) to the southeast. This distance is over seven times the distance from the center of Units 2 and 3 to the closest LPZ boundary, and 4.8 times the radius of the LPZ (because the LPZ is centered on Unit 1). Both of these distances meet the requirement that the population center distance be at least one and one-third times the distance from the reactor to the outer boundary of the LPZ. Therefore, the NRC staff concludes that the proposed site meets the population center distance requirement specified in 10 CFR 100.21.

Regulatory Position C.4 of RG 4.7, Revision 2, states that the population density, including the weighted transient population projected at the time of initial site approval and five years thereafter should not exceed 500 persons per square mi averaged over any radial distance out to 20 mi (cumulative population at a distance divided by the area at that distance).

The NRC staff evaluated the site population density provided by the applicant in FSAR Figure 2.1-220 against the criterion in Regulatory Position C.4 of RG 4.7, Revision 2. Figure 2.1-220 shows that the population density for the years 2000 through the year 2060 is between 200 and approximately 250 persons per square mi, thus it would not exceed the criteria of 500 persons per square mi averaged over a radial distance of up to 20 mi (cumulative population at a distance divided by the area at that distance). Review of U.S. Census Bureau data provided assurance that the population density met the guidance in RG 4.7. Therefore, the NRC staff concludes that VCSNS conforms to Regulatory Position C.4 of RG 4.7, Revision 2.

2.1.3.5 *Post Combined License Activities*

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

2.1.3.6 *Conclusion*

The NRC staff reviewed the application and checked the referenced DCD. The NRC staff's review confirmed that the applicant addressed the required information relating to population distribution, and there is no outstanding information expected to be addressed in the VCSNS COL FSAR related to this section. The results of the NRC staff's technical evaluation of the information incorporated by reference in the VCSNS COL application are documented in NUREG-1793 and its supplements.

As set forth above, the applicant has provided an acceptable description of current and projected population densities in and around the site. The staff has reviewed VCS COL 2.1-1, and for the reasons given above, concludes that the population data 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. This conclusion is based on the applicant having provided an acceptable description and safety assessment of the site, which includes present and projected population densities that are within the guidelines of Regulatory Position C.4 of RG 4.7, and properly specified the LPZ and population center distance. In addition, the staff has reviewed and confirmed, by comparison with independently obtained population data, the applicant's estimates of the present and projected populations surrounding the site, including transients.

2.2 <u>Nearby Industrial, Transportation, and Military Facilities</u>

2.2.1 Locations and Routes

2.2.1.1 *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 NUREG-0800, 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 in the "Contents of Application" sections of the applicable subparts to 10 CFR Part 52.

2.2.1.2 *Summary of Application*

Section 2.2 of the VCSNS COL FSAR, Revision 5, incorporates by reference Section 2.2 of the AP1000 DCD, Revision 19.

In addition, in VCSNS COL FSAR Section 2.2, the applicant provided the following:

<u>Tier 2 Departure</u>

- VCS DEP 2.0-1

The evaluation of this departure is in Section 2.0 of this SER.

<u>AP1000 COL Information Item</u>

- VCS COL 2.2-1

The applicant provided additional information in VCS COL 2.2-1 to resolve COL Information Item 2.2-1 (COL Action Item 2.2-1), which addresses information about industrial, military, and transportation facilities and routes to establish the presence and magnitude of potential external hazards.

2.2.1.3 *Regulatory Basis*

The regulatory basis of the information incorporated by reference is addressed in NUREG-1793 and its supplements.

In addition, the acceptance criteria associated with the relevant requirements of the Commission regulations for the nearby industrial, transportation, and military facilities are given in Sections 2.2.1 and 2.2.2 of NUREG-0800.

The applicable regulatory requirements for identifying locations and routes are:

- 10 CFR 100.20(b), which requires that the nature and proximity of man related hazards (e.g., airports, dams, transportation routes, military and chemical facilities) be evaluated to establish site parameters for use in determining whether plant 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, which require the location and description of industrial, military, or transportation facilities and routes, and of 10 CFR 52.79(a)(1)(vi) as it relates to the compliance with 10 CFR Part 100.

The related acceptance criteria from Section 2.2.1-2.2.2 of NUREG-0800 are as follows:

- Data in the FSAR adequately describes the locations and distances from the plant for nearby industrial, military, and transportation facilities and that such 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, are adequate to permit identification of the possible hazards cited in Section III of Sections 2.2.1 and 2.2.2 of NUREG-0800.

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

2.2.1.4 *Technical Evaluation*

The NRC staff reviewed Section 2.2 of the VCSNS COL FSAR and checked the referenced DCD to ensure that the combination of the DCD and the COL application represents the complete scope of information relating to this review topic.[1] The NRC staff's review confirmed that the information in the application and incorporated by reference addresses the required information relating to nearby industrial, transportation, and military facilities. The results of the NRC staff's evaluation of the information incorporated by reference in the VCSNS COL application are documented in NUREG-1793 and its supplements.

The staff reviewed the information in the VCSNS COL FSAR:

AP1000 COL Information Item

- VCS COL 2.2-1

The NRC staff reviewed VCS COL 2.2-1 related to information about industrial, military, and transportation facilities and routes to establish the presence and magnitude of potential external hazards included in Section 2.2 of the VCSNS COL FSAR. COL Information Item in AP1000 DCD Section 2.2.1 states:

> Combined License applicants referencing the AP1000 certified design will provide site-specific information related to the identification of potential hazards within the site vicinity, including an evaluation of potential accidents and verify that the frequency of site-specific potential hazards is consistent with the criteria outlined in Section 2.2. The site-specific information will provide a review of aircraft hazards, information on nearby transportation routes, and information on potential industrial and military hazards.

The NRC staff reviewed the VCSNS COL FSAR using the review procedures described in Section 2.2.1-2.2.2 of NUREG-0800.

This SER section identifies and provides the information that would help in evaluating potential effects on the safe operation of the nuclear facility by industrial, transportation, mining, and military installations in the VCSNS area.

Locations and Routes

The applicant identified and provided information regarding potential external hazard facilities and operations within a 5-mi radius of the VCSNS site, which include four industrial facilities that lie within 5 mi of Units 2 and 3. These facilities include Unit 1, which has been in operation since 1984, the Fairfield Pumped Storage Facility, the Parr Hydro, and the Parr Combustion Turbines.

Unit 1

The NRC verified that Unit 1 is a 1000 megawatt electric (MWe) pressurized-water reactor (PWR) licensed by the NRC that has been in commercial operation since 1984. Units 2 and 3 are both located in the Unit 1 vicinity, as shown in VCSNS COL FSAR Figure 2.2-201. The center of the Unit 2 containment is located approximately 4,550 feet south-southwest from the center of the Unit 1 containment building, and the center of the Unit 3 containment is located 900 feet south-southwest from the center of the Unit 2 containment. FSAR Table 2.2-202 identifies the chemicals stored at the Unit 1 facility. These chemicals are evaluated in Section 2.2.3 of this SER.

Fairfield Pumped Storage Facility

The applicant described the Fairfield Pumped Storage Facility as a hydroelectric plant that produces 576 megawatts (MW) of electricity. It is located near Unit 1, approximately 0.5 mi east of the Broad River and approximately 1.5 mi northwest of Units 2 and 3. Its primary purpose is to pump water from the Parr Reservoir to the Monticello Reservoir for storage and later release for hydroelectric generation. There are no significant quantities of hazardous materials stored at this facility, which would pose a hazard to the personnel of Units 2 and 3 greater than the hazard of those chemicals stored at Unit 1, listed in VCSNS COL FSAR Table 2.2-202. Thus, the applicant determined no further analysis was required. The NRC staff, using a site visit and the site map provided in the Units 2 and 3 FSAR, verified the information provided by the applicant and concurs with this conclusion.

Parr Hydro

The applicant described the Parr Hydro as a hydroelectric facility that produces 14 MW of electricity located along the Broad River approximately 1.7 mi southwest of Units 2 and 3. The hazardous materials stored at this facility are bounded by the materials stored at Unit 1. Thus, the applicant determined no further analysis was required. The NRC staff used a site visit to verify the information provided and concurs with this conclusion.

Parr Combustion Turbines

The applicant described the Parr Combustion Turbines as being located along the Broad River near the Parr Hydro facility approximately 1.7 mi southwest of Units 2 and 3. A natural gas pipeline and an 800,000-gallon fuel oil storage tank surrounded by a dike capable of containing the tank contents plus 10 percent (880,000 gallons) are located approximately 6,944 feet and 7,267 feet, respectively, southwest of Unit 3. Both of these fuel sources are used by the Parr Combustion Turbines. These fuel sources are evaluated in Section 2.2.3 of this SER. The information supplied by the applicant was verified by a site visit and maps and satellite pictures publically available.

Mining Facilities

The applicant stated that there are no active mining or quarry activities taking place within 5 mi of Units 2 and 3. However, the applicant noted that a number of local facilities outside of the 5-mi radius continue to maintain active mining permits but are inactive in operations. The permitted facilities are listed as Hanson Aggregates Southeast, Inc., (Permit Number I-00797), Martin Marietta Materials, Inc., which holds two permits (Permit Numbers I-00100 and I-00101), and Quality Stone, Inc., (Permit Number I-001380). All blasting activities at the quarries are contracted to an outside independent licensed party with no explosive storage taking place in Fairfield, Newberry, or Richland counties. Considering that the distance of the facilities are beyond the 5-mi radius, their safety hazard to Units 2 and 3 are regarded as being insignificant by the applicant. Thus, the applicant determined no further analysis was required. The NRC staff used mine location maps that showed all active mine sites located within 20 miles of the VCSNS site, and satellite pictures to verify the information supplied by the applicant. The NRC staff, using the guidance of RG 1.91 concurs with the applicant's conclusion.

Military Facilities

The applicant stated that there are no military facilities within 20 mi of Units 2 and 3. The nearest military facility to the site is Fort Jackson, which is approximately 24 mi southeast of the site. Considering the large distance from the site to the nearest military facilities, the applicant determined no further evaluation was required. The NRC staff used maps, satellite pictures and information publically available to verify the information supplied by the applicant and concurs with this conclusion.

Pipelines

The applicant stated and the NRC staff used a site visit and information publically available to verify that the only pipeline within five miles of the site is a buried natural gas pipeline owned by South Carolina Electric and Gas (SCE&G) that extends to the Parr Combustion Turbines from the southeast, as shown on VCSNS COL FSAR Figure 2.2-201. The closest approach of the pipeline to Units 2 and 3 occurs near the Parr Combustion Turbines, at a distance of approximately 6,944 feet southwest of Unit 3. The line was installed to transport natural gas as a fuel source for the Parr Combustion Turbines. The 12-inch diameter pipeline is more than 30 years old, buried at a depth of 3 feet with a maximum operating pressure of 700 pounds per square inch (psi). Isolation of the line is obtained with a 12-inch Cameron ASA 600 ball valve located approximately 13,800 feet south of Unit 1. The applicant stated, and the NRC staff verified during a site visit, that there is no gas storage at the Parr Combustion Turbines other than what is in the pipeline and there are no plans to use the pipeline for the transport of materials other than natural gas. This fuel source is evaluated in Section 2.2.3 of this SER.

Description of Waterways

The applicant described the Broad River as the most prominent hydrologic feature in the vicinity of Units 2 and 3. The Broad River is located approximately 1 mi west of Units 2 and 3. While no commercial navigation takes place on the Broad River, it is used for recreational purposes. The Parr Reservoir, located approximately 1 mi west of the proposed site for Units 2 and 3 on the Broad River, was created in 1914 by the construction of a dam on the Broad River at Parr Shoals. The Monticello Reservoir, which provides cooling water to all three VCSNS units, is located approximately 1 mi north of Units 2 and 3. The raw water system intake structure for Units 2 and 3 is a non-safety-related structure located along the bank of the Monticello Reservoir. Like the Broad River and Parr Reservoir, the Monticello Reservoir is also used as a recreational resource by the local population. Since the Broad River, Parr Reservoir, and the Monticello Reservoir are not used as commercial transport waterways, the potential safety effect to the site is regarded as being insignificant by the applicant. Thus, the applicant determined no further analysis was necessary. The NRC staff verified the information supplied by the applicant during a site visit and by a review of satellite photographs, and recreation information publically available and concurs with the applicant's conclusion.

Description of Highways

The applicant stated that access from Columbia to the site is via highway SC 215 or I-26 to US 176 and then to SC 213, as shown in VCSNS COL FSAR Figure 2.2-201 and Figure 2.2-203. SC 213 and SC 215 merge near the center of Jenkinsville and continue northbound for approximately 3.2 mi, at which point the routes split up with SC 215 continuing on in a northerly direction while SC 213 veers off to the northeast. Merged SC 213/215, at approximately 7,661 feet east of the center of Unit 2, is the nearest approach of any state highway to the site.

A traffic corridor analysis study was performed by the applicant for the purpose of identifying hazardous chemicals, such as chlorine, at nearby fixed facilities whose transportation routes may pass within the vicinity of Units 2 and 3. The criterion for this study was based on Federal Highway Administration guidance to assess vulnerability zones and apply methodologies. The corridor analysis for Units 2 and 3 applied a modified sketch planning tool to represent the chemicals located near the facility. The methodology consisted of: (1) plotting all of the chemical sites identified by the Environmental Protection Agency (EPA); (2) categorizing them along the viable corridors, and then; (3) ascertaining the proximity of these corridors into routes along nearby zones that could be used as an approach to the plant site as illustrated in VCSNS COL FSAR Figure 2.2-203.

The results of this study concluded that no routes passed near (within 5 mi of) the plant. The closest approach is on I-26. Use of an alternate route is not likely when direct interstate routes or U.S. highways are provided and contain the predominant fixed locations. The only hazardous material potentially transported on SC 215 that was identified for further analysis was gasoline. An underground storage tank present at Unit 1 located approximately 2,362 feet from Unit 2 is filled by delivery tanker trucks capable of transporting 50,000 pounds of gasoline. The location of the delivery tanker truck that services the underground storage tank is closer to Unit 2 than that of the highway distance of approximately 7,661 feet. Therefore, the applicant stated a hazardous analysis for gasoline is bounded by an onsite delivery truck hazard and not as a highway hazard. Thus, the applicant determined no further analysis for highways was necessary. The NRC staff used a site visit and publically available maps and satellite photographs to verify the information supplied by the applicant and determined that the study conclusion was reasonable and concurs with the conclusion that no further analysis is necessary.

Description of Railroads

The applicant described the Norfolk Southern Railroad as being located within 5 mi of Units 2 and 3, as shown in VCSNS COL FSAR Figure 2.2-201. The Norfolk Southern Railroad line parallels the Broad River west of the site, along the east bank of the Broad River from Spartanburg, South Carolina toward Columbia, South Carolina, approximately 4,200 feet west of the Unit 3 auxiliary building. This line provides rail access to the site by having a spur track owned by SCE&G leading off the main line from a switch southwest of the site. No passenger traffic uses this line. The applicant identifies the top 25 commodities shipped through Alston, South Carolina, between April 2005 and April 2006, in VCSNS COL FSAR Table 2.2-203. The NRC staff verified the information supplied by the applicant by reviewing publically available information on the locations of the railroad and the principal commodities shipped on this railroad. This hazard is reviewed in Section 2.2.3 of this SER.

Description of Airports

The applicant's review of airport facilities within 10 mi of the site has identified only one helipad, located at the Unit 1 site. The location of airports and significant flight paths occurring in a general area of the site are shown in VCSNS COL FSAR Figure 2.2-202. The applicant listed airport facilities located close to Units 2 and 3, along with their significance factor in Table 2.2-204. The airport facilities are described below in order of proximity to the site. Based on a review of publically available data, the NRC staff verified the information supplied by the applicant.

Summer Station Helipad

The applicant described the Summer Station (SC63) as a private, unattended 30-foot by 30-foot concrete paved helipad located approximately 4,550 feet northeast of the site. This helipad is a privately owned facility used primarily for medical or emergency evacuation of personnel. Yearly operations are approximately five or less per year. Because of its infrequent use and limited capabilities, the applicant does not consider it a safety hazard to the site. Thus, the applicant determined no analysis was necessary. Based on a review of publically available, applicable data, the NRC staff verified the location and usage information supplied by the applicant and concurs with the applicant's conclusion that no additional analysis is necessary.

Fairfield County Airport

The applicant described the Fairfield County Airport (FDW) as a public airport located approximately 11.42 mi east-northeast from the site, thus making it the nearest airport to Units 2 and 3. It consists of an asphalt paved runway approximately 5,003 feet long and 100 feet wide with a heading of 043 magnetic, 038 true (Runway 4) and 223 magnetic, 218 true (Runway 22). Twenty-eight aircraft are based on the field; of these, 25 are single-engine while 3 are multiengine airplanes. Average daily aircraft operations for the year 2005 were approximately 47 operations per day. Based on the significance factor listed in VCSNS COL FSAR Table 2.2-204, this airport is not considered a safety hazard to the site by the applicant. Thus, the applicant determined no further analysis was required. Based on a review of publically available information on the airport's location, description, and usage, the NRC staff verified the information supplied by the applicant and concurs with the applicant's conclusion.

Shealy Airport

The applicant described the Shealy Airport (SC14) as a privately owned, continuously attended airport located approximately 14 mi southwest of the site. It consists of a turf-surfaced runway approximately 1700 feet long and 85 feet wide. Four single-engine airplanes are based on the field. Based on the significance factor listed in VCSNS COL FSAR Table 2.2-204, this airport is not considered a safety hazard to the site by the applicant. Thus, the applicant determined no further analysis was required. Based on a review of publically available information on the airport's location, description, and usage, the NRC staff verified the information supplied by the applicant and concurs with the applicant's conclusion.

Newberry County Airport

The applicant described the Newberry County Airport (27J) as a public airport attended to between 0800 and 1700, Monday through Friday, located approximately 18 mi west of the site. It consists of an asphalt/aggregate paved runway approximately 3,498 feet long by 60 feet wide with a heading of 042 magnetic, 037 true (Runway 4) and 222 magnetic, 217 true (Runway 22). Twenty-two aircraft are based on the field. Of these, 18 are single-engine, 2 are multiengine, and 2 are ultralights. Average daily aircraft operations for the year ending in 2005 were approximately 43 operations per day. Based on the significance factor listed in VCSNS COL FSAR Table 2.2-204, this airport is not considered a safety hazard to the site by the applicant. Thus, the applicant determined no further analysis was required. Based on a review of publically available information on the airport's location, description, and usage, the NRC staff verified the information supplied by the applicant and concurs with the applicant's conclusion.

Columbia Metropolitan Airport (CAE)

Columbia Metropolitan Airport (CAE) is a continuously attended public airport located approximately 22 mi southeast of the site. It has two paved asphalt runways and one helipad. The primary instrument runway is an asphalt/grooved runway approximately 8,601 feet long by 150 feet wide with a heading of 110 magnetic, 105 true (Runway 11) and 290 magnetic, 285 true (Runway 29). The secondary runway is an asphalt/concrete runway approximately 8,001 feet long and 150 feet wide with a heading of 50 magnetic, 45 true (Runway 5) and 230 magnetic, 225 true (Runway 23). Helipad H1 is a 50-foot by 50-foot concrete paved pad. One hundred aircraft are based on the field of which 60 are single engine, 25 are multiengine, 14 are jet airplanes, and 1 is a military aircraft operated by the South Carolina Army National Guard. Average daily aircraft operations for the year ending in 2005 were approximately 315 operations per day. Based on the significance factor listed in VCSNS COL FSAR Table 2.2-204, this airport is not considered a safety hazard to the site by the applicant. Thus, the applicant determined no further analysis is required. Based on a review of publically available information on the airport's location, description, and usage, the NRC staff verified the information supplied by the applicant and concurs with the applicant's conclusion.

Aircraft and Airway Hazards

The applicant described the regulatory guidance related to evaluating aircraft and airway hazards. RG 1.206 and NUREG-0800 state that the risk due to aircraft hazards should be sufficiently low. Furthermore, aircraft accidents that could lead to radiological consequences in excess of the exposure guidelines of 10 CFR 50.34(a)(1) with a probability of occurrence greater than an order of 10^{-7} per year should be considered in the design of the units. Section 3.5.1.6 of NUREG-0800 provides three acceptance criteria for the probability of aircraft accidents to be less than an order of magnitude of 10^{-7} per year by inspection. If all three criteria are met, no further analysis is required.

- The plant-to-airport distance, D is between 5 and 10 statute mi, and the projected annual number of operations is less than 500 D^2, or the plant-to-airport distance D is greater than statute 10 mi, and the projected annual number of operations is less than 1000 D^2.

- The plant is at least 5 mi from the nearest edge of military training routes, including low-level training routes, except for those associated with use greater than 1000 flights per year.

- The plant is at least 2 mi beyond the nearest edge of a federal airway, holding pattern, or approach pattern.

The applicant identified one low altitude federal airway (18,000 feet mean sea level (msl) and lower) that is inside 5 mi of the site. Airway V53 passes approximately 2.25 mi southwest of the site on a heading of 331° from the CAE. Airway V155, which is also within the vicinity of the site, passes approximately 8.5 mi southeast of the site. Federal airways are typically 8 nautical mi wide extending 4 nautical mi from the centerline. Since the centerline of Airway V53 is approximately 2.25 mi from the site, this indicates that the third criterion in Section 3.5.1.6 of NUREG-0800 is not met. In the case of Airway V155, the 8.5 mi separation provides sufficient distance to meet the acceptance criteria of NUREG-0800. The NRC verified the data supplied by the applicant and concurred with both conclusions.

Because the applicant did not meet the third criterion, it performed a calculation to determine the probability of an aircraft accident that could possibly result in radiological consequences to the site for Airway V53 following NUREG-0800, Section 3.5.1.6 and Department of Energy (DOE) Standard 3014-96, "Accident Analysis for Aircraft Crash Into Hazardous Facilities." The applicant's calculated result determined that the probable accidental rate of an aircraft affecting the site would be on the order of 3.64×10^{-8} per year. When estimating the number of flights along Airway V53, the fractions of the types of aircraft using the airway were assumed by the applicant to be the same as the fractions using CAE. The applicant stated that this is a conservative assumption since general aviation aircraft mainly fly under visual flight rules or instrument flight rules condition and under new Federal Aviation Administration (FAA) regulations; most commercial and military aircraft will fly point to point rather than in specific airways. Thus, the applicant determined the presence of Airway V53 is not considered to be a safety concern since the probable accidental rate calculated is less than 10^{-7} per year. The NRC staff verified this calculation and concurs with the conclusion provided by the applicant.

Projections of Industrial Growth

The applicant contacted the Newberry and Fairfield County's Office of Economic Development. The Newberry County Office of Economic Development revealed that there is an industrial park located at the junctions of I-26 and SC 219 and a new industrial park at I-26 and SC 773. The Fairfield County Office of Economic Development revealed that there is an industrial park at I-77 and SC 200 and a new industrial park at I-77 and SC 34. Since these facilities are outside of the 5-mi radius of the site, the applicant determined no further analysis was necessary. The VCSNS site is located in a sparsely populated area, with an abandoned industrial development inside the 10-mi radius. The applicant stated that industrial growth in the Winnsboro area of Fairfield County, located approximately 15 mi east-northeast of the site has gone away from mining to light industry with four new light manufacturing facilities moving into the county. Economic growth potential exists in nearby Newberry County in the I-26 corridor at the intersection of SC 219 at I-26 where Newberry Industrial Park is located. Access via I-77 and I-26 to the Winnsboro and Newberry areas provides potential growth opportunities to the respective communities. The NRC staff conducted a review of publically available information to verify the information supplied by the applicant and concurs that the applicant's conclusion is reasonable.

2.2.1.5 *Post Combined License Activities*

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

2.2.1.6 *Conclusion*

The NRC staff reviewed the application and checked the referenced DCD. The NRC staff's review confirmed that the applicant addressed the required information relating to nearby industrial, transportation, and military facilities, and there is no outstanding information expected to be addressed in the VCSNS COL FSAR related to this section. The results of the NRC staff's technical evaluation of the information incorporated by reference in the VCSNS COL application are documented in NUREG-1793 and its supplements.

As set forth above, the applicant has presented and substantiated information to establish an identification of potential hazards in the site vicinity. The staff has reviewed VCS COL 2.2-1, and for the reasons given above, concludes that the applicant has provided information with respect to identification of potential hazards in accordance with the requirements of 10 CFR 52.79(a)(1)(iv) and 10 CFR 52.79(a)(1)(vi). 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 any such activities that have the potential for adversely affecting plant safety-related structures. Based on an evaluation of information in the VCSNS COL FSAR, as well as information that the staff independently obtained, the staff has concluded that all potentially hazardous activities on 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.

2.2.2 Refer to 2.2.1

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 site and in the vicinity of the proposed site to confirm that appropriate data and analytical models have been used. The 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*

Section 2.2 of the VCSNS COL FSAR, Revision 5, incorporates by reference Section 2.2 of the AP1000 DCD, Revision 19.

In addition, in VCSNS COL FSAR Section 2.2, the applicant provided the following:

<u>*AP1000 COL Information Item*</u>

- VCS COL 2.2-1

The applicant provided additional information in VCS COL 2.2-1 to resolve COL Information Item 2.2-1 (COL Action Item 2.2-1), which addresses information about industrial, military, and transportation facilities and routes to establish the presence and magnitude of potential external hazards, including the following accident categories: explosions, flammable vapor clouds (delayed ignition), toxic chemicals, fires, and airplane crashes.

- VCS COL 6.4-1

The applicant provided additional information in VCS COL 6.4-1 to address COL Information Item 6.4-1 (COL Action Item 6.4-1) related to the evaluation of potential accidents involving hazardous materials that may impact the control room habitability.

- STD COL 6.4-1

In a letter dated June 24, 2010, the applicant provided additional information as STD COL 6.4-1, related to the onsite chemical hazards. Specifically, the applicant provided a proposed revision to VCSNS FSAR Table 6.4-1 that provides a description of the onsite chemicals, including an identification of which chemicals are expected to be standard to all AP1000 COLs. The FSAR table also provides a description using the VCS COL 6.4-1 annotation for which chemicals are expected to be plant specific.

STD COL 6.4-1 addresses COL Information Item 6.4-1 (COL Action Item 6.4-1) related to the evaluation of potential accidents involving hazardous materials that may impact the control room habitability.

2.2.3.3 *Regulatory Basis*

The regulatory basis of the information incorporated by reference is addressed in NUREG-1793 and its supplements.

In addition, the acceptance criteria associated with the relevant requirements of the Commission regulations for the evaluation of potential accidents are given in Section 2.2.3 of NUREG-0800.

The applicable regulatory requirements for evaluation of potential accidents are:

- 10 CFR 100.20(b), which requires that the nature and proximity of man-made related hazards (e.g., airports, dams, transportation routes, military and chemical facilities) be evaluated to establish site parameters for use in determining whether plant 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, which require the location and description of industrial, military, or transportation facilities and routes, and the requirements of 10 CFR 52.79(a)(1)(vi) as they relate to compliance with 10 CFR Part 100.

The related acceptance criteria from Section 2.2.3 of NUREG-0800 are as follows:

- Event Probability: The identification of design-basis events (DBEs) 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 DBEs 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.

In addition, the toxic gas evaluations should be consistent with appropriate sections from RG 1.78, "Evaluating the Habitability of a Nuclear Power Plant Control Room During a Postulated Hazardous Chemical Release," Revision 1.

2.2.3.4 *Technical Evaluation*

The NRC staff reviewed Section 2.2 of the VCSNS COL FSAR and checked the referenced DCD to ensure that the combination of the DCD and the COL application represents the complete scope of information relating to this review topic.[1] The NRC staff's review confirmed that the information in the application and incorporated by reference addresses the required information relating to the evaluation of potential accidents. The results of the NRC staff's evaluation of the information incorporated by reference in the VCSNS COL application are documented in NUREG-1793 and its supplements.

The staff reviewed the information in the VCSNS COL FSAR:

AP1000 COL Information Item

- VCS COL 2.2-1
- VCS COL 6.4-1
- STD COL 6.4-1

The NRC staff reviewed the resolution to the VCS COL 2.2-1 (related to COL Information Item 2.2-1), which address specific items related to the identification and evaluation of potential accidents resulting from external hazards or hazardous materials included in Section 2.2.1 of the VCSNS COL FSAR.

The NRC staff reviewed VCS COL 2.2-1 related to information about industrial, military, and transportation facilities and routes to establish the presence and magnitude of potential external hazards, including the following accident categories: explosions, flammable vapor clouds (delayed ignition), toxic chemicals, fires, and airplane crashes included in Section 2.2.3 of the VCSNS COL FSAR. COL Information Item in Section 2.2 of the AP1000 DCD states:

> Combined License applicants referencing the AP1000 certified design will provide site-specific information related to the identification of potential hazards within the site vicinity, including an evaluation of potential accidents and verify that the frequency of site-specific potential hazards is consistent with the criteria outlined in Section 2.2. The site-specific information will provide a review of aircraft hazards information on nearby transportation routes, and information on potential industrial and military hazards.

VCS COL 6.4-1 and STD COL 6.4-1 (related to COL Information Item 6.4-1) are addressed in Section 6.4 of this SER.

Explosions

The applicant considered hazards involving potential explosions resulting in blast overpressure due to detonation of explosives, munitions, chemicals, liquid fuels, and gaseous fuels for facilities and activities either onsite or within the site vicinity of the proposed units. The applicant evaluated potential explosions from nearby highways, railways, or facilities using 1 psi overpressure as a criterion for adversely effecting plant operation or preventing safe shutdown of the plant. In accordance with RG 1.91, "Evaluations of Explosions Postulated to Occur on Transportation Routes Near Nuclear Power Plants," peak positive incident overpressures below 1 psi are considered to cause no significant damage.

The applicant determined a minimum safe standoff distance of 260 feet for truck transport, and 363 feet for rail transport on the basis of using conservative assumptions and the RG 1.91 methodology. These calculated distances are shorter than the respective closest highway distance of 7,761 feet and railroad distance of 4,200 feet from the nearest safety-related structure. The NRC staff performed independent calculations, which confirmed the applicant's results. Therefore, the NRC staff concludes that the applicant's assumptions and methodology are acceptable.

In RAI 2.2.1-2.2.2-4, the staff asked the applicant to justify omitting any discussion of the transport of explosives from nearby mining sites via routes in close proximity to VCSNS Units 2 and 3. The applicant responded by stating that the routes from explosive suppliers to the active mine sites in the region do not come within five miles of the Unit 2 and 3 site. Therefore, the trucks would not pass within the safe standoff distance for trucks and would not require further analysis. The NRC staff reviewed the RAI response and, using available maps, verified that the trucks would not come within five miles of VCSNS Units 2 and 3. The staff concurs with the applicant's conclusion that no further analysis was required for trucks carrying mining explosives and considers RAI 2.2.1-2.2.2-4 closed.

In RAI 2.2.1-2.2.2-1, the staff asked the applicant to provide the basis for defining fireworks transported on railroads as being too broad of a category to analyze. The applicant responded by stating that Norfolk Southern, owner/operator of the rail line past the site, had identified that the fireworks shipped on that line fall under DOT Class 1, Division 1.4 explosives. As described by 49 CFR 173.50, "Division 1.4 consists of explosives that present a minor explosion hazard. The explosive effects are largely confined to the package and no projection of fragments of appreciable size or range is to be expected." As the fireworks fall under this classification, no further explosion analysis is required to determine overpressure hazards or hazards due to missiles. The NRC staff verified the applicant's supplied information and, upon reviewing 49 CFR 173.50, concurs with the applicant's conclusion and considers RAI 2.2.1-2.2.2-1 closed.

The Broad River, Parr Reservoir, and Monticello Reservoir are not navigable for commercial shipping; therefore, they are not considered for hazard evaluations. Based on NRC staff site visits, the staff concurs with this decision.

The nearest natural gas pipeline is owned by SCE&G and extends from the southeast to the Parr Combustion Turbines, as shown on VCSNS COL FSAR Figure 2.2-201. The closest approach of the pipeline to Units 2 and 3 occurs near the Parr Combustion Turbines, at a distance of approximately 6,944 feet southwest of Unit 3. The line was installed to transport natural gas as a fuel source for the Parr Combustion Turbines. The 12-inch diameter pipeline is more than 30 years old, buried at a depth of 3 feet with a maximum operating pressure of 700 psi. Isolation of the line is obtained with a 12-inch Cameron ASA 600 ball valve located approximately 13,800 feet south of Unit 1. There is no gas storage at the Parr Combustion Turbines other than what is in the pipeline. The applicant analyzed the pipeline and presented results of peak overpressure of 1.0 psi at 6,284 feet from the origin of the explosion. Since 6,284 feet is less than the 6,944 feet of the closest approach to Unit 2 or Unit 3, the 1.0 psi pressure wave does not reach Unit 2 or Unit 3 and, hence, there would be no significant effect on Unit 2 or 3 as a result of a natural gas explosion. The NRC staff performed similar analysis and concurred that the applicant's conclusions were correct.

Railroad Tank Car Shipment Explosions

As described in VCSNS COL FSAR Section 2.2.2.6, Norfolk Southern's rail line passes approximately 4,200 feet west of the nearest safety-related structure—the Unit 3 auxiliary building. Based on RG 1.91, the maximum explosive cargo in a single railroad box car is approximately 132,000 pounds.

The hazardous materials shipped by rail that were identified for further analysis with regard to explosion potential are: ethanol, isopropanol, and cyclohexylamine. A conservative analysis using TNT equivalency methods described in VCSNS COL FSAR Section 2.2.3.1.1 was used to determine safe distances for the identified hazardous materials. The results indicate that the safe distances are less than the minimum separation distance from the nearest safety-related structure—the Unit 3 auxiliary building—to the rail line. The safe distance for ethanol is 317 feet; for isopropanol, 316 feet; and for cyclohexylamine, 363 feet (Table 2.2-207). All of these chemicals are transported approximately 4,200 feet from the nearest safety-related structure, the Unit 3 auxiliary building. Therefore, an explosion from any of the transported rail hazardous materials evaluated would not adversely affect the safe operation or shutdown of Units 2 and 3. The NRC staff performed independent calculations that supported the applicant's conclusions.

Flammable Vapor Clouds (Delayed Ignition)

The explosion hazard sites reviewed previously were also reviewed as possible sources of flammable vapor clouds. The applicant's analysis of flammable vapor clouds from the nearest gas pipeline, railroad, Unit 1 onsite stored chemicals, highways and other offsite facilities (delayed ignition), showed a peak pressure of less than 1 pound per square inch gauge (psig) at the nearest safety-related structure. VCSNS COL FSAR Table 2.2-208 shows a summary of the results of the analysis of the sources of potentially flammable vapor clouds. The NRC staff performed similar analysis and concurred that the applicant's analysis was correct.

For Unit 1 chemical storage locations, gasoline and hydrazine were analyzed and determined to have storage locations at safe distances from safety-related structures at VCSNS Units 2 and 3. The NRC staff, on the basis of its own analysis, considers the applicant's analysis acceptable.

Toxic Chemicals

The applicant addressed potential release of toxic chemicals from onsite storage facilities and nearby mobile and stationary sources.

As described in VCSNS COL FSAR Table 2.2–209, Unit 1 has one onsite stored chemical "Ammonium Hydroxide (28%)" that exceeds the immediately dangerous to life and health (IDLH) threshold at the control room.

As described in VCSNS COL FSAR Section 2.2.2.6, Norfolk Southern's rail line passes approximately 4,200 feet west of the nearest safety-related structure, the Unit 3 auxiliary building. The hazardous material shipped by rail that was identified for further analysis with regard to toxic potential is cyclohexylamine. Analysis showed that the IDLH of cyclohexylamine would be exceeded at the control room.

Verification of the control room habitability for the 28 percent ammonium hydroxide and cyclohexylamine are discussed in SER Section 6.4.

In RAI 2.2.3-1, the staff asked the applicant to explain why ethanol and isopropanol transported by rail were only evaluated as potential explosive hazards in the FSAR, and not analyzed as potential toxic hazards in FSAR Section 2.2.3.1.3.3 and FSAR Table 2.2-209, even though both chemicals are considered both explosive and toxic. In its response, the applicant stated that prior to Revision 2 of the application; ethanol and isopropanol had previously been screened as meeting the weight and distance guidelines in RG 1.78, Revision 1. However, based on a revised screening evaluation prompted by an update to the control room air exchange rate, ethanol and isopropanol no longer meet the guidance for weighted air exchange rates, toxicity limits, and distances from the control room presented in RG 1.78, Revision 1. Additionally, the applicant performed an updated analysis on each chemical transported by rail having a specified toxicity limit with the potential to form a vapor cloud. As a result of the revised analyses, the applicant committed to revising the FSAR to add chlorodifluoromethane, ethanol, and isopropanol to the railroad sections of FSAR Table 2.2-209 and FSAR Section 2.2.3.1.3.3. This response satisfied RAI 2.2.3-1. The revision of the VCSNS COL FSAR to incorporate the response to RAI 2.2.3-1 is **VCSNS Confirmatory Item 2.2-1**. The staff's confirmatory analysis agreed with the applicant's conclusion that the IDLH of chlorodifluoromethane would be exceeded at the control room intake. Therefore, verification of the control room habitability for chlorodifluoromethane is discussed in SER Section 6.4.

<u>Resolution of VCSNS Confirmatory Item 2.2-1</u>

VCSNS Confirmatory Item 2.2-1 is an applicant commitment to update its FSAR to include the changes to the FSAR described in its response to RAI 2.2.3-1. The staff verified that the VCSNS COL FSAR was appropriately updated. As a result, VCSNS Confirmatory Item 2.2-1 is now closed.

The results of the analysis of potential sources of toxic clouds from Unit 1, and local facilities, including railroad and highway traffic are shown in VCSNS COL FSAR Table 2.2-209. The NRC staff performed independent calculations that verified the applicant's conclusions.

In RAI 2.2.3-2, the staff asked the applicant to clarify their discussion in VCSNS COL FSAR Section 2.2.3.1.3 and FSAR Table 2.2-209 of onsite chemicals, as the chemicals listed in FSAR Table 2.2-209 did not match any of the VCSNS Units 2 and 3 chemicals listed in FSAR Table 6.4-201. In its response to RAI 2.2.3-2, the applicant clarified that the discussion of onsite chemicals in FSAR Section 2.2.3.1.3 and FSAR Table 2.2-209 referred to Unit 1 only, and proposed changes to FSAR Section 2.2.3.1.3 and FSAR Table 2.2-209 to clarify that fact. This response satisfied RAI 2.2.3-2. The revision of the VCSNS COL FSAR to incorporate the response to RAI 2.2.3-2 is **VCSNS Confirmatory Item 2.2-2**.

<u>Resolution of VCSNS Confirmatory Item 2.2-2</u>

VCSNS Confirmatory Item 2.2-2 is an applicant commitment to update its FSAR to include the changes to its FSAR described in its response to RAI 2.2.3-2. The staff verified that the VCSNS COL FSAR was appropriately updated. As a result, VCSNS Confirmatory Item 2.2-2 is now closed.

In a letter dated June 24, 2010, the applicant provided a proposed revision to VCSNS COL FSAR Table 6.4-201 that provides a description of the onsite chemical including an identification of which chemicals are expected to be standard to all AP1000 COLs. The staff's review of the standard chemical for all AP1000 plants is found under STD COL 6.4-1 below. The staff's review of the site-specific chemicals is included under VCS COL 6.4-1 below.

Section 1.2.3 of this SER provides a discussion of the strategy used by the NRC to perform one technical review for each standard issue outside the scope of the DC and use this review in evaluating subsequent COL applications. To ensure that the staff's findings on standard content that were documented in the SER for the reference COL application (Vogtle Electric Generating Plant [VEGP] Units 3 and 4) were equally applicable to the VCSNS Units 2 and 3 COL application, the staff undertook the following reviews:

- The staff compared the VEGP COL FSAR, Revision 2, to the VCSNS COL FSAR. In performing this comparison, the staff considered changes made to the VCSNS COL FSAR (and other parts of the COL application, as applicable) resulting from RAIs.

- The staff confirmed that all responses to RAIs identified in the corresponding standard content evaluation were endorsed.

- The staff verified that the site-specific differences were not relevant.

The staff has completed its review and found the evaluation performed for the standard content to be directly applicable to the VCSNS COL application. This standard content material is identified in this SER by use of italicized, double-indented formatting.

The following portion of this technical evaluation section is reproduced from Section 2.2.3.4 of the VEGP SER:

> *STD COL 6.4-1*
>
> *On the basis of the staff's confirmatory analysis of the standard chemicals, the concentration of two chemicals, hydrazine and carbon dioxide, exceeded respective chemical IDLH concentration outside the control room. Therefore, these chemicals are being further evaluated as part of control room habitability systems in SER Section 6.4, along with the review of other chemicals listed in FSAR Table 6.4-201 in the applicant's June 17, 2010, letter.*
>
> *The staff reviewed the applicant's Table 6.4-201 standard AP1000 chemicals stored onsite, and the applicant's screening out of chemicals that do not pose a threat to control room habitability. Based on evaluation of the information presented in the VEGP COL FSAR, confirmatory analyses, and review of the response to the request for additional information (RAI 2.2.3-1), the staff evaluated whether any additional chemicals needed to be evaluated further in Section 6.4 along with the applicant's identified list of toxic chemicals for control room habitability. The staff concluded that the two standard AP1000 chemicals hydrazine and carbon dioxide exceeded IDLH concentration outside the control room; these are further evaluated in SER Section 6.4 for control room habitability.*
>
> *The inclusion of the VEGP FSAR Table 6.4-201 standard chemicals in the applicant's letter dated June 17, 2010, in the next revision of the VEGP COL FSAR is **Confirmatory Item 2.2-2**.*

<u>Resolution of Standard Content Confirmatory Item 2.2-2</u>

Confirmatory Item 2.2-2 is an applicant commitment to revise its FSAR Table 6.4-201. The staff verified that the VEGP COL FSAR Table 6.4-201 was appropriately revised. As a result, Confirmatory Item 2.2-2 is now closed.

- VCS COL 6.4-1

The staff reviewed the applicant's list of onsite, site-specific chemicals provided in VCS COL 6.4-1 (VCSNS COL FSAR Table 6.4-201 found in the applicant's June 24, 2010 letter), and the applicant's screening out of chemicals that do not pose a threat to control room habitability. Based on evaluation of the information presented in VCS COL 6.4-1, and the staff's confirmatory analyses, the staff determined that no additional chemicals from VCS COL 6.4-1 needed to be evaluated further in Section 6.4 for control room habitability.

The update of the VCSNS COL FSAR Table 6.4-201 in the applicant's letter dated June 24, 2010, in the next revision of the VCSNS COL FSAR is **VCSNS Confirmatory Item 2.2-3**.

<u>Resolution of VCSNS Confirmatory Item 2.2-3</u>

VCSNS Confirmatory Item 2.2-3 is an applicant commitment to update its FSAR to include the changes to the FSAR described in its June 24, 2010, response. The staff verified that the VCSNS COL FSAR was appropriately updated. As a result, VCSNS Confirmatory Item 2.2-3 is now closed.

<u>Forest Fire Smoke and Heat Fluxes</u>

The NRC staff submitted RAI 2.2.1-1-2.2.2-2 related to smoke, non-flammable gases, or chemical-bearing clouds that could occur as a consequence of forest/grass fires. Only high heat flux is addressed in the VCSNS COL FSAR. The applicant revised FSAR Section 2.2.1.3.4 to clarify why smoke and gases from forest/grass fires would not be a problem. The revision included the following: "Due to the lack of facilities with hazardous materials that could create non-flammable gases or chemical bearing clouds as a result of a forest fire located within 5 miles of the site as described in Section 2.2.2, these clouds are not considered to be a concern." The applicant also explained how potential fuels for forest and grass fires were minimized in the plant area. The NRC staff considered this FSAR revision acceptable and closed the RAI. After reviewing potential fuel sources and the applicant's plans for controlling them, the staff concurred with the applicant's conclusion that smoke and vapors from forest/grass fires would not prevent the safe operation of the plant.

Accidents were considered in the vicinity of Units 2 and 3 that could lead to high heat fluxes or smoke, and nonflammable gas or chemical-bearing clouds from the release of materials as a consequence of fires. Large amounts of vegetation are in the vicinity of Units 2 and 3 and a wildfire could occur. An analysis following the methodology in NUREG-1805, "Fire Dynamics Tools (FDTs) Quantitative Fire Hazard Analysis Methods for the U.S. Nuclear Regulatory Commission Fire Protection Inspection Program," was performed to determine the incident heat flux on Units 2 and 3. The following conservative assumptions were used in calculating the incident heat flux:

- The wildfire was assumed to occur at plant elevation.
- The closest forest area with a significant fire line is that due west of the southernmost unit, Unit 3.
- It was assumed that the wildfire is burning toward the plant (transmission lines) in a uniform fire line perpendicular to the line identifying the closest separation. This fire line is conservatively confined to 1,000 feet, running north to south along the western edge of the transmission line. This area is assumed to continuously and simultaneously burn at peak output.
- Tree heights are conservatively assumed to be 82 feet.
- The flame height calculated is conservatively assumed to be the height of the calculated flame in addition to the tree height.
- The wildfire postulated was assumed to have a spread rate of 0.5 meters per second (m/s).

The incident heat flux at the closest structure, the firewater storage tank of Unit 3 located 1,050 feet from the postulated fire was calculated to be 1.287 kW/m^2.

Therefore, given the low incident heat flux calculated, the long separation distances to safety-related structures, and the various conservatisms, a wildfire would not affect the safe operation or shutdown of Units 2 and 3.

The NRC staff verified by site visits and a review of publically available site maps and satellite photographs that the applicant's assumptions were either reasonable or conservative and verified that the calculated flux value would not affect the safe operation of either unit.

<u>Collision with Intake Structure</u>

Commercial tankers or shipping barges do not navigate the Monticello Reservoir. Taking into account the small size of the recreational water vehicles that can navigate on the reservoir, no significant collision can take place at the intake structure.

The NRC staff verified, by site visits and a review of publically available information, that Monticello reservoir is not navigable by commercial traffic. Therefore, a collision with the intake structure is not a credible plant safety or operability event.

Liquid Spills

The accidental release of oil or liquids that may be corrosive, cryogenic, or coagulant were considered to determine if a potential exists for such liquids to be drawn into the plant's intake structure and circulating water system or otherwise affect the plant's safe operation. No storage facilities for corrosive, cryogenic, or coagulant oil or liquids were identified; therefore, they are neither drawn into the intake structures nor affect the plant's safe operation. Commercial tankers or shipping barges do not navigate the Monticello Reservoir. Therefore, the NRC staff concurs that no significant corrosive, cryogenic, or coagulant spills could be drawn into the non-safety-related intake structure.

2.2.3.5 *Post Combined License Activities*

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

2.2.3.6 *Conclusion*

The NRC staff reviewed the application and checked the referenced DCD. The NRC staff's review confirmed that the applicant addressed the required information relating to evaluation of potential accidents, and there is no outstanding information expected to be addressed in the VCSNS COL FSAR related to this section. The results of the NRC staff's technical evaluation of the information incorporated by reference in the VCSNS COL application are documented in NUREG-1793 and its supplements.

On the basis of confirmatory analysis, the staff determined that the concentrations of the two standard AP1000 chemicals, hydrazine, and carbon dioxide, the 28% ammonium hydroxide stored on Unit 1's site, and two of the chemicals transported on the Norfolk Southern rail line, cyclohexylamine and chlorodifluoromethane all exceed the respective IDLH concentration outside the control room. Therefore, the two standard AP1000 chemicals, hydrazine and carbon dioxide, the 28% ammonium hydroxide stored on Unit 1's site, and two of the chemicals transported on the Norfolk Southern rail line, cyclohexylamine and chlorodifluoromethane are identified for further evaluation by the staff in SER Section 6.4 for control room habitability, along with the review and evaluation of other chemicals listed in Table 6.4-201.

As set forth above, the applicant has identified potential accidents related to the presence of hazardous materials or activities in the site vicinity that could affect a nuclear power plant.

The staff has reviewed VCS COL 2.2-1, VCS COL 6.4-1, and STD COL 6.4-1 and, for the reasons given above, concludes that the applicant has established that the construction and operation of a nuclear power plant or plants of the specified type on the proposed site location is acceptable to meet the requirements of 10 CFR 52.79(a)(1)(iv) and 10 CFR 52.79(a)(1)(vi) with respect to determining the acceptability of the site.

2.3 Meteorology

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

2.3.1 Regional Climatology

2.3.1.1 *Introduction*

Section 2.3.1, "Regional Climatology," of the VCSNS 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.

This SER section also addresses the supplemental information in VCSNS COL FSAR Section 2.3.6 related to regional climatology.

2.3.1.2 *Summary of Application*

Section 2.3 of the VCSNS COL FSAR, Revision 5, incorporates by reference Section 2.3 of the AP1000 DCD, Revision 19.

In addition, in VCSNS COL FSAR Section 2.3, the applicant provided the following:

Tier 1 and 2 Departure

- VCS DEP 2.0-2

The applicant proposed a departure from the maximum safety wet-bulb (noncoincident) air temperature in both Tier 1 and Tier 2 material of the AP1000 DCD. The 87.3 °F maximum safety wet-bulb (noncoincident) air temperature identified in VCSNS COL FSAR Table 2.0-201 exceeds the value in AP1000 DCD Tier 1 Table 5.0-1 and DCD Tier 2 Table 2-1.

AP1000 COL Information Item

- VCS COL 2.3-1

The applicant provided additional information in VCS COL 2.3-1 to address COL Information Item 2.3-1 (COL Action Item 2.3.1-1). VCS COL 2.3-1 addresses site-specific information related to regional climatology.

Supplemental Information

- VCS SUP 2.3-1

The applicant provided supplemental information in VCSNS COL FSAR Section 2.3, discussing regional climatology and local meteorological conditions, the onsite meteorological measurements program, and short-term and long-term diffusion estimates.

- VCS SUP 2.3.6-1

The applicant provided supplemental information in VCSNS COL FSAR Section 2.3.6.1, discussing climatological characteristics of the site region.

2.3.1.3 *Regulatory Basis*

The regulatory basis of the information incorporated by reference is addressed in NUREG-1793 and its supplements.

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

The applicable regulatory requirements for identifying regional meteorology are:

- 10 CFR 52.79(a)(1)(iii), as it relates to identifying the more 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), with respect to the consideration given to the regional meteorological characteristics of the site.

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

- The basic (straight-line) 100-year return period 3-second gust wind speed 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 1, the ultimate heat sink (UHS) meteorological data that would result in the maximum evaporation and drift loss of water and minimum water cooling should be based on long-period regional records that represent site conditions. (Not applicable to a passive containment system design that does not utilize a cooling tower or cooling pond).

- The weight of the 100-year return period snowpack 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 probable 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 applicant as design and operating bases should be documented and substantiated.

Generally, the information should be presented and substantiated in accordance with acceptable practice and data as promulgated by NOAA, industry standards, and regulatory guides.

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," was issued subsequent to the publication of NUREG-0800, Section 2.3.1 to clarify 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.

2.3.1.4 *Technical Evaluation*

The NRC staff reviewed Section 2.3.1 of the VCSNS COL FSAR and checked the referenced DCD to ensure that the combination of the DCD and the COL application represents the complete scope of information relating to this review topic.[1] The NRC staff's review confirmed that the information in the application and incorporated by reference addresses the required information relating to regional climatology. The results of the NRC staff's evaluation of the information incorporated by reference in the VCSNS COL application are documented in NUREG-1793 and its supplements.

The staff reviewed the information in the VCSNS COL FSAR:

<u>*Tier 1 and 2 Departure*</u>

- VCS DEP 2.0-2

The applicant proposed a departure from the maximum safety wet-bulb (noncoincident) air temperature in both Tier 1 and Tier 2 material of the AP1000 DCD. The 87.3 °F maximum safety wet-bulb (noncoincident) air temperature identified in VCSNS COL FSAR Table 2.0-201 exceeds the value in AP1000 DCD Tier 1 Table 5.0-1 and DCD Tier 2 Table 2-1. The evaluation of the appropriateness of the 87.3 °F value for the VCSNS site is in Section 2.3.1.4.5 of this SER.

AP1000 COL Information Item

- VCS COL 2.3-1

The NRC staff reviewed VCS COL 2.3-1 related to the provision of regional climatology included in Section 2.3.1 of the VCSNS COL FSAR. The COL Information Item in Section 2.3.6.1 of the AP1000 DCD states:

> Combined License applicants referencing the AP1000 certified design will address site-specific information related to regional climatology.

Evaluation of the information provided in VCS COL 2.3-1 is discussed below.

Supplemental Information

- VCS SUP 2.3-1

The NRC staff reviewed supplemental information in VCSNS COL FSAR Section 2.3 discussing regional climatological conditions and local meteorological conditions, the onsite meteorological measurements program, and short-term and long-term diffusion estimates.

- VCS SUP 2.3.6-1

The NRC staff reviewed supplemental information in VCSNS COL FSAR Section 2.3.6.1, discussing climatological characteristics in the site region.

The NRC staff relied upon the review procedures presented in NUREG-0800, Section 2.3.1, to independently assess the technical sufficiency of the information presented by the applicant.

2.3.1.4.1 Data Sources

The applicant used several sources of data in their discussion describing the regional climatology. They used a total of 14 stations within a 50 mi radius of the VCSNS site, including the Columbia, South Carolina, NWS reporting station. The non-NWS sites were located in Fairfield, Newberry, Lexington, Union, Chester, Saluda, Kershaw, Lancaster, York, and Edgefield Counties, South Carolina. The applicant chose these sites to accurately depict the conditions that might be expected at the VCSNS site. The staff used the first-order NWS station at Columbia, South Carolina to independently confirm the representativeness of the applicant's description of the regional climate.

2.3.1.4.2 General Climate

The applicant described the general climate of the proposed VCSNS site by discussing the terrain in the Piedmont region of South Carolina, as well as the general synoptic conditions historically reported. The applicant noted that the VCSNS site is located in the southwestern portion of Climate Division SC-03 (North Central), but also lies directly adjacent to two other climate division boundaries.

The NRC staff has compared the applicant's general climate description to a similar National Climatic Data Center (NCDC) narrative description of the climate of South Carolina and has confirmed its accuracy and completeness; thus, the staff accepts the applicant's description of the general climate. (NCDC, Climates of the States #60).

2.3.1.4.3 Severe Weather

2.3.1.4.3.1 Extreme Winds

Using the American Society of Civil Engineers/Structural Engineering Institute (ASCE/SEI) Standard 7-02, "Minimum Design Loads for Buildings and Other Structures," the applicant found that the basic wind speed is about 95 miles per hour (mph). The staff confirmed this value using ASCE/SEI 7-05. ACSE/SEI 7-05 describes the basic wind speed to be the "[t]hree second wind gust speed at 33 ft (10 meters (m)) above the ground in Exposure Category C." Exposure Category C relies on the surface roughness categories as defined in Chapter 6, Wind Loads, of ASCE/SEI 7-05. Exposure Category C is acceptable at the VCSNS site due to scattered obstructions of various sizes in the immediate site area. Exposure Category B specifies that there must be urban and suburban areas, wooded areas, or other terrain with numerous closely spaced obstructions having the size of single-family dwellings or larger, prevailing in the upwind direction for a distance of at least 2,600 ft (792 m) or 20 times the height of the building, whichever is greater. Exposure Category D specifies that there must be flat, unobstructed areas and water surfaces prevailing in the upwind direction for a distance greater than 5,000 ft (1,525 m) or 20 times the building height, whichever is greater. Neither Exposure Category B nor Exposure Category D accurately describes the conditions at the VCSNS meteorological tower. ASCE/SEI 7-05 states that Exposure Category C shall apply for all cases where Exposures B or D does not apply.

The staff compared the applicant's extreme wind calculations against data from the National Institute of Standards and Technology (NIST) and Texas Tech. This NIST and Texas Tech wind speed database includes all peak gust data available in digital form at NCDC at the time of the request[2]. All peak gust speed data records were extracted from TD-3210, Summary of the Day first order tapes, from the beginning of record through the most recent data available from 1990. The staff found a maximum 10-m wind speed for Columbia, South Carolina to be 82.4 mph, which occurred on June 6, 1990. In RAI 2.3.1-2, the staff requested that the applicant provide more information about wind speeds during Hurricane Hugo (1989). In response to RAI 2.3.1-2, the applicant stated that during Hurricane Hugo, wind speeds of 109 mph were recorded at Shaw Air Force Base (AFB). Shaw AFB is located approximately 54 mi from the VCSNS site and is closer to the coast, making it more prone to high winds associated with landfalling tropical systems. Hugo's intensity rapidly decreased as it moved further inland, exhibiting only 70 mph winds at the Columbia NWS reporting station. The staff independently confirmed the applicant's assessment of the storm, and accepts the content of the RAI response as correct and adequate; therefore, RAI 2.3.1-2 is closed.

Consistent with NUREG-0800, Section 2.3.1, the applicant chose the 100-year return period 3-second wind gust site characteristic based on ASCE/SEI 7-05, "Minimum Design Loads for Buildings and Other Structures," for the proposed COL site. The applicant states that the 50-year return period 3-second gust is 95 mph. The applicant used a scaling factor of 1.07 to determine the 100-year return period 3-second gust of 102 mph.

A comparison between the AP1000 site parameters and the VCSNS site characteristics for the maximum 3-second wind gust is presented in VCSNS COL FSAR Table 2.0-201. The

[2] http://www.itl.nist.gov/div898/winds/nistttu.htm Accessed on 11/18/2008.

applicant's site characteristics for extreme winds are conservatively bounded by the AP1000 DCD site parameters. Using the most recent data from ASCE/SEI 7-05 (data through 2005), as well as the maximum wind speed data from the NIST database, the staff was able to confirm that the 100-year return period 3-second gust is the bounding nontornado related wind speed for the site region. Therefore, the staff accepts this value as the VCSNS site characteristic operating basis wind speed.

2.3.1.4.3.2 Tornadoes

VCSNS COL FSAR Table 2.3-227 lists the tornadoes that have been reported in the nine counties surrounding the VCSNS site. The applicant stated that there have been 124 tornadoes reported in these counties during the period from 1950 through August 2003. This results in approximately 2.3 tornadoes per year within about 50 mi of the VCSNS site. Using data from the NCDC Storm Events Database, the staff has confirmed the number of tornadoes reported in the counties surrounding the VCSNS site.

The applicant chose tornado site characteristics based on RG 1.76, Revision 1, and NUREG/CR-4461, "Tornado Climatology of the Contiguous United States," Revisions 1 and 2. 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 I where the most severe tornadoes frequently occur and corresponds to the most severe design-basis tornado characteristics. The applicant proposed the following tornado site characteristic, which is listed in VCSNS COL FSAR Table 2.0-201:

Maximum Wind Speed	230 mph

Because the applicant has identified design-basis tornado site characteristics based on RG 1.76, Revision 1, the staff concludes that the applicant's tornado site characteristic is acceptable. As shown in FSAR Table 2.0-201, the VCSNS site characteristic tornado wind speed is bounded by the AP1000 DCD site parameter value of 300 mph.

2.3.1.4.3.3 Tropical Cyclones

The applicant discussed a history of hurricanes and tropical storms impacting the area around the VCSNS site between 1851 and 2006. The applicant stated that 85 tropical cyclone centers or storm tracks have passed within 100 nautical mi of the Units 2 and 3 site during this historical period. Of the 85 storms, 37 were tropical storms, 7 were Category 1, 3 were Category 2, 1 was a Category 3, and 1 was a Category 4 hurricane.

The staff found that there were 57 tropical cyclones (Tropical Storms – Category 5) that passed within 100 nautical mi of Fairfield County. Of those 57 storms, 39 of them were tropical storms, 11 were Category 1, 4 were Category 2, 2 were Category 3, and 1 was Category 4. The staff recognizes that there are differences in the number of storms reported in the area between the staff and the applicant. However, the staff finds these differences to be small and does not consider them to have an impact on the safety analysis. Therefore, the staff accepts the applicant's descriptions of the number of hurricanes in the vicinity of Fairfield County, South Carolina.

2.3.1.4.3.4 Precipitation Extremes

The applicant stated that precipitation can vary significantly from one station to another because precipitation is a point measurement. The staff agrees with this assessment because extreme precipitation events are generally short lived and confined to a small region. Because of this, one station may report extreme precipitation; whereas, a nearby station may report much less. Based on observations from 14 nearby climatological observing stations, the applicant presented historical precipitation extremes for the region. The applicant stated that the highest 24-hour rainfall total in the area was 10.42 inches on August 18, 1986, about 18 mi to the west of the VCSNS site. The highest monthly rainfall total in the site area was 18.55 inches recorded during August 1952, at a site about 44 mi to the east-northeast of the VCSNS site. Site characteristic values corresponding to the site parameter precipitation (rain) rates for 1-hour and 5-minute rainfall rates are addressed in VCSNS COL FSAR Section 2.4.2.3.

The applicant states that frozen precipitation in the form of snow occurs occasionally in the Piedmont of South Carolina. According to the applicant, the highest recorded snowfall in the region occurred on February 10, 1973, when 15.7 inches of snow fell at the Columbia, South Carolina NWS station, approximately 26 mi south-southeast of the VCSNS site.

The staff also reviewed the applicant's additional information related to winter precipitation roof loading provided in VCSNS COL FSAR Section 2.3.1.3.4. The applicant stated, in FSAR Section 2.4.10, that the AP1000 safety-related roofs are sloped and designed to handle winter snowpack with margin to handle rainfall on top of the 100-year snowpack. According to the applicant, the roofs of safety-related buildings are sloped such that rainfall is directed towards gutters located along the edges of the roofs; therefore, ponding of rain water with pre-existing snow pack conditions will not occur. During the course of the review, an inconsistency was noticed between the value stated by the applicant for VCSNS site-specific 100-year ground snow load in VCSNS COL FSAR Table 2.0-201 of 12.2 pounds per square foot (lb/ft^2), and that stated in VCSNS COL FSAR Section 2.3.1.3.4 of 12.4 lb/ft^2. In RAI 2.3.1-9, the staff requested that the applicant clarify this discrepancy. In response to RAI 2.3.1-9, the applicant proposed revising the VCSNS COL FSAR Table 2.0-201 to reflect a 100-year ground snow load of 12.4 lb/ft^2. The staff finds the ground snow load of 12.4 lb/ft^2 to be acceptable because it is supported by local NWS data; therefore, RAI 2.3.1-8 is resolved. The commitment to update the FSAR to reflect the ground snow load of 12.4 lb/ft^2 is being tracked as **Confirmatory Item 2.3.1-1**. The VCSNS site-specific 100-year ground snow load of 12.4 lb/ft^2 is well within the AP1000 design basis ground snow load site parameter value of 75 lb/ft^2.

Resolution of Confirmatory Item 2.3.1-1

Confirmatory Item 2.3.1-1 is an applicant commitment to update its FSAR to include the changes to FSAR Table 2.0-201 to reflect a 100-year ground snow load of 12.4 lb/ft^2. The staff verified that the VCSNS COL FSAR was appropriately updated. As a result, Confirmatory Item 2.3.1-1 is now closed.

The NRC staff issued DC/COL-ISG-007, which clarifies the NRC 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 NRC staff guidance as discussed in NUREG-0800, Section 2.3.1.

The ISG states that normal and extreme winter precipitation events should be identified in NUREG-0800, Section 2.3.1 as COL site characteristics for use in NUREG-0800, Section 3.8.4

in determining the 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 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-mi) area at a particular geographical location during those months with the historically highest snowpacks.

The applicant referenced VCSNS COL FSAR Section 2.4.10 and AP1000 DCD Section 3.4.1.1.1, which state that "the roofs are sloped such that rainfall is directed towards gutters located along the edges of the roofs. Therefore, ponding of water on the roofs is precluded."

The applicant identified the maximum 24-hour snowfall for the area surrounding the VCSNS site to be 15.7 inches on February 10, 1973. This was measured at the Columbia, South Carolina NWS station located about 26 mi south-southeast of the Units 2 and 3 site. The applicant identified its extreme frozen winter precipitation event as 12.4 lb/ft^2, based on the 100-year return period 48-hour snowfall event for any of the climatological reporting stations in the area (15.9 inches at the Catawba, South Carolina cooperative station). The applicant also presented the normal winter precipitation event value of 12.4 lb/ft^2 based on the 100-year return period 48-hour snowfall event. The staff notes that the extreme winter precipitation ground load resulting from the combination of the antecedent 100-year return period snowpack (12 lb/ft^2) and the extreme frozen winter precipitation event (12.4 lb/ft^2) is significantly less than the AP1000 design basis ground snow load site parameter value of 75 lb/ft^2. The applicant also presented its extreme liquid winter precipitation event as 27.4 inches liquid depth, which was identified as the 48-hour PMWP. The applicant stated in VCSNS COL FSAR Section 2.4.10, that the sloped roof of the AP1000 is designed such that the 100-year snowpack will not prevent the PMWP from draining off the sloped roof system. The staff has independently confirmed the winter precipitation data presented by the applicant and finds it to be complete and acceptable.

A comparison between the AP1000 site parameter and the VCSNS site characteristic for snow load is presented in VCSNS COL FSAR Table 2.0-201. The applicant's site characteristic for snow load is conservatively bounded by the AP1000 DCD site parameter.

2.3.1.4.3.5 Snowstorms and Ice Storms

The staff found, through the South Carolina State Climatology Office (SCSCO) that the frequency of sleet and freezing rain is approximately 3.75 events per year in Chesterfield County, which is located approximately 50 mi east-northeast of the VCSNS site. This is in contrast to an average of approximately 0.75 events per year in the Lowcountry.[3] In many discussions of South Carolina geography, the term "Lowcountry" is used to describe the State's central and southern coastal counties, including Georgetown, Colleton, Beaufort, and Jasper. The Lowcountry is generally characterized by warmer temperatures, fewer frozen precipitation events, and less severe weather when compared with the region surrounding the VCSNS site.

The applicant stated that snow is not unusual in the Piedmont of South Carolina, where the VCSNS unit is located, and heavy snowstorms do occasionally occur. The applicant also states that freezing precipitation occurs about 3 to 5 days per year in the area that includes the Units 2 and 3 site.

According to the SCSCO, the area surrounding the VCSNS site received approximately 2 to 3 inches of snow on average between 1961 and 1990.[4] The SCSCO also shows that the chance of Fairfield County receiving snowfall each year is between 40 percent and 50 percent.[5]

The staff has independently confirmed the snowstorm and ice storm data presented by the applicant, through the application of ASCE SEI 7-05 and NCDC data, and finds it to be complete and acceptable.

2.3.1.4.3.6 Thunderstorms, Hail, and Lightning

The discussion on hail in VCSNS COL FSAR Section 2.3.1.3.5 has been moved to this section of the SER to provide continuity with severe weather phenomena.

The following discussion on thunderstorms, hail, and lightning is intended to provide a general understanding of the severe weather phenomena in the site region but does not result in the generation of site characteristics for use as design or operating bases.

The applicant stated that thunderstorms have been observed on an average of about 52 days per year based on a 57-year period of record for Columbia, South Carolina. Thunderstorms have occurred most frequently during the months of June, July, and August. Consistent with NUREG-0800, Section 2.3.1, the applicant compiled this information from the 2004 Local Climatological Data (LCD) for Columbia, South Carolina from the NCDC.

Using both 2004 and 2007 LCDs for Columbia from the NCDC, the staff found that thunderstorms have been observed on an average of 52 days per year. The staff agrees with the applicant that thunderstorms have occurred most frequently during the months of June, July, and August at the Columbia, South Carolina NWS station.

The applicant stated that the area surrounding the VCSNS site can expect, on average, hail with diameters of 0.75 inches or greater about 2 to 3 days per year. Hail with diameters greater than or equal to 1-inch falls, on average, about 1 or 2 days per year in the surrounding area. The

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[3] http://www.dnr.sc.gov/climate/sco/ClimateData/cli_sc_climate.php#precipitation Accessed 1/7/2009.
[4] http://www.dnr.sc.gov/climate/sco/ClimateData/map_yearly_snowfall_sc.php Accessed 1/7/2009.
[5] http://www.dnr.sc.gov/climate/sco/ClimateData/map_yearly_chance_snow.php Accessed 1/7/2009.

applicant also notes that the NCDC cautions that hailstones are point observations and are somewhat dependent on population density. Hail has been most commonly observed during the spring and early summer months, reaching a peak in May. Hail occurs least often from late summer to late winter in the area surrounding the site. Consistent with the guidance provided in NUREG-0800, Section 2.3.1, the applicant compiled this information from the NCDC. Using NCDC data for Fairfield, Newberry, Lexington, and Richland Counties, the staff found an average of 3.71 hail days per year between 1959 and 2008.

The SCSCO states that hail occurs most often during spring thunderstorms from March through May. They state that the incidence of hail occurs approximately 1- to 1.5-hail days per year in the Midlands, Piedmont, and Foothills.

The applicant stated that there are 16.0 lightning flashes to earth per year per square mi (~6.1 flashes to earth per square km) in the VCSNS site area based on data from Columbia, South Carolina. The staff independently evaluated this estimate based on LCDs for Columbia from the NCDC, a method attributed to the Electric Power Research Institute (EPRI) (~6 flashes to earth per square km), a 5-year flash density map from Vaisala[6] (4 - 8 flashes to earth per square km), and a 1999 paper by G. Huffines and R.E. Orville, titled "Lightning Ground Flash Density and Thunderstorm Duration in the Continental United States: 1989-96" (5 - 7 flashes to earth per square km). Thus, the applicant provided a reasonable estimate of the frequency of lightning flashes.

Based on a mean frequency of 16.0 lightning flashes to earth per year per square km and a power block area (PBA) area of approximately 0.063 square mi for the proposed Units 2 and 3, the applicant predicted that 1.01 lightning flashes per year can be expected within the PBA. The staff has confirmed the applicant's calculation and finds it to be a reasonable estimate.

Consistent with NUREG-0800, Section 2.3.1, the applicant has provided the necessary information regarding thunderstorms, hail, and lightning. As previously discussed, the staff has independently confirmed the descriptions provided by the applicant and accepts them as correct and adequate.

2.3.1.4.4 Meteorological Data for Evaluating the Ultimate Heat Sink

The applicant states that meteorological conditions will not impact the passive containment cooling system in the AP1000 design. The staff agrees with this statement for the reasons discussed below.

Many plants use a cooling tower as a UHS to dissipate residual heat after an accident. Instead of using a cooling tower to release heat to the atmosphere, the AP1000 design uses a passive containment cooling system (PCS) to provide the safety-related UHS. The PCS is designed to withstand the maximum safety dry-bulb and coincident wet-bulb air temperature site parameters specified in the AP1000 DCD. Therefore, the applicant need not identify meteorological characteristics for evaluating the design of a UHS cooling tower.

[6] http://www.weather.gov/om/lightning/images/map.pdf Accessed 1/7/2009.

2.3.1.4.5 Design Basis Dry and Wet-Bulb Temperatures

The AP1000 DCD site parameters for ambient air temperature are defined as follows:

- Maximum Safety Dry-Bulb Temperature and Coincident Wet-Bulb Temperature: 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.

- Maximum Safety Noncoincident Wet-Bulb Temperature: 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.

- Maximum Normal Dry-Bulb Temperature and Coincident Wet-Bulb Temperature: The dry-bulb temperature component of this site parameter pair is represented by a maximum dry-bulb temperature that exists for 2 hours or more, excluding the highest 1 percent of the values in an hourly data set. The wet-bulb temperature component is similarly represented by the highest wet-bulb temperature excluding the highest 1 percent of the data, although there is no minimum 2-hour persistence criterion associated with this wet-bulb temperature.

- Maximum Normal Noncoincident Wet-Bulb Temperature: This site parameter value represents a maximum wet-bulb temperature, excluding the highest 1 percent of the values in an hourly data set (i.e., a 1 percent exceedance), that exists for 2 hours or more.

The safety temperature site characteristic values are based on conservative 100-year estimates. The ambient air temperatures used for comparison against the AP1000 site parameters are listed in VCSNS COL FSAR Table 2.0-201.

The staff evaluated the design-basis temperature site characteristic values primarily based on Columbia, South Carolina hourly temperature data from 1936 through 2008. Columbia is the closest climate observation station to the VCSNS site (located approximately 26 mi to the south-southwest) with hourly temperature and humidity data. Because it is located at approximately the same elevation as the VCSNS site, the staff expects that the temperature and humidity data recorded at Columbia should be generally representative of VCSNS site conditions. In order to confirm this hypothesis, the staff generated 2007 and 2008 Columbia dry-bulb statistics from the NCDC online database and compared them with similar statistics generated from the applicant's 2007 and 2008 onsite meteorological database. The results of this comparison are as follows:

DRY-BULB STATISTIC	2007		2008	
	Columbia	VCSNS	Columbia	VCSNS
Maximum	41.0 °C	37.6 °C	38.0 °C	37.1 °C
1 Percent Exceedance	36.0 °C	34.8 °C	34.0 °C	33.8 °C
Median	19.0 °C	19.1 °C	18.3 °C	17.7 °C
99 Percent	-3.0 °C	-0.8 °C	-4.0 °C	-2.4 °C

DRY-BULB STATISTIC	2007		2008	
	Columbia	VCSNS	Columbia	VCSNS
Exceedance				
Minimum	-6.0 °C	-6.4 °C	-9.0 °C	-6.8 °C

The staff also compiled and compared the Columbia dew point statistics with the onsite dew point data provided by the applicant.

DEW POINT STATISTIC	2007		2008	
	Columbia	VCSNS	Columbia	VCSNS
Maximum	24.0 °C	23.7 °C	24.0 °C	23.6 °C
1 Percent Exceedance	23.0 °C	22.5 °C	22.8 °C	22.0 °C
Median	12.0 °C	12.4 °C	12.2 °C	12.1 °C

This comparison shows that the Columbia dry-bulb and dew point (humidity) data are generally representative of (e.g., within 1 degree Celsius [C]) or slightly more conservative than the VCSNS data.

The American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE) Weather Data Viewer, Version 3.0 was used to verify the applicant's 100-year return period dry-bulb temperature values. A linear regression analysis was used by the staff to confirm the applicant's 100-year maximum coincident wet-bulb temperature.

As shown in VCSNS COL FSAR Table 2.0-201, most of the applicant's site characteristics for ambient air temperature are conservatively bounded by the AP1000 DCD site parameters. In response to RAI 2.3.1-7, dated October 8, 2009, the applicant presented updated site characteristic dry-bulb and wet-bulb temperatures. These temperatures included the use of 100-year return period dry-bulb temperatures with the maximum coincident wet-bulb temperatures and the 100-year return period noncoincident wet-bulb temperatures. 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 applicant's, both the staff's and applicant's dry-bulb and coincident wet-bulb temperatures are well within bounds of the AP1000 DCD parameter of 86.1 °F for the coincident wet-bulb temperature. In response to the RAI, the applicant stated that the 100-year return period noncoincident wet-bulb temperature of 87.3 °F exceeds the AP1000 DCD site parameter value of 86.1 °F. The applicant's value bounds the staff's independently calculated 100-year return period noncoincident wet-bulb temperature, and is, therefore, acceptable to the staff.

The applicant stated that an exemption from 10 CFR Part 52, Appendix D, Section IV.A.2.d, pursuant to 10 CFR 52.7 and 10 CFR 52.93 and a departure from AP1000 DCD Table 2-1 is necessary. Details on the departure (VCS DEP 2.0-2) and associated exemption for the maximum safety wet-bulb (noncoincident) air temperature of 87.3 °F can be found in Part 7.B.3, of the VCSNS COL application. The staff has determined that the applicant's stated maximum safety wet-bulb (noncoincident) air temperature of 87.3 °F is appropriate for the VCSNS site.

The staff's evaluation of the effects that this higher temperature has on the operation of the AP1000 design is addressed in Sections 2.0, 5.4, 6.2, 6.4, 9.1.3, 9.2.2 and 9.2.7 of this SER. .

2.3.1.4.6 Restrictive Dispersion Conditions

The following discussion on inversions and high air pollution potential is intended to provide a general understanding of the phenomena in the site region but does not result in the generation of site characteristics for use as design or operating bases.

The applicant used model-derived mixing height data to characterize the potential for inversions at the VCSNS site. These data were determined by using an interactive, spatial database developed by the U.S. Department of Agriculture – Forest Service, referred to as the Ventilation Climate Information System. VCSNS COL FSAR Table 2.3-204 lists the maximum, mean, and minimum monthly mixing depths during the AM and PM hours, as derived from the interactive database. The lowest mean monthly mixing height occurs during the morning hours of October (313m) and the greatest mean mixing height occurs in afternoon hours of May (1745m). The staff verified the results in VCSNS COL FSAR Table 2.3-204 by using data published in documents referenced in NUREG-0800, Section 2.3.1.

2.3.1.4.7 Climate Changes

The applicant provided a lengthy discussion on the climatology of the VCSNS region with regards to the trends in meteorological phenomena.

As specified in NUREG-0800, the applicability of data used to discuss severe weather phenomena that may impact the proposed COL site during the expected period of reactor operation should be substantiated. Long-term environmental changes and changes to the region resulting from human or natural causes may affect the applicability of the historical data to describe the site's climate characteristics. Although there is no scientific consensus regarding the issue of climate change, the staff believes current climate trends should be analyzed for the potential of ongoing environmental changes.

The applicant analyzed trends in temperature and rainfall normals over a 70-year period for successive 30-year intervals by decade beginning in 1931 (e.g., 1931 – 1960, 1941 – 1970, etc.) for the climate division SC-03. The applicant stated that the normal (i.e., 30-year average) temperature decreased over most of the 70-year period, with a slight increase of about 0.2 °F to 0.4 °F during the most recent normal period and the normal rainfall has trended upward by about 1.6 to 4.6 inches.

The U.S. Global Change Research Program (USGCRP) released a report to the President and Members of Congress in June 2009 entitled "Global Climate Change Impacts in the United States." This report, produced by an advisory committee chartered under the Federal Advisory Committee Act, summarizes the science of climate change and the impacts of climate change on the United States.

The USGCRP report found that the average annual temperature of the Southeast (which includes South Carolina, where the VCSNS site is located) did not change significantly over the past century as a whole, but the annual average temperature has risen about 2 °F since 1970 with the greatest seasonal increase in temperature occurring during the winter months. Climate models predict continued warming in all seasons across the Southeast and an increase in the rate of warming throughout the end of the 21st century. Average temperatures in the Southeast are projected to rise by 2 - 5 °F by the end of the 2050's, depending on assumptions regarding emissions.

The USGCRP report also states that there is a 5- to 10-percent decrease in observed annual average precipitation from 1958 to 2008 in the region where the VCSNS site is located. Future changes in total precipitation are more difficult to project than changes in temperature. Model projections of future precipitation generally indicated that southern areas of the United States will become drier. Except for indications that the amount of rainfall from individual hurricanes will increase, climatic models provide divergent results for future precipitation for most of the Southeast.

The USGCRP reports that the power and frequency of Atlantic hurricanes has increased substantially in recent decades, but the number of North American mainland landfalling hurricanes does not appear to have increased over the past century. The USGCRP reports that likely future changes for the United States and surrounding coastal waters include more intense hurricanes with related increases in wind and rain, but not necessarily an increase in the number of these storms that make landfall.

The applicant stated that the number of recorded severe weather events has generally increased since detailed records were routinely kept beginning around 1950. However, some of this increase is attributable to a growing population, greater public awareness and interest, and technological advances in detection. The USGCRP reaches the same conclusion. The USGCRP further states that there is no clear trend in the frequency or strength of tornadoes since the 1950s for the United States as a whole.

The USGCRP reports that the distribution by intensity for the strongest 10 percent of hail and wind reports is little changed, providing no evidence of an observed increase in the severity of such events. Climate models project future increases in the frequency of environmental conditions favorable to severe thunderstorms. But the inability to adequately model the small-scale conditions involved in thunderstorm development remains a limiting factor in projecting the future character of severe thunderstorms and other small-scale weather phenomena.

In conclusion, the staff acknowledges that long-term climatic change resulting from human or natural causes may introduce changes into the most severe natural phenomena reported for the site. However, no conclusive evidence or consensus of opinion is available on the rapidity or nature of such changes. There is a level of uncertainty in projecting future conditions because the assumptions regarding the future level of emissions of heat trapping gases depend on projections of population, economic activity, and choice of energy technologies. If it becomes evident that long-term climatic change is influencing the most severe natural phenomena reported at the site, the COL holders have a continuing obligation to ensure that their plants stay within the licensing basis.

2.3.1.5 *Post Combined License Activities*

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

2.3.1.6 *Conclusion*

The NRC staff reviewed the application and checked the referenced DCD. The NRC staff's review confirmed that the applicant addressed the required information relating to regional climatology, and there is no outstanding information expected to be addressed in the VCSNS COL FSAR related to this section. The results of the NRC staff's technical evaluation of the information incorporated by reference in the VCSNS COL application are documented in NUREG-1793 and its supplements.

AP1000 DCD, Section 2.3.6.1 states that a COL applicant shall address the site-specific regional climatological information. As set forth above, the applicant has presented and substantiated information to establish the regional meteorological characteristics. The staff has reviewed the information provided in VCS COL 2.3-1, VCS SUP 2.3-1, and VCS SUP 2.3.6-1 and, concludes that the applicant has established the meteorological characteristics at the site and in the surrounding area acceptable to meet the requirements of 10 CFR 100.20(c)(2) and 10 CFR 100.21(d) with respect to determining the acceptability of the site. The staff has reviewed VCS DEP 2.0-2 and has determined that the applicant's stated maximum safety wet-bulb (noncoincident) air temperature of 87.3 °F is acceptable for the VCSNS site. The staff finds that the applicant has provided a sufficient description to meet the requirements of the AP1000 DCD. VCS COL 2.3-1 has been adequately addressed by the applicant and is resolved.

The staff also finds that the applicant has considered the most severe natural phenomena historically reported for the site and surrounding area in establishing the site characteristics. Specifically, the staff has accepted the methodologies used to analyze these natural phenomena and determine the severity of the weather phenomena reflected in these site characteristics. Because the applicant has correctly implemented these methodologies, as described above, the staff has determined that the applicant has considered these historical phenomena with margin sufficient for the limited accuracy, quantity, and period of time in which the data have been accumulated in accordance with 10 CFR 52.79(a)(1)(iii).

2.3.2 Local Meteorology

2.3.2.1 *Introduction*

Section 2.3.2, "Local Meteorology," of the VCSNS COL FSAR addresses the local (site) meteorological parameters, 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 operation, and a topographical description of the site and its environs.

2.3.2.2 *Summary of Application*

Section 2.3 of the VCSNS COL FSAR, Revision 5, incorporates by reference Section 2.3 of the AP1000 DCD, Revision 19.

In addition, in VCSNS COL FSAR Section 2.3, the applicant provided the following:

AP1000 COL Information Item

- VCS COL 2.3-2

The applicant provided additional information in VCS COL 2.3-2 to address COL Information Item 2.3-2 (COL Action Item 2.3.2-1). VCS COL 2.3-2 addresses the provisions of local meteorology.

Supplemental Information

- VCS SUP 2.3-1

The applicant provided supplemental information in VCSNS COL FSAR Section 2.3, discussing regional climatological and local meteorological conditions, the onsite meteorological measurements program, and short-term and long-term diffusion estimates.

- VCS SUP 2.3.6-2

The applicant provided supplemental information in VCSNS COL FSAR Section 2.3.6.2 addressing site-specific meteorological characteristics related to atmospheric dispersion, climatological conditions, other related information that both influences and may affect those characteristics, and air quality conditions in the broader site area.

2.3.2.3 *Regulatory Basis*

The regulatory basis of the information incorporated by reference is addressed in NUREG-1793 and its supplements.

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) with respect 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, “Meteorological Monitoring Programs for Nuclear Power Plants,” 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. 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 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 NRC staff reviewed Section 2.3.2 of the VCSNS COL FSAR and checked the referenced DCD to ensure that the combination of the DCD and the COL application represents the complete scope of information relating to this review topic.[1] The NRC staff's review confirmed that the information in the application and incorporated by reference addresses the required information relating to local meteorology. The results of the NRC staff's evaluation of the information incorporated by reference in the VCSNS COL application are documented in NUREG-1793 and its supplements.

The staff reviewed the information in the VCSNS COL FSAR:

AP1000 COL Information Item

- VCS COL 2.3-2

The NRC staff reviewed VCS COL 2.3-2, related to the provisions of local meteorology included in Section 2.3.2 of the VCSNS COL FSAR. The COL information item in Section 2.3.6.2 of the AP1000 DCD states:

> Combined License applicants referencing the AP1000 certified design will address site-specific local meteorology information.

Evaluation of the information provided in VCS COL 2.3-2 is discussed below.

Supplemental Information

- VCS SUP 2.3-1

The NRC staff reviewed the supplemental information VCS SUP 2.3-1 in VCSNS COL FSAR Section 2.3, discussing local meteorological conditions.

- VCS SUP 2.3.6-2

The NRC staff reviewed the supplemental information in VCSNS COL FSAR Section 2.3.6.2 addressing site-specific meteorological characteristics related to atmospheric dispersion, climatological conditions, other related information that both influences and may affect those characteristics, and air quality conditions in the broader site area.

The NRC staff relied upon the review procedures presented in NUREG-0800, Section 2.3.2, to independently assess the technical sufficiency of the information presented by the applicant.

2.3.2.4.1 Data Sources

Local meteorology data for the VCSNS site was provided by the first-order NWS station at Columbia, South Carolina, and 13 other nearby cooperative network observing stations, and measurements from the onsite meteorological measurements program operated in support of Units 2 and 3.

Measurements from the tower-mounted meteorological monitoring system that supports Units 2 and 3 include wind direction, wind speed, and atmospheric stability. These measurements are used as the basis for determining and characterizing atmospheric dispersion conditions in the vicinity of the site. The measurements from this tower were taken over a period of two annual cycles from January 1, 2007 through December 31, 2008.

2.3.2.4.2 Normal, Mean, and Extreme Values of Meteorological Parameters

2.3.2.4.2.1 Average Wind Direction and Wind Speed Conditions

This section discusses VCSNS COL FSAR Section 2.3.2.2.1, "Average Wind Direction and Wind Speed Conditions," and FSAR Section 2.3.2.2.2, "Wind Direction Persistence."

The applicant produced monthly and annual wind summaries from the onsite meteorological data from January 1, 2007 through December 31, 2008. VCSNS COL FSAR Tables 2.3-207 and 2.3-208 presented the wind direction persistence/wind speed distributions for the Units 2 and 3 monitoring program for both the 10-m and 60-m heights, respectively. The 2-year joint frequency distribution, based on the lower-level measurement height, was used as input to the atmospheric dispersion models discussed in FSAR Sections 2.3.4 and 2.3.5. Using the hourly meteorological data provided by the applicant, the staff independently produced the 2-year joint frequency distributions at both the lower-level and upper-level measurement heights and has confirmed the applicant's wind summaries as correct and acceptable.

2.3.2.4.2.2 Atmospheric Stability

The applicant classified atmospheric stability in accordance with the guidance provided in RG 1.23, Revision 1. Atmospheric stability is a critical parameter for estimating dispersion characteristics in VCSNS COL FSAR Sections 2.3.4 and 2.3.5. Dispersion of effluents is greatest for extremely unstable atmospheric conditions (i.e., Pasquill stability Class A) and decreases progressively through extremely stable conditions (i.e., Pasquill stability Class G). The applicant based its stability classification on temperature change with height (i.e., delta-temperature or $\Delta T/\Delta Z$) between the 60-m and 10-m height, as measured by the VCSNS onsite meteorological measurements program from January 1, 2007 through December 31, 2008.

Frequency of occurrence for each stability class is one of the inputs to the dispersion models used in VCSNS COL FSAR Sections 2.3.4 and 2.3.5. The applicant included these data in the form of a joint frequency distribution (JFD) of wind speed and direction data as a function of stability class. A comparison of a JFD developed by the staff from the hourly data submitted by the applicant with the JFD developed by the applicant showed reasonable agreement.

Based on the staff's past experience with stability data at various sites, a predominance of neutral (Pasquill stability Class D) and slightly stable (Pasquill stability Class E) conditions at the proposed VCSNS site is generally consistent with expected meteorological conditions. Using a JFD of wind speed, wind direction, and atmospheric stability, the staff has independently confirmed that the 2-year statistics presented by the applicant are correct and adequate.

2.3.2.4.2.3 Temperature

The applicant characterized normal and extreme temperatures for the site based on the 13 surrounding observation stations listed in VCSNS COL FSAR Section 2.3.1.1, as well as the Columbia, South Carolina NWS station. The extreme maximum temperatures recorded near the site range from 106 °F to 111 °F and the extreme minimum temperatures recorded near the site range from -1 °F to -5 °F. Annual average temperatures for the 14 surrounding sites range from 59.9 °F to 63.6 °F. The applicant stated that the annual average diurnal (day-to-night) temperature differences in the site vicinity range from 21.1 °F to 26.8 °F. The applicant states that this difference in diurnal temperature ranges may be due in part to the differences in station elevation.

Using data from the NCDC, the staff reviewed the daily mean temperatures, the extreme temperatures, and the diurnal temperature ranges presented by the applicant. The staff confirmed the temperature characterizations, as presented in VCSNS COL FSAR Section 2.3.2.2.4, and accepts them as correct.

2.3.2.4.2.4 Atmospheric Water Vapor

The applicant presented wet-bulb temperatures, dew point temperatures, and relative humidity data summaries from the Columbia NWS observation station to characterize the typical atmospheric moisture conditions near the proposed VCSNS site.

Based on a 21-year period of record, the applicant indicated that the mean annual wet-bulb temperature is 57.0 °F. The highest monthly mean wet-bulb temperature is 73.5 °F during July and the lowest monthly mean wet-bulb temperature is 50.1 °F during January. According to the applicant, the mean annual dew point temperature at Columbia is 51.6 °F, which also reaches its maximum during summer and minimum during winter. The applicant gives the highest monthly mean dew point temperature as 69.9 °F during July and the lowest monthly mean dew point temperature as 33.2 °F during January.

Based on a 30-year period of record, the applicant indicates that relative humidity averages 70 percent on an annual basis. The average early morning relative humidity levels exceed 90 percent during August, September, and November. Typically, the relative humidity values reach their diurnal maximum in the early morning and diurnal minimum during the early afternoon.

The staff reviewed the data listed in the NCDC “Columbia, South Carolina 2007 Local Climatological Data, Annual Summary with Comparative Data” to verify the wet-bulb temperatures, dew point temperatures, and relative humidity statistics presented by the applicant and discussed above. The staff concludes that the applicant’s values are correct and appropriate.

2.3.2.4.2.5 Precipitation

Based on data from the 14 surrounding observation stations, the applicant stated that the average annual precipitation (water equivalent) totals vary by approximately 5.7 inches (or about 12 percent), ranging from 43.59 inches to 49.33 inches. The applicant states that there are two seasonal maximums, the highest during the summer and the second during the winter into early spring. The applicant stated that the long-term average annual total rainfall at the VCSNS site could reasonably be expected to be within this range.

Using daily snowfall and rainfall data from the NCDC, the staff has independently verified the precipitation statistics presented in VCSNS COL FSAR Section 2.3.2.2.6 and accepts them as correct.

2.3.2.4.2.6 Fog

The applicant stated that Columbia is the closest station to the proposed VCSNS site that makes fog observations. The applicant stated that, based on a 56-year period of record, Columbia averages about 26 days per year of heavy fog conditions (e.g., visibility is reduced to 0.25 mi or less). The peak frequency occurs from November to January, averaging approximately 3 days per month. Heavy fog occurs least often from mid-spring to early summer (i.e., April to June), averaging less than 1.5 days per month.

The staff agrees with the applicant that the frequency of heavy fog conditions at the proposed VCSNS site will be higher due to the proximity of the Monticello and Parr Reservoirs, its location near the Broad River, and gradually increasing elevations toward the northwest.

The staff reviewed the data listed in the NCDC "Columbia, South Carolina 2007 Local Climatological Data, Annual Summary with Comparative Data" to verify the fog statistics presented by the applicant and concludes that the applicant's fog statistics are correct and appropriate.

2.3.2.4.3 Topographic Description

The proposed VCSNS site is located within the larger VCSNS site property, which is in the southeast corner of Fairfield County, South Carolina. The VCSNS site is located approximately 2 mi inland (to the south) of the southern shore of the Monticello Reservoir, and about 0.75 mi east of the Parr Reservoir. The applicant also provided terrain elevation profiles along each of the 16 standard 22½-degree compass radials out to a distance of 50 mi. Based on these profiles, the applicant characterized the proposed VCSNS site terrain as gently rolling hills to hilly with elevations decreasing to the east through the southeast beyond approximately 15 to 20 mi.

The staff agrees with this terrain characterization based on topography data from the United States Geological Survey (USGS) and a site visit. The staff concludes that the applicant provided all the necessary topographic information.

2.3.2.4.4 Potential Influence of the Plant and Related Facilities on Meteorology

The applicant stated that the associated paved, concrete, or other improved surfaces resulting from the construction of the proposed nuclear facility are insufficient to generate discernible, long-term effects to local- or micro-scale meteorological conditions. Wind flow may be altered immediately adjacent to and downwind of larger site structures, but these effects will likely dissipate within 10 structure heights downwind. SER Section 2.3.3 discusses the effects of these larger structures on wind flow.

The applicant stated that although temperature may increase above altered surfaces, the effects will be too limited in their vertical profile and horizontal extent to alter local- or regional-scale ambient temperature changes. Site clearing, grubbing, excavation, leveling, and landscape activities associated with plant construction will be localized and will not represent a significant change to the gently rolling topographic character of the site and its surrounding site area.

The staff agrees that the activities discussed above are too small-scale to impact the local meteorological characteristics of the site.

In response to RAI 2.3.2-2, dated July 20, 2009, the applicant provided a discussion concerning the impact of the AP1000 service water system (SWS) cooling tower operation on safety-related equipment and structures. The 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 PCS is the only safety-related system listed that could potentially be exposed to plume impingement. The applicant states that the plume from the mechanical draft cooling towers is unlikely to affect the PCS due to the location of the containment building being over 300 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 the discussion by the applicant to be adequate.

In response to RAI 2.3.2-3, dated July 30, 2009, the applicant provided a discussion of the effects of salt and moisture deposition on the VCSNS Units 2 and 3 transformers, switchyard equipment, or transmission lines. The 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 applicant made conservative assumptions. The SACTI results indicate that several months of salt accumulation would result in 0.03 mg/cm^2, which is the lower end of the "Light Contamination Level" range defined by the Institute of Electrical and Electronic Engineers (IEEE) standard. The staff has independently verified the source cited by the 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.

2.3.2.4.5 Current and Projected Site Air Quality

This section discusses VCSNS COL FSAR Sections 2.3.2.5.1 and 2.3.2.5.2. The applicant stated that the proposed VCSNS site is located in the Columbia Intrastate Air Quality Control Region. Fairfield and Newberry Counties, within this region, have been designated as being in attainment, or unclassified for all EPA criteria air pollutants (i.e., ozone, carbon monoxide, nitrogen dioxide, sulfur dioxide, particulate matter, and lead) (40 CFR 81.341, "South Carolina," and 40 CFR 81.108, "Columbia Intrastate Air Quality Control Region"). Lexington and Richland Counties are in attainment for all criteria pollutants with the exception of the 8-hour National Ambient Air Quality Standards for ozone (40 CFR 81.341).

According to the applicant, the proposed nuclear steam supply system (NSSS) and other radiological systems related to the proposed facility will not be sources of criteria pollutants or other hazardous air pollutants. Other proposed supporting equipment such as diesel generators, fire pump engines, auxiliary boilers, emergency station-blackout generators, and other nonradiological emission-generating sources are not expected to be, in the aggregate, a significant source of criteria pollutant emissions. The staff agrees with this assessment because these systems will be used on an infrequent basis.

2.3.2.5 *Post Combined License Activities*

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

2.3.2.6 *Conclusion*

The NRC staff reviewed the application and checked the referenced DCD. The NRC staff's review confirmed that the applicant addressed the required information relating to local meteorology, and there is no outstanding information expected to be addressed in the VCSNS COL FSAR related to this section. The results of the NRC staff's technical evaluation of the information incorporated by reference in the VCSNS COL application are documented in NUREG-1793 and its supplements.

AP1000 DCD, Section 2.3.6.2 states that a COL applicant shall address the site-specific local meteorological information. As set forth above, the applicant has presented and substantiated information describing the local meteorological, air quality, and topographic characteristics important to evaluating the adequacy of the design and siting of this plant. The staff has reviewed the information provided in VCS COL 2.3-2, and VCS SUP 2.3.6-2 and, for the reasons given above, concludes that the identification and consideration of the meteorological, air quality, and topographical characteristics of the site and the surrounding area are acceptable and meet the requirements of 10 CFR 100.20(c) and 10 CFR 100.21(d), with respect to determining the acceptability of the site. The staff finds that the applicant has provided a sufficient description to meet the requirements of the DCD. VCS COL 2.3-2 has been adequately addressed by the applicant and is resolved.

The staff also finds that the applicant has considered the appropriate site phenomena in establishing the site characteristics. Specifically, the staff has accepted the methodologies used to determine the meteorological, air quality, and topographic characteristics. Because the applicant has correctly implemented these methodologies, as described above, the staff has determined that the use of these methodologies results in site characteristics including margin sufficient for the limited accuracy, quantity, and period of time in which the data have been accumulated in accordance with 10 CFR 52.79(a)(1)(iii).

2.3.3 Onsite Meteorological Measurements Program

2.3.3.1 *Introduction*

The VCSNS onsite meteorological measurements program addresses the need for onsite meteorological monitoring and the resulting data. The NRC 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.

This section verifies that the applicant successfully implemented an appropriate onsite meteorological measurements program and that data from this program provide an acceptable basis for estimating atmospheric dispersion for DBAs and routine releases from a nuclear power plant of the type specified by the applicant.

2.3.3.2 *Summary of Application*

Section 2.3 of the VCSNS COL FSAR, Revision 5, incorporates by reference Section 2.3 of the AP1000 DCD, Revision 19.

In addition, in VCSNS COL FSAR Section 2.3, the applicant provided the following:

<u>*AP1000 COL Information Item*</u>

- VCS COL 2.3-3

The applicant provided additional information in VCS COL 2.3-3 to address COL Information Item 2.3-3 (COL Action Item 2.3.3-1). VCS COL 2.3-3 addresses the onsite meteorological measurements program.

<u>*Supplemental Information*</u>

- VCS SUP 2.3-1

The applicant provided supplemental information in VCSNS COL FSAR Section 2.3, discussing regional climatological and local meteorological conditions, the onsite meteorological measurements program, and short-tem and long-term diffusion estimates.

- VCS SUP 2.3.6-3

The applicant provided supplemental information in VCSNS COL FSAR Section 2.3.6.3 discussing site specific details regarding the onsite meteorological measurements program.

2.3.3.3 *Regulatory Basis*

The regulatory basis of the information incorporated by reference is addressed in NUREG-1793 and its supplements.

In addition, the acceptance criteria associated with the relevant requirements of the Commission regulations for the onsite meteorological measurements programs are given in Section 2.3.3 of NUREG-0800.

The applicable regulatory requirements for identifying onsite meteorological measurements program are:

- 10 CFR 100.20(c)(2), with respect to the meteorological characteristics of the site that are necessary for safety analysis or that may have an impact upon plant design in determining the acceptability of a site for a nuclear power plant.

- 10 CFR 100.21(c), with respect to the meteorological data used to evaluate site atmospheric dispersion characteristics and establish dispersion parameters such that: (1) radiological effluent release limits associated with normal operation can be met for any individual located off site; and (2) radiological dose consequences of postulated accidents meet prescribed dose limits at the EAB and the outer boundary of the LPZ.

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

- 10 CFR 50.47(b)(4), 10 CFR 50.47(b)(8), and 10 CFR 50.47(b)(9), as well as Section IV.E.2 of Appendix E, "Emergency Planning and Preparedness for Production and Utilization Facilities," to 10 CFR Part 50, with respect to the onsite meteorological information available for determining the magnitude and continuously assessing the impact of the releases of radioactive materials to the environment during a radiological emergency.

- 10 CFR Part 50, Appendix I, "Numerical Guides for Design Objectives and Limiting Conditions for Operation to Meet the Criteria," with respect to meteorological data used in determining the compliance with numerical guides for design objectives and limiting conditions for operation to meet the requirement that radioactive material in effluents released to unrestricted areas be kept as low as is reasonable achievable (ALARA).

- 10 CFR Part 20, "Standards for Protection Against Radiation," Subpart D, "Radiation Dose Limits for Individual Members of the Public," with respect to the meteorological data used to demonstrate compliance with dose limits for individual members of the public.

The following RG is applicable to this section:

- RG 1.23, "Meteorological Monitoring Programs for Nuclear Power Plants," Revision 1.

The related acceptance criteria from Section 2.3.3 of NUREG-0800 are as follows:

- The preoperational and operational monitoring programs should be described, including: (1) a site map (drawn to scale) that shows tower location and true north with respect to man-made structures, topographic features, and other features that may influence site meteorological measurements; (2) distances to nearby obstructions of flow in each downwind sector; (3) measurements made; (4) elevations of measurements; (5) exposure of instruments; (6) instrument descriptions; (7) instrument performance specifications; (8) calibration and maintenance procedures and frequencies; (9) data output and recording systems; and (10) data processing, archiving, and analysis procedures.

- Meteorological data should be presented in the form of JFD of wind speed and wind direction by atmospheric stability class in the format described in RG 1.23, Revision 1. An hour-by-hour listing of the hourly-averaged parameters should be provided in the format described in RG 1.23, Revision 1. If possible, evidence of how well these data represent long-term conditions at the site should also be presented, possibly through comparison with offsite data.

- At least two consecutive annual cycles (and preferably 3 or more whole years), including the most recent 1-year period, should be provided with the application. These data should be used by the applicant to calculate: (1) the short-term atmospheric dispersion estimates for accident releases discussed in SAR Section 2.3.4; and (2) the long-term atmospheric dispersion estimates for routine releases discussed in SAR Section 2.3.5.

- The applicant should identify and justify any deviations from the guidance provided in RG 1.23, Revision 1.

2.3.3.4 *Technical Evaluation*

The NRC staff reviewed Section 2.3.3 of the VCSNS COL FSAR and checked the referenced DCD to ensure that the combination of the DCD and the COL application represents the complete scope of information relating to this review topic.[1] The NRC staff's review confirmed that the information in the application and incorporated by reference addresses the required information relating to the onsite meteorological measurements program. The results of the NRC staff's evaluation of the information incorporated by reference in the VCSNS COL application are documented in NUREG-1793 and its supplements.

The staff reviewed the information in the VCSNS COL FSAR:

AP1000 COL Information Item

- VCS COL 2.3-3

The NRC staff reviewed VCS COL 2.3-3 related to the onsite meteorological measurements program included under Section 2.3.3 of the VCSNS COL FSAR. The COL information item in Section 2.3.6.3 of the AP1000 DCD states:

> Combined License applicants referencing the AP1000 certified design will address the site-specific onsite meteorological measurements program.

Evaluation of the information provided in VCS COL 2.3-3 is discussed below.

Supplemental Information

- VCS SUP 2.3-1

The NRC staff reviewed supplemental information VCS SUP 2.3-1 in VCSNS COL FSAR Section 2.3, discussing the onsite meteorological measurements program.

- VCS SUP 2.3.6-3

The NRC staff reviewed supplemental information in VCSNS COL FSAR Section 2.3.6.3 addressing site-specific details regarding the onsite meteorological measurements program.

The staff's evaluation is based on the descriptions provided by the applicant in VCSNS COL FSAR Section 2.3.3 and a preapplication readiness assessment held on April 16-17, 2007. The purpose of the readiness assessment was to: (1) become familiar with the prospective applicant's site and site selection process, plans, schedules, and initiatives; (2) observe and review the preoperational onsite meteorological measurements program; and (3) review the prospective applicant's plans for its operational onsite meteorological measurements program.

The NRC staff relied upon the review procedures presented in NUREG-0800, Section 2.3.3, to independently assess the technical sufficiency of the information presented by the applicant.

2.3.3.4.1 Site Description and Topographical Features of the Site Area

The applicant stated that the VCSNS site is located in central South Carolina, approximately 140 mi northwest of the Atlantic Ocean and 100 mi southeast of the Appalachian Mountains. Further the applicant stated that the terrain in the general area consists of gently to moderately rolling hills, and provided a topographic map of the site area within 50 mi of the site in VCSNS COL FSAR Figure 2.3-214. The staff independently verified the applicant's topographic description of the area by reviewing USGS topographic data and conducting a site visit and finds it acceptable.

2.3.3.4.2 Siting of Meteorological Towers

In VCSNS COL FSAR Section 2.3.3.2, the applicant identified pertinent siting criteria used to select a location for the meteorological tower such that data collected at the tower would be representative of the conditions at VCSNS Units 2 and 3. The criteria included elevation, obstruction distances, moisture sources, and prevailing wind. The surrounding terrain was characterized as gently rolling with small variations, therefore, minimal local wind flow alterations or disruptions are expected at the site and its vicinity.

The applicant evaluated heat and moisture sources that might influence ambient temperature and relative humidity measurements. These included vegetation, cooling towers, water bodies, and large parking lots. Heat reflection characteristics of the surface underlying the meteorological tower were also considered.

The applicant stated that the VCSNS Unit 2 and 3 tower is located in an open grassy field containing a small area of a mixture of grass, soil, and gravel immediately underlying the tower. The applicant further stated that the heat reflection characteristics of the surface underlying the meteorological tower that could have localized influence on the measurements are expected to be minimal. Based on the staff's preapplication site visit, the staff agrees with the applicant's characterization.

The applicant stated that the VCSNS Unit 1 meteorological tower would serve as a backup data source for the VCSNS Units 2 and 3 tower. The siting of this tower was evaluated by the staff at the preapplication readiness assessment (April 16-17, 2007), discussed above, and found to be acceptable[7].

Based on the applicant's description of the site, and the staff's preapplication readiness assessment, the staff has confirmed that the applicant applied the siting guidance provided in RG 1.23, Revision 1. The staff, therefore, finds the siting of the meteorological towers acceptable.

2.3.3.4.3 Preoperational Meteorological Measurement Program

The onsite meteorological measurements program at the VCSNS Units 2 and 3 began in December 2006. VCSNS COL FSAR Figure 1.1-202 shows the location of the meteorological

[7] U.S. NRC, Virgil C. Summer Nuclear Station – NRC Inspection Report 05000395-2006009, March 9, 2006.

tower with respect to the two proposed units along with the topography of the site. The meteorological tower is a 60-m (197-ft) guyed, open-latticed meteorological tower located at an elevation of approximately 132.7 m (435.5 ft) above MSL. The tower design complies with the recommendations provided in RG 1.23, Revision 1; therefore, it is acceptable to the staff.

The largest structures in the vicinity that have the potential to influence the meteorological measurements are the proposed VCSNS Unit 2 and Unit 3 containment shield buildings at 230 ft in height. RG 1.23, Revision 1 indicates that obstructions to flow (such as buildings) should be located at least 10 obstruction heights from the meteorological tower to prevent adverse building wake effects. The applicant stated that the VCSNS Unit 2 and 3 tower is approximately 4,365 ft from the center of the proposed Unit 2 containment and 3,470 ft from the center of the proposed Unit 3 containment. The height and distance to these obstructions comply with the recommendations provided in RG 1.23, Revision 1; therefore, it is acceptable to the staff.

2.3.3.4.3.1 Measurements Made and Instrument Elevations and Exposures

VCSNS COL FSAR Section 2.3.3.3.1 and Figure 2.3-219 identify three measurement levels and the measurements made as part of the VCSNS preoperational onsite meteorological measurements program. The applicant stated that wind speed, wind direction, relative humidity, and ambient temperature were monitored at the 10-, 30-, and 60-m levels. Temperature difference was calculated between 60-m and 10-m levels.

In addition to the standard 10-m and 60-m levels, the applicant chose to take measurements at the 30-m level. The applicant stated that wind speed, wind direction, relative humidity, and ambient temperature are monitored at each level. Further the applicant stated that the 30-m level was chosen because it would best represent the approximate discharge height of the cooling tower plumes. The applicant also stated that no rainfall or barometric pressure measurements are made at the VCSNS Units 2 and 3 meteorological tower; instead precipitation and barometric pressure data collected from the Unit 1 tower would be used because variations between the two locations would be minimal. The staff agrees with this assessment. The measurements made comply with the recommendations of RG 1.23, Revision 1; therefore, they are acceptable to the staff.

2.3.3.4.3.2 Meteorological Sensors Used

VCSNS COL FSAR Section 2.3.3.3.2 presented the instruments that were used to measure wind speed, wind direction, temperature, and relative humidity. Wind speed and wind direction are monitored at the 10-, 30-, and 60-m levels. Measurements are made using a WS425 Ultrasonic Wind Sensor. This instrument has no moving parts and has a measurement range of 0 to 144 mph.

Ambient temperature and delta temperature are monitored at the lower-, middle-, and upper-level of the tower. The ambient temperature and relative humidity are measured using the HMP45D relative humidity/temperature sensor. The applicant stated that this sensor was installed with a specially modified fan-aspirated radiation shield.

In RAI 2.3.3-2, the staff questioned the use of collecting temperature through an instrument that has a system accuracy of only -0.6 °F to 107.7 °F (based on observed temperatures), when the site characteristic temperatures are -5 °F to 105.1 °F. In response to this RAI, dated June 19, 2009, the applicant explained the instruments are suitable to be used because they are located on the 10-m or higher levels, which are less susceptible to extreme temperatures. The reasoning for this is based on the fact that strong lapse rates (i.e., change in temperature as a function of height) are a necessary condition for extreme temperatures and in the extreme cold condition the coldest temperatures are generally found closer to the surface. Although the -5 °F site characteristic value is outside the bounds of the system accuracy, the -5 °F value was observed at 1.5 to 2 m off the ground, while the VCSNS data is collected at a 10-m height. Therefore, it is likely that a -5 °F value at 1.5- to 2-m height would result in a temperature value at the 10-m height that would be within the system accuracy of VCSNS data collection system. In addition, a value of less than -0.6 °F would still be recorded because the temperature range of the instrument is -40 °F to 140 °F as listed in VCSNS COL FSAR Table 2.3-216, "Meteorological System Accuracies (Units 2 and 3 System)." Based on the value at the 10-m height being higher than the value recorded at 1.5 to 2 m in extreme cold weather cases and that the value will still be recorded the staff finds the response to RAI 2.3.3-2 acceptable and considers this RAI closed.

After reviewing the information presented in VCSNS COL FSAR Section 2.3.3.3.2 and FSAR Table 2.3-216, the staff finds the applicant's choice of meteorological monitoring equipment to be in compliance with RG 1.23, Revision 1, and therefore is acceptable.

2.3.3.4.3.3 Data Acquisition and Reduction

Data from the meteorological tower are processed through a computer mounted at the base of the tower on a cabinet rack. This computer is used to receive, process, manage, and archive all of the data collected from the monitoring tower. The computer system also calculates the values for differential temperature and dew point temperature from the ambient temperature and humidity measurements. The applicant stated that the sensor output is sampled by the computer, from the tower, at the following frequencies:

- Wind speed/wind direction (1 second)
- Ambient temperature (5 seconds)
- Relative humidity/temperature (5 seconds)

These data are then processed by the computer on the following frequencies:

- Wind speed/wind direction (60-second average value)
- Dew point (60-second average value)
- Relative humidity (60-second average value)
- Ambient temperature (60-second average value)
- Differential temperature (60-second average value)

These data are downloaded on a weekly basis for analysis and review. The computer has sufficient storage to archive several months of data.

According to the applicant, the data screening and validation, and identification and handling of suspect data are evaluated through a rigorous process. Hourly data are reviewed based on a predetermined expected data range and data trending. The data and screening results are reviewed to determine the data validity. Questionable data are also compared to measurements taken at the VCSNS Unit 1 tower or a nearby NWS station for a consistency check. During the review process, inconsistent data entries are identified for further review. If the data is determined to be invalid, then data substitution is made by reviewing the 15-minute time-averaged data to determine if a valid 15-minute period average of continuous data can be obtained to replace the invalid hourly period.

2.3.3.4.3.4 Instrumentation Surveillance

The applicant stated that the meteorological equipment is checked and calibrated on a routine basis in accordance with NRC guidance. In order to achieve the required level of system reliability, as specified in RG 1.23, Revision 1, the applicant employs the following maintenance techniques: (1) calibrating meteorological instrumentation semiannually; (2) calibrating or replacing the instrumentation with NIST-traceable calibrated sensors semiannually; (3) meteorological tower structure and lighting are inspected every 3 years to ensure structure safety; (4) meteorological monitoring site checks are performed to identify any abnormal functions, and to check site conditions once per week; (5) inspecting the tower hardware prior to instrument maintenance and calibration events on a semi-annual basis; and (6) data are reviewed to identify equipment failures and to validate data on a monthly basis.

The instrument maintenance and calibration techniques comply with the recommendations provided in RG 1.23, Revision 1; therefore, they are acceptable to the staff.

2.3.3.4.3.5 System Accuracy and Annual Data Recovery Rate

VCSNS COL FSAR Table 2.3-216 summarizes the accuracy of the measurements taken as part of the VCSNS onsite meteorological measurements program. The accuracy of the 2-year period of record for the data provided was consistent with the requirements of RG 1.23, Revision 1. Therefore, the accuracy of the measurements is acceptable to the staff.

VCSNS COL FSAR Table 2.3-217 summarizes the annual data recovery rate for the VCSNS Units 2 and 3 meteorological monitoring system. The applicant has shown in the table, and stated, that the recovery rate meets the requirements of RG 1.23, Revision 1. Since the recovery rate for all of the parameters is well above 90 percent for the period submitted, they are acceptable to the staff.

2.3.3.4.4 Operational Meteorological Measurement Program

The applicant stated that the operational meteorological measurement program for VCSNS Units 2 and 3 would consist of the Units 2 and 3 meteorological tower as the primary data collection system, with the Unit 1 tower as a backup during routine service and maintenance of the Units 2 and 3 tower and during and following any accidental atmospheric radiological releases from the new units.

The applicant provided a description of the operational monitoring program in Section 2.3.3.4 of the VCSNS COL FSAR. The operational meteorological measurement program is consistent with RG 1.23, Revision 1; therefore, the staff finds the operational monitoring program for VCSNS Units 2 and 3 acceptable.

2.3.3.4.5 Meteorological Data

The staff performed a quality review of the January 1, 2007 through December 31, 2008, hourly meteorological database using the methodology described in NUREG-0917, “Nuclear Regulatory Commission Staff Computer Programs for Use with Meteorological Data,” issued July 1982. The staff used computer spreadsheets to perform further review. As expected, the staff's examination of the data revealed generally stable and neutral atmospheric conditions at night and unstable and neutral conditions during the day. Wind speed, wind direction, and stability class frequency distributions for each measurement channel were reasonably similar from year to year.

In order to evaluate the representativeness of the 2007 - 2008 data sets, the staff compared the hourly temperature and wind measurements to the nearby Columbia, South Carolina NWS observation site. Based on an independent quality review of the onsite meteorological data and a comparison with offsite Columbia data, the staff accepts the 2 years of onsite data provided by the applicant as being representative of the site and an acceptable basis for estimating atmospheric dispersion for accidental and routine releases in VCSNS COL FSAR Sections 2.3.4 and 2.3.5.

2.3.3.5 *Post Combined License Activities*

Part 10 of the COL application describes proposed COL conditions, including inspection, test, analysis, and acceptance criteria (ITAAC). Table 3.8-1 in Part 10 of the COL application includes the emergency planning (EP) ITAAC. The following two EP-ITAACs involve demonstrating that the operational onsite meteorological monitoring program appropriately supports the VCSNS emergency plan:

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

- EP-ITAAC 6.4: The means exists to acquire and evaluate meteorological information. The acceptance criterion is that a report exists that confirms that meteorological data was available at the emergency operations facility (EOF), Technical Support Center (TSC), Control Room, offsite NRC Operations Center, and the state of South Carolina. This data will be verified to be assured that it is in the format needed for the appropriate emergency planning implementing procedures.

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

2.3.3.6 *Conclusion*

The NRC staff reviewed the application and checked the referenced DCD. The NRC staff's review confirmed that the applicant addressed the required information relating to the onsite meteorological measurements program, and there is no outstanding information expected to be addressed in the VCSNS COL FSAR related to this section. The results of the NRC staff's technical evaluation of the information incorporated by reference in the VCSNS COL application are documented in NUREG-1793 and its supplements.

AP1000 DCD, Section 2.3.6.3 states that a COL applicant shall address the site-specific onsite meteorological measurements program. As set forth above, the applicant has presented and substantiated information pertaining to the onsite meteorological measurements program and the resulting database. The staff has reviewed the information provided in VCS COL 2.3-3, and

VCS SUP 2.3.6-3 and, for the reasons given above, concludes that the applicant has established consideration of the onsite meteorological measurements program and the resulting database are acceptable and meet the requirements of 10 CFR 100.20 with respect to determining the acceptability of the site. The staff also finds that the onsite data also provide an acceptable basis for making estimates of atmospheric dispersion for DBA and routine releases from the plant to meet the requirements of 10 CFR 100.21, GDC 19, 10 CFR Part 20, and Appendix I to 10 CFR Part 50. Finally, the equipment provided for measurement of meteorological parameters during the course of accidents is sufficient to provide reasonable prediction of atmospheric dispersion of airborne radioactive materials in accordance with Appendix E to 10 CFR Part 50. The staff finds that the applicant has provided a sufficient description to meet the requirements of the DCD. VCS COL 2.3-3 has been adequately addressed by the applicant and can be considered resolved.

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 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 σ_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 in the "Contents of Application" sections of the applicable subparts to 10 CFR Part 52.

2.3.4.2 *Summary of Application*

Section 2.3.4 of the VCSNS COL FSAR, Revision 5, incorporates by reference Section 2.3.4 of the AP1000 DCD, Revision 19.

In addition, in VCSNS COL FSAR Section 2.3, the applicant provided the following:

<u>*AP1000 COL Information Item*</u>

- VCS COL 2.3-4

The applicant provided additional information in VCS COL 2.3-4 to address COL Information Item 2.3-4. VCS COL 2.3-4 addresses the provisions of site-specific short-term diffusion estimates for NRC review to ensure that the envelope values (Table 2-1 and Appendix 15A from the AP1000 DCD) of relative concentrations are not exceeded.

Supplemental Information

- VCS SUP 2.3-1

The applicant provided additional information in VCSNS COL FSAR Section 2.3 discussing regional climatological and local meteorological conditions, the onsite meteorological measurement program, and short-term and long-term diffusion estimates.

- VCS SUP 2.3.6-4

The applicant provided supplemental information in VCSNS COL FSAR Section 2.3.6.4 discussing the results of site-specific, short-term accident-related dispersion modeling analysis.

2.3.4.3 *Regulatory Basis*

The regulatory basis of the information incorporated by reference is addressed in NUREG-1793 and its supplements.

In addition, the acceptance criteria associated with the relevant requirements of the Commission regulations for the short-term diffusion estimates are given in Section 2.3.4 of NUREG-0800.

The applicable regulatory requirements for the applicant's description of atmospheric diffusion estimates for accidental releases are as follows:

- 10 CFR Part 50, Appendix A, GDC 19, "Control room," with respect to the meteorological considerations used to evaluate the personnel exposures inside the control room during radiological and airborne hazardous material accident conditions.

- 10 CFR 52.79(a)(1)(vi), with respect to a safety assessment of the site, including consideration of major SSCs of the facility and site meteorology, to evaluate the offsite radiological consequences at the EAB and LPZ.

- 10 CFR 100.21(c)(2), with respect to the atmospheric dispersion characteristics used in the evaluation of EAB and LPZ radiological dose consequences for postulated accidents.

The following RGs are applicable to this section:

- RG 1.78, "Evaluating the Habitability of a Nuclear Power Plant Control Room During a Postulated Hazardous Chemical Release," Revision 1

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

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

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 and hazardous materials to 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 (σy and σz) 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 release to the control room for design basis, other accidents and for onsite and offsite releases of hazardous airborne materials should be provided.

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

2.3.4.4 *Technical Evaluation*

The NRC staff reviewed Section 2.3.4 of the VCSNS COL FSAR and checked the referenced DCD to ensure that the combination of the DCD and the COL application represents the complete scope of information relating to this review topic.[1] The NRC staff's review confirmed that the information in the applicant and incorporated by reference addresses the required information relating to the short-term diffusion estimates. The results of the NRC staff's evaluation of the information incorporated by reference in the VCSNS COL application are documented in NUREG-1793 and its supplements.

The staff reviewed the information in the VCSNS COL FSAR:

AP1000 COL Information Item

- VCS COL 2.3-4

The NRC staff reviewed VCS COL 2.3-4 related to the short-term diffusion estimates included under Section 2.3.4 of the VCSNS COL FSAR. The COL information item in Section 2.3.6.4 of the AP1000 DCD states:

> Combined License applicants referencing the AP1000 certified design will address the site-specific χ/Q values specified in subsection 2.3.4. For a site selected that exceeds the bounding χ/Q values, the Combined License applicant will address how the radiological consequences associated with the controlling design basis accident continue to meet the dose reference values given in

10 CFR Part 50.34 and control room operator dose limits given in General Design Criteria 19 using site-specific χ/Q values. The Combined License applicant should consider topographical characteristics in the vicinity of the site for restrictions of horizontal and/or vertical plume spread, channeling or other changes in airflow trajectories, and other unusual conditions affecting atmospheric transport and diffusion between the source and receptors. No further action is required for sites within the bounds of the site parameters for atmospheric dispersion.

With regard to assessment of the postulated impact of an accident on the environment, the COL applicant will provide χ/Q values for each cumulative frequency distribution which exceeds the median value (50 percent of the time).

Evaluation of the information provided in VCS COL 2.3-4 is discussed below.

Supplemental Information

- VCS SUP 2.3-1

The NRC staff reviewed supplemental information VCS SUP 2.3-1 in VCSNS COL FSAR Section 2.3, discussing the short-term diffusion estimates.

- VCS SUP 2.3.6-4

The NRC staff reviewed supplemental information in VCSNS COL FSAR Section 2.3.6.4 addressing the results of the site-specific, short-term, accident-related dispersion modeling analysis.

The NRC staff relied upon the review procedures presented in NUREG-0800, Section 2.3.4, to independently assess the technical sufficiency of the information presented by the applicant.

2.3.4.4.1 Atmospheric Dispersion Models

2.3.4.4.1.1 Offsite Dispersion Estimates

The applicant used the computer code PAVAN (NUREG/CR-2858, “PAVAN: An Atmospheric Dispersion Program for Evaluating Design-Basis Accidental Releases of Radioactive Materials from Nuclear Power Stations”) to estimate χ/Q values at the EAB and at the outer boundary of the LPZ for potential accidental releases of radioactive material. The PAVAN model implements the methodology outlined in RG 1.145, Revision 1.

The PAVAN code estimates χ/Q values for various time-average periods ranging from 2 hours to 30 days. The meteorological input to PAVAN consists of a JFD of hourly values of wind speed and wind direction by atmospheric stability class. The χ/Q values calculated through PAVAN 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 point of release and all distances for which χ/Q values are calculated.

For each of the 16 downwind direction sectors (e.g., N, NNE, NE, ENE), PAVAN calculates χ/Q values for each combination of wind speed and atmospheric stability at the appropriate downwind distance (i.e., the EAB and the outer boundary of the LPZ). The χ/Q values calculated for each sector are then ordered from greatest to smallest and an associated cumulative frequency distribution is derived based on the frequency distribution of wind speed and stabilities for each sector. The smallest χ/Q value in a distribution will have a corresponding cumulative frequency equal to the wind direction frequency for that particular sector. PAVAN determines for each sector an upper envelope curve based on the derived data (plotted as χ/Q versus probability of being exceeded), such that no plotted point is above the curve. From this upper envelope, the χ/Q value, which is equaled or exceeded 0.5 percent of the total time, is obtained. The maximum 0.5 percent χ/Q value from the 16 sectors becomes the 0–2 hour "maximum sector χ/Q value."

Using the same approach, PAVAN also combines all χ/Q values independent of wind direction into a cumulative frequency distribution for the entire site. An upper envelope curve is determined, and the program selects the χ/Q value which is equaled or exceeded 5.0 percent of the total time. This is known as the 0–2 hour "5-percent overall site χ/Q value."

The larger of the two χ/Q values, either the 0.5-percent maximum sector value or the 5-percent overall site value, is selected to represent the χ/Q value for the 0–2 hour time interval (note that this resulting χ/Q value is based on 1-hour averaged data but is conservatively assumed to apply for 2 hours).

To determine χ/Q values for longer time periods (i.e., 0–8 hour, 8–24 hour, 1–4 days, and 4-30 days), PAVAN performs a logarithmic interpolation between the 0–2 hour χ/Q values and the annual average (8760–hour) χ/Q values for each of the 16 sectors and overall site. For each time period, the highest among the 16 sector and overall site χ/Q values is identified and becomes the short-term site characteristic χ/Q value for that time period.

2.3.4.4.1.2 Control Room Dispersion Estimates

The 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-average periods ranging from 2 hours to 30 days. The meteorological input to ARCON96 consists of hourly values of wind speed, wind direction, and atmospheric stability class. The χ/Q values calculated through ARCON96 are based on the theoretical assumption that material released 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 five percent of the time for each averaging period is determined.

2.3.4.4.2 Meteorological Data Input

2.3.4.4.2.1 Offsite Dispersion Estimates

The meteorological input to PAVAN used by the applicant consisted of a JFD of wind speed, wind direction, and atmospheric stability based on hourly onsite data from a 2-year period from January 1, 2007 through December 31, 2008. 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 60-m and 10-m levels on the onsite meteorological tower.

All of the RAIs related to the acceptability of the hourly meteorological data as discussed in SER Section 2.3.3 have been resolved, and as such, the staff considers the 2007 - 2008 onsite meteorological database suitable for input to the PAVAN model.

2.3.4.4.2.2 Control Room Dispersion Estimates

The meteorological input to ARCON96 used by the applicant consisted of wind speed, wind direction, and atmospheric stability data based on hourly onsite data from a 2-year period from January 1, 2007 through December 31, 2008. The wind data were obtained from the 10-m and 60-m levels of the onsite meteorological tower, and the stability data were derived from the vertical temperature difference (delta-temperature) measurements taken between the 60-m and 10-m levels on the onsite meteorological tower.

All RAIs related to the acceptability of the hourly meteorological data have been resolved, and as discussed previously in SER Section 2.3.4, the staff considers the 2007 - 2008 onsite meteorological database suitable for input to the ARCON96 model.

2.3.4.4.3 Diffusion Parameters

2.3.4.4.3.1 Offsite Dispersion Estimates

The applicant chose to implement the diffusion parameter assumptions outlined in RG 1.145, Revision 1, as a function of atmospheric stability, for its PAVAN model runs. The staff evaluated the applicability of the PAVAN diffusion parameters and concluded that no unique topographic features (such as rough terrain, restricted flow conditions, or coastal or desert areas) preclude the use of the PAVAN model for the VCSNS site. Therefore, the staff finds that the applicant’s use of diffusion parameter assumptions, as outlined in RG 1.145, Revision 1 is acceptable.

2.3.4.4.3.2 Control Room Dispersion Estimates

The diffusion coefficients used in ARCON96 have three components. The first component is the diffusion coefficient used in other NRC models such as PAVAN. The other two components are corrections to account for enhanced dispersion under low wind speed conditions and in building wakes. These components are based on analysis of diffusion data collected in various building wake diffusion experiments under a wide range of meteorological conditions. Because the diffusion occurs at short distances within the plant’s building complex, the ARCON96 diffusion parameters are not affected by nearby topographic features such as bodies of water. Therefore, the staff finds the applicant’s use of the ARCON96 diffusion parameter assumptions acceptable.

2.3.4.4.4 Relative Concentration for Accident Consequences Analysis

2.3.4.4.4.1 Conservative Short-Term Atmospheric Dispersion Estimates for EAB and LPZ

As described in VCSNS COL FSAR Section 2.3.4.2, the applicant created a boundary called the Power Block Area Circle (PBAC) to use in determining their offsite χ/Q values. The PBAC has a radius of 750 ft (229 m) from the center point between VCSNS Units 2 and 3, or 450 ft (138 m) from each unit's Shield Building. The χ/Q values were calculated for the Dose Evaluation Periphery (DEP), which is a concentric circle around the PBAC located at a distance equal to the minimum radial distance between the PBAC and the actual Site Boundary/EAB. This distance is 2640 ft or 805 m. This is a conservative method because the use of the PBAC lessens the distance from the release point to the receptor point (DEP). The use of the shortest distance results in higher (more conservative) χ/Q values for ground level releases and is, therefore, acceptable to the staff.

The applicant modeled a ground-level release point and 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. A ground-level release assumption, which does not take credit for building wake effects, is acceptable to the staff.

In accordance with AP1000 DCD, Section 2.3.6.4, VCSNS COL FSAR Tables 2.3-220 and 2.3-221 listed the χ/Q values for each of the 16 sectors and the averaging time. A table in VCSNS COL FSAR Section 2.3.4.2.1.1 compared the site-specific EAB/DEP and LPZ χ/Q values to the corresponding site parameters provided in the DCD. This comparison showed that the AP1000 DCD EAB and LPZ χ/Q values conservatively bounded the site-specific values.[8] It was noted, however, that the site-specific limits stated at the bottom of VCSNS COL FSAR Table 2.3.221 for 8-24 hours and 1-4 days of 7.45E-04 and 2.84E-04, respectively, were inconsistent with the corresponding values of 7.45E-05 and 2.84E-05 stated in VCSNS COL FSAR Table 2.0-201 and VCSNS COL FSAR Section 2.3.4.2.1.1. In RAI 2.3.1-9, the staff requested that the applicant clarify this discrepancy. In response to RAI 2.3.1-9, the applicant proposed revising VCSNS COL FSAR Table 2.3-221 to reflect site-specific limits at 8-24 hours and 1-4 days of 7.45E-05 and 2.84E-05, consistent with VCSNS COL FSAR Table 2.0-201 and VCSNS COL FSAR Section 2.3.4.2.1.1. The staff finds this proposed revision to be acceptable because it is supported by the data collected at the site. Therefore, RAI 2.3.1-9 is resolved. The commitment to update the FSAR to reflect site-specific limits at 8-24 hours and 1-4 days of 7.45E-05 and 2.84E-05 is being tracked as **Confirmatory Item 2.3.4-1**.

Resolution of Confirmatory Item 2.3.4-1

Confirmatory Item 2.3.4-1 is an applicant commitment to update its FSAR to include the changes to FSAR Table 2.3-221. The staff verified that the VCSNS COL FSAR was appropriately updated. As a result, Confirmatory Item 2.3.4-1 is now closed.

[8] Smaller χ/Q values are associated with greater dilution capability, resulting in lower radiological doses. When comparing a DCD site parameter χ/Q value and a site characteristic χ/Q value, the site is acceptable for the design if the site characteristic χ/Q value is smaller that the site parameter χ/Q value. Such a comparison shows that the site has better dispersion characteristics than that required by the reactor design.

Using the information provided by the applicant, including the 10-m level JFDs of wind speed, wind direction, and atmospheric stability presented in VCSNS COL FSAR Table 2.3-210, the staff has confirmed the applicant's χ/Q values by running the PAVAN computer code and obtaining similar results. The applicant's JFDs used 12 wind speed categories based on RG 1.23, Revision 1. In light of the foregoing, the staff accepts the long-term χ/Q values presented by the applicant.

AP1000 DCD, Section 2.3.6.4 also states that with regard to assessment of the postulated impact of an accident on the environment, χ/Q values for each cumulative frequency distribution, which exceeds the median value (50 percent of the time) should be provided. These χ/Q values will be evaluated as part of the concurrent environmental review and subsequent results presented in the environmental impact statement (EIS).

2.3.4.4.4.2 Short-Term Atmospheric Dispersion Estimates for the Control Room

The applicant provided the following as the necessary input to ARCON96:

Onsite Hourly Meteorological Data:	January 1, 2007 – December 31, 2008
AP1000 DCD Table 15A-7:	Control Room Source/Receptor Data
AP1000 DCD Figure 15A-1:	Site Plant with Release and Intake Locations
VCSNS COL FSAR Figure 2.1-203:	Plant Layout on the VCSNS Site

The applicant provided the distances and directions from receptors to sources, as well as the release types in a table in response to RAI 2.3.4-1, dated July 20, 2009. The staff accepted the information in the response to RAI 2.3.4-1 as correct and adequate and considers RAI 2.3-4 closed.

VCSNS COL FSAR Section 2.0 states that for VCSNS Units 2 and 3, the plant orientation is rotated 68 degrees counter-clockwise with respect to true north. In accordance with the AP1000 DCD, two receptor (i.e., air intake) points, the control room heating, ventilation, and air conditioning (HVAC) intake and control room door, were modeled for the following eight release points:

- Containment Shell
- Fuel Building Blowout Panel
- Fuel Building Rail Bay Door
- Steam Vent
- Power-Operated Relief Valve (PORV)/Safety Valves
- Condenser Air Removal Stack
- Plant Vent
- PCS Air Diffuser

VCSNS COL FSAR Tables 2.3-222 and 2.3-223 list the control room atmospheric dispersion estimates that the applicant derived from its ARCON96 modeling run results. In accordance with AP1000 DCD, Section 2.3.6.4, FSAR Tables 2.3-222 and 2.3-223 compared the site-specific control room χ/Q values to the corresponding site parameters provided in the DCD. This comparison showed that the AP1000 control χ/Q values conservatively bounded the site-specific values. This comparison is reproduced in VCSNS COL FSAR Table 2.0-201.

The staff confirmed the applicant's atmospheric dispersion estimates for the 2007 - 2008 data by running the ARCON96 computer model and obtaining similar results (i.e., values on average within ± 1.9 percent). Both the staff and 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 applicant.

2.3.4.4.5 Onsite and Offsite Hazardous Materials

A review of the identification of onsite and off-site hazardous materials that could threaten control room habitability is performed in SER Sections 2.2.1, 2.2.2, and 2.2.3. The accident scenarios, including release characteristics and atmospheric dispersion model descriptions are also found in these sections.

2.3.4.5 *Post Combined License Activities*

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

2.3.4.6 *Conclusion*

The NRC staff reviewed the application including VCS COL 2.3-4 and VCS SUP 2.3.6-4 and checked the referenced DCD. The NRC staff's review confirmed that the applicant addressed the required information relating to short-term diffusion estimates, and there is no outstanding information expected to be addressed in the VCSNS COL FSAR related to this section. The results of the NRC staff's technical evaluation of the information incorporated by reference in the VCSNS COL application are documented in NUREG-1793 and its supplements.

AP1000 DCD, Section 2.3.6.4 states that a COL applicant shall address the site-specific χ/Q values as specified in AP1000 DCD Section 2.3.4. The staff concludes that the applicant's atmospheric dispersion estimates are acceptable and meet the relevant requirements of 10 CFR 100.21(c)(2). This conclusion is based on the conservative assessments of post-accident atmospheric dispersion conditions that have been made by the applicant and the staff from the applicant's meteorological data and appropriate diffusion models.

These atmospheric dispersion estimates are appropriate for the assessment of consequences from radioactive releases for DBAs in accordance with 10 CFR 52.79(a)(1)(vi), 10 CFR 100.21(c)(2), GDC 19. The staff finds that the applicant has provided sufficient information to meet the requirements of the AP1000 DCD.

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*

Section 2.3.5 of the VCSNS COL FSAR, Revision 5, incorporates by reference Section 2.3.5 of the AP1000 DCD, Revision 19.

In addition, in VCSNS COL FSAR Section 2.3, the applicant provided the following:

AP1000 COL Information Item

- VCS COL 2.3-5

The applicant provided additional information in VCS COL 2.3-5 to address COL Information Item 2.3-5. VCS COL 2.3-5 addresses long-term χ/Q and D/Q estimates for calculating concentrations in air and the amount of material deposited on the ground as a result of routine releases of radiological effluents to the atmosphere during normal plant operation.

Supplemental Information

- VCS SUP 2.3-1

The applicant provided supplemental information in VCSNS COL FSAR Section 2.3, discussing regional climatological and local meteorological conditions, the onsite meteorological measurements program, and short-term and long-term diffusion estimates.

- VCS SUP 2.3.6-5

The applicant provided supplemental information in VCSNS COL FSAR Section 2.3.6.5, "Long-Term Diffusion Estimates," discussing the results of site specific, long-term dispersion modeling analysis.

In addition, this section addresses Interface Item 2.4 related to the limiting meteorological parameters (χ/Q values) for routine releases.

2.3.5.3 *Regulatory Basis*

The regulatory basis of the information incorporated by reference is addressed in NUREG-1793 and its supplements.

In addition, the acceptance criteria associated with the relevant requirements of the Commission regulations for long-term diffusion estimates are given in Section 2.3.5 of NUREG-0800.

The applicable regulatory requirements for the applicant's description of atmospheric dispersion and dry deposition estimates for routine releases of radiological effluents to the atmosphere are as follows:

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

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

- 10 CFR 100.21(c)(2), with respect to establishing atmospheric dispersion site characteristics such that radiological effluent release limits associated with normal operation can be met for any individual located offsite.

The following RGs are applicable to this section:

- RG 1.23, "Meteorological Monitoring Programs for Nuclear Power Plants," 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

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

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 applicant to calculate annual average concentrations in air and amount of material deposited as a result of routine releases of radioactive materials to the atmosphere.

- A discussion of atmospheric diffusion parameters, such as vertical plume spread (σ_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 Section 2.3.5.2 of RG 1.206, Revision 0: (1) maximum annual average χ/Q values and D/Q values at or beyond the site boundary and at specific locations of potential receptors of interest utilizing appropriate meteorological data for each routine venting location; 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.

2.3.5.4 *Technical Evaluation*

The NRC staff reviewed Section 2.3.5 of the VCSNS COL FSAR and checked the referenced DCD to ensure that the combination of the DCD and the COL application represents the complete scope of information relating to this review topic.[1] The NRC staff's review confirmed that the information in the application and incorporated by reference addresses the required information relating to the long-term diffusion estimates. The results of the NRC staff's evaluation of the information incorporated by reference in the VCSNS COL application are documented in NUREG-1793 and its supplements.

The staff reviewed the information in the VCSNS COL FSAR:

AP1000 COL Information Item

- VCS COL 2.3-5

The NRC staff reviewed VCS COL 2.3-5 related to the long-term diffusion estimates included under Section 2.3.5 of the VCSNS COL FSAR. The specific text of this COL information item in Section 2.3.6.4 of the AP1000 DCD states:

> Combined License applicants referencing the AP1000 certified design will address long-term diffusion estimates and χ/Q values specified in subsection 2.3.5. The Combined License applicant should consider topographical characteristics in the vicinity of the site for restrictions of horizontal and/or vertical plume spread, channeling or other changes in airflow trajectories, and other unusual conditions affecting atmospheric transport and diffusion between the source and receptors. No further action is required for sites within the bounds of the site parameter for atmospheric dispersion.

With regard to environmental assessment, the COL applicant will also provide estimates of annual average χ/Q values for 16 radial sectors to a distance of 50 mi from the plant.

Evaluation of the information provided in VCS COL 2.3-5 is discussed below.

Supplemental Information

- VCS SUP 2.3-1

The NRC staff reviewed supplemental information VCS SUP 2.3-1 in VCSNS COL FSAR Section 2.3, discussing the long-term diffusion estimates.

- VCS SUP 2.3.6-5

The NRC staff reviewed supplemental information in VCSNS COL FSAR Section 2.3.6.5, “Long-Term Diffusion Estimates,” addressing the results of the site-specific, long-term, dispersion modeling analysis.

The NRC staff relied upon the review procedures presented in NUREG-0800, Section 2.3.5, to independently assess the technical sufficiency of the information presented by the applicant.

2.3.5.4.1 Atmospheric Dispersion Model

The 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.

2.3.5.4.2 Release Characteristics and Receptors

The applicant modeled one ground-level release point, assuming a minimum building cross-sectional area of 2,636 m^2 and a building height of 43.9 m. The applicant assumed a ground-level release to model routine releases. A ground-level release is a conservative assumption at a relatively flat terrain site, such as the VCSNS site, resulting in higher χ/Q and D/Q values when compared to a mixed-mode (e.g., part-time ground, part-time elevated) release or a 100-percent elevated release, as discussed in RG 1.111, Revision 1. A ground-level release assumption is, therefore, acceptable to the staff.

The distance to the receptors of interest (i.e., the DEP and the LPZ boundary, the nearest milk animal, residence, garden, meat animal, Unit 3) were presented in VCSNS COL FSAR Table 2.3-224. The χ/Q and D/Q is being evaluated at Unit 3 to determine the impact during the time that Unit 2 is operational and Unit 3 is still under construction. The distances to each of these receptors have been derived from a land use consensus table provided by the applicant in Reference 221. The distances were adjusted to reflect the source originating at Unit 2, since the original land use evaluation was centered on Unit 1. These assumptions are acceptable to the staff.

2.3.5.4.3 Meteorological Data Input

The meteorological input to XOQDOQ used by the applicant consisted of a JFD of wind speed, wind direction, and atmospheric stability based on hourly onsite data from a 2-year period from January 1, 2007 through December 31, 2008. 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 60-m and 10-m levels on the onsite meteorological tower.

All of the RAIs related to the acceptability of the hourly meteorological data and as discussed in SER Section 2.3.3 have been resolved, and as such the staff considered the 2007 - 2008 onsite meteorological database suitable for input to the XOQDOQ model.

2.3.5.4.4 Diffusion Parameters

The applicant chose to implement the diffusion parameter assumptions outlined in RG 1.111, Revision 1, as a function of atmospheric stability, for its 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 VCSNS site. Therefore, the staff finds the applicant's use of diffusion parameter assumptions, as outlined in RG 1.111, Revision 1 acceptable.

2.3.5.4.5 Resulting Relative Concentration and Relative Deposition Factors

VCSNS COL FSAR Table 2.3-225 lists the long-term atmospheric dispersion and deposition estimates for the DEP and special receptors of interest that the applicant derived from its XOQDOQ modeling results. VCSNS COL FSAR Table 2.3-226 lists the 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 VCSNS COL FSAR Table 2.3-225 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 VCSNS COL FSAR Table 2.3-225 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 applicant, including the 10-m level JFDs of wind speed, wind direction, and atmospheric stability presented in VCSNS COL FSAR Tables 2.3.2-201 through 2.3.2-208, the staff confirmed the applicant's χ/Q and D/Q values by running the XOQDOQ computer code and obtaining similar results (i.e., values on average within 6.6 percent).

AP1000 DCD, Section 2.3.6.5 also states that with regard to environmental assessment, estimates of annual average χ/Q values for 16 radial sectors to a distance of 50 mi from the plant should be provided. The applicant provided these values in VCSNS COL FSAR Table 2.3-226. These χ/Q values were confirmed by the staff and were found to be adequate and acceptable.

2.3.5.5 *Post Combined License Activities*

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

2.3.5.6 *Conclusion*

The NRC staff reviewed the application including VCS COL 2.3-1 and VCS SUP 2.3.6-5 and checked the referenced DCD. The NRC staff's review confirmed that the applicant addressed the required information relating to long-term diffusion estimates, and there is no outstanding information expected to be addressed in the VCSNS COL FSAR related to this section. The results of the NRC staff's technical evaluation of the information incorporated by reference in the VCSNS COL application are documented in NUREG-1793 and its supplements.

AP1000 DCD, Section 2.3.6.5 states that a COL applicant shall address the site-specific diffusion estimates and χ/Q values as specified in DCD Section 2.3.5. Based on the meteorological data provided by the 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 applicant has provided sufficient information to meet the requirements of the AP1000 DCD.

2.4 <u>Hydrologic Engineering</u>

To ensure that one or more nuclear power plants can be safely operated on the applicant's proposed site and in accordance with the NRC's regulations, the NRC staff evaluates the hydrologic site characteristics of the proposed site. These site characteristics included the maximum flood elevation of surface water, associated static and dynamic characteristics, and the maximum elevation of groundwater. The characteristic ability of the site to attenuate a postulated accidental release of radiological material into surface water and groundwater before it reaches a receptor is also described.

The staff prepared Sections 2.4.1 through 2.4.14 of this SER in accordance with the review procedures described in NUREG-0800 using information presented in Section 2.4, "Hydrologic Engineering," of the VCSNS COL FSAR, Revision 5; the AP1000 DCD, Revision 19; responses to staff RAIs; and generally available reference materials (e.g., those cited in applicable sections of NUREG-0800).

The ultimate heat sink of the AP1000 design is the atmosphere. Therefore, hydrologic characteristics associated with conditions that would result in a loss of external water supply (e.g., low water, channel diversions) are not relevant for this particular design. Also, seismic design considerations of water supply structures are not relevant for this particular design. Therefore, RG 1.27, “Ultimate Heat Sink for Nuclear Power Plants,” and RG 1.29, “Seismic Design Classification,” were not a necessary part of the regulatory basis for this Section 2.4 review.

2.4.1 Hydrologic Description

2.4.1.1 *Introduction*

FSAR Section 2.4.1 of the VCSNS COL application described the site and all safety-related elevations, structures and systems from the standpoint of hydrologic considerations and provided a topographic map showing the proposed changes to grading and to natural drainage features.

Section 2.4.1 of this SER provides a review of the following specific areas: (1) interface of the plant with the hydrosphere including descriptions of site location, major hydrologic features in the site vicinity, surface water and groundwater characteristics, and the proposed water supply to the plant; (2) hydrologic 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 hydrologic 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 in the “Contents of Application” sections of the applicable subparts to 10 CFR Part 52.

Based on information in Section 2.5.2 of this SER, which discusses “Vibratory Ground Motion,” the staff determined that seismic events that could impact hydrology at the VCSNS site are not likely due to: 1) the distance of the site from active sources including the design earthquake (the Updated Charleston Seismic Zone); 2) the lack of site features resulting from previous seismic activity (i.e., liquefaction features); 3) the lack of capable seismic structures at or near the site; and 4) the hard rock lithology underlying the site. As a result, a detailed evaluation of item (6) above was not performed by the staff as part of this section.

2.4.1.2 *Summary of Application*

This section of the VCSNS COL FSAR describes the site and all safety-related elevations, structures and systems from the standpoint of hydrologic considerations and provides a topographic map showing the proposed changes to grading and to natural drainage features. The applicant addressed these issues as follows:

AP1000 COL Information Item

- VCS COL 2.4-1

In addition, this section addresses the following COL Information Item 2.4-1 (COL Action Item 2.6.1) identified in Section 2.4.1.1 of the DCD.

Combined License applicants referencing the AP1000 certified design will describe major hydrologic features on or in the vicinity of the site including critical elevations of the nuclear island and access routes to the plant.

VCS COL 2.4-1 adds VCSNS COL FSAR Section 2.4.1 in its entirety.

2.4.1.3 *Regulatory Basis*

The acceptance criteria associated with the relevant requirements of the Commission regulations for the identification of floods and flood design considerations, and the associated acceptance criteria, are given in Section 2.4.1 of NUREG-0800.

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

- 10 CFR Part 100, as it relates to identifying and evaluating hydrologic features of the site.
- 10 CFR 100.20(c), regarding requirements to consider physical site characteristics in site evaluations.
- 10 CFR 52.79(a)(1)(iii), as it relates to the hydrologic 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.

The related acceptance criteria are as follows:

- RG 1.59, “Design Basis Floods for Nuclear Power Plants,” Revision 2, as supplemented by best current practices
- RG 1.102, “Flood Protection for Nuclear Power Plants,” Revision 1

2.4.1.4 *Technical Evaluation*

The NRC staff reviewed Section 2.4.1 of the VCSNS COL FSAR and checked the referenced DCD to ensure that the combination of the DCD and the COL application represents the complete scope of information relating to this review topic.[1] The NRC staff’s review confirmed that the information in the application and incorporated by reference addresses the required information relating to the site hydrological description. The results of the NRC staff’s evaluation of the information incorporated by reference in the VCSNS COL application are documented in NUREG-1793 and its supplements.

The staff reviewed the information in the VCSNS COL FSAR:

AP1000 COL Information Item

- VCS COL 2.4-1

2.4.1.4.1 Site and Facilities

Information Submitted By the Applicant

The applicant stated in FSAR Section 2.4.1 that the VCSNS Units 2 and 3 site is located to the south of Monticello Reservoir on a hilltop about 1 mi east of the Broad River near Parr Shoals Dam. VCSNS Unit 1 is located and currently operating north of the proposed locations of Units 2 and 3 near the Monticello Reservoir (VCSNS COL FSAR Figure 2.4-201). The site grade elevation for the proposed units is 400 ft North American Vertical Datum, 1988 (NAVD88), which is equivalent to the AP1000 DCD plant floor elevation of 100 ft. (The applicant reported that 400 ft NAVD88 is equivalent to 400.7 ft National Geodetic Vertical Datum, 1929 (NGVD29)). VCSNS Units 2 and 3 will be located on a hilltop at about 150 ft above the normal pool elevation of Parr Reservoir/Broad River flood plain and 25 ft below the maximum operating pool elevation of Monticello Reservoir.

VCSNS COL FSAR Figure 1.1-201 is a site location map that depicts the spatial relationship between the major surface hydrologic features. A finer scale figure focusing on just the major surface hydrologic features is shown in FSAR Figure 2.4-202. The topography near VCSNS Units 2 and 3 is depicted in VCSNS COL FSAR Figure 1.1-202 and VCSNS COL FSAR Figure 2.4-201. The applicant stated that the VCSNS site is about 1 mi from Monticello Reservoir. The existing Unit 1 lies between Monticello Reservoir and the proposed Units 2 and 3 as shown on VCSNS COL FSAR Figure 2.4-202.

The applicant stated that all safety-related water to AP1000 units would be supplied by onsite engineered storage tanks. VCSNS Units 2 and 3 will draw makeup water from Monticello Reservoir at a maximum rate of 61,600 gallons per minute (gpm) for normal operations, a portion of which is consumptively used for evaporative cooling. Water is exchanged between Parr Reservoir and Monticello Reservoir though the Fairfield Pumped Storage Facility (FPSF).

NRC Staff's Technical Evaluation

Based on the staff's site audit and the review of United States Geological Survey (USGS) topographic maps, the staff confirmed the location and approximate elevations of the site and adjacent water features. The staff compared the information presented by the applicant in VCSNS COL FSAR Section 2.4.1 with publicly available maps and data regarding the VCSNS site and it surrounding region. The staff estimated that the site is located about 3.5 km (2.2 mi) northwest of Jenkinsville, South Carolina, 9.3 km (5.8 mi) east northeast from Pomaria, South Carolina, 5.3 km (3.3 mi) north of Peak, South Carolina, and about 225 km (140 mi) northwest from the Atlantic Ocean. The staff determined that the current land elevation at the site varies from 117 to 128 m (385 to 420 ft) NAVD88 (USGS National Map Viewer website). Based on the staff's evaluation of the AP1000 DCD in NUREG-1793, Section 22.5.6, "Post-72-Hour Actions and Equipment," the staff concurs with the applicant's determination that the plant is not dependent on the adjacent or the underlying hydrological environment for water as makeup for safety-related needs.

2.4.1.4.2 Overview of Hydrosphere

Information Submitted by the Applicant

The applicant described surface water bodies in the vicinity of the VCSNS Units 2 and 3 site, including descriptions of the Broad River Basin, Parr and Monticello Reservoirs and Mayo Creek, adjacent drainage basins, and surface water use.

NRC Staff's Technical Evaluation

The applicant stated that elevations reported in NAVD88 datum are 0.2 m (0.7 ft) less than when reported in NGVD29 datum.

Hydrological features of hydrologic relevance include the dikes and dams that confine Monticello Reservoir and Parr Reservoir. The staff relied on the description of these structures in the VCSNS COL FSAR. All dams that impound Frees Creek to form Monticello Reservoir have crest elevations of 132.3 m (434 ft) NGVD29. Parr Shoals Dam has a crest elevation of 81.1 m (266 ft) NGVD29 with an earth dike on the west side of the dam that has crest elevation of SI (272.1 ft) and concrete non-overflow section on the east with a crest elevation of 82.9 m (271.1 ft) NGVD29. The staff used this information in subsequent technical evaluation sections of this SER Section 2.4.

The staff conducted a site audit during the period of November 17-19, 2008. The staff toured the site and observed key hydrologic features including the Monticello Reservoir; the Parr Reservoir on the Broad River; the FPSF; the watersheds draining away from the proposed site; and the topography in the area at the site. The staff also observed an unnamed creek southwest of the VCSNS Unit 3 site and the Mayo Creek east of the VCSNS Units 2 and 3 site. Mayo Creek is a small creek that flows from east to west south of the Monticello Reservoir, the VCSNS Unit 1 site, and the VCSNS Units 2 and 3 site. It drains into the Broad River downstream of the Parr Shoals Dam. The staff used their observations to understand the hydrologic setting and interfaces of the VCSNS Units 2 and 3 site with the environment.

No long-term continuous streamflow measurements are available for either the Mayo Creek or the unnamed creek. The staff requested additional information from the applicant regarding Mayo Creek in RAI 2.4.13-9 related to the calculation of the 100-year low annual mean flow using limited available data. The applicant responded to this RAI on October 8, 2009. The applicant described limited flow observations in the Mayo Creek. Five flow measurements were made between October 1984 and July 1986 with discharges ranging from 0.01 to 0.05 cubic meters per second (m^3/s) (0.36 to 1.70 cubic feet per second (cfs)). The technical evaluation of RAI 2.4.13-9 is in Section 2.4.13 of this SER.

2.4.1.4.3 Hydrosphere

An accurate description of the interface of the plant with the hydrosphere is needed by the staff in order to perform safety assessment of the plant's structures, systems, and components (SSC) and to consider the effects of any accidental release of radioactive effluent on public health and safety. The staff reviewed the information provided by the applicant in FSAR Section 2.4.1. The staff's independent review and determinations regarding the hydrosphere are described below.

The plant water demands are described in Section 3.3 of the Environmental Report (ER) of the application.

2.4.1.4.3.1 Rivers and Streams

Information Submitted by the Applicant

The applicant described the Broad River above the VCSNS site. The Broad River and its watershed (above the proposed VCSNS Units 2 and 3) are shown in VCSNS COL FSAR Figure 2.4-204. The watershed above the site was estimated to have an area of 4,750 square miles (sq mi). The headwaters of the Broad River extend into North Carolina. The applicant reported that the average annual precipitation in the watershed is about 45 inches (in) and the average annual runoff is about 17.8 in. USGS streamflow gauges downstream from the site are at Alston (USGS Gauge 02161000) and Richtex (USGS Gauge 02161500). The closest upstream USGS stream flow gauge is at Carlisle (USGS Gauge 02156500). The locations of the stations are shown in VCSNS COL FSAR Figure 2.4-204. The applicant summarized the streamflow data from these stations in FSAR Section 2.4.1.2.1. The period of record for these stations included data from 1896 to 2005; of which streamflow data was available 41 to 60 years for these stations during the period of record. The applicant synthesized the flow records to obtain a longer and continuous record of flow characterized as being representative of flow in the Broad River near the VCSNS site. The applicant used the flows at Alston to characterize streamflow because this station is closest to the VCSNS Units 2 and 3 site.

NRC Staff's Technical Evaluation

The Broad River flows southward about one mile west of the site. The staff identified the USGS streamflow gage upstream from the site at Carlisle (USGS Gage 02156500) and two gages downstream from the site at Richtex and Alston (USGS Gages 02161500 and 02161000, respectively). The staff evaluated the streamflow at these stations to characterize the flow in the Broad River adjacent to the VCSNS Units 2 and 3 site.

The staff examined the USGS streamflow summary for Carlisle (02156500) using the USGS Water Data Report 2009. The USGS report included: (1) the location of the Carlisle gage; (2) the drainage area above this gage, which is 7226 sq km (2,790 sq mi); and (3) the daily water discharges for October 1938 to present. The lowest, mean, and highest annual mean flow for years 1939 to 2009 were 34.6, 107.0, and 169.3 m^3/s, respectively (1,221, 3,780 and 5,977 cfs). Annual runoff during this period was 46.7 centimeters (cm) (18.4 in). Ten percent of the flow exceeded 185.2 m^3/s (6,540 cfs), 50 percent exceeded 78.2 m^3/s (2,760 cfs), and 90 percent exceeded 33.7 m^3/s (1,190 cfs) over this period. (USGS, 2009).

The staff examined the USGS streamflow summary for Alston (02161000, HUC 03050106) using the USGS Water Data Report 2009. The USGS report included: (1) the location of the Alston gage; (2) the drainage area above this gage, which is 12,406 sq km (4,790 sq mi); and (3) the daily water discharges for October 1896 to 1907 and October 1980 to present. USGS reported that records from 1897 to 1908 water years were of low quality. The lowest, mean, and highest annual mean flow for years 1981 to 2009 were (50.5, 150.5, 273.2 m^3/s, respectively (1,782, 5,316 and 9,649 cfs). Annual runoff during this period was 38.4 cm (15.1 in). Ten percent of the flow exceeds 300.2 m^3/s (10,600 cfs), 50 percent exceed 101.7 m^3/s (3,590 cfs), and 90 percent exceed 34.3 m^3/s (1,210 cfs) over this period. (USGS, 2009).

The staff examined the USGS streamflow summary for Richtex (02161500) using information made available by the USGS. The USGS report included: (1) the location of the Alston gage in Fairfield County at Latitude 34 11 05 and 81 11 48 NAD27; (2) the drainage area above this gage, which is 12,561 sq km (4,850 sq mi); and (3) the daily water discharges for October 1925 to 1983. The lowest, mean, and highest annual mean flow for years 1925 to 1983 were 96.4, 174.4, and 265.8 m^3/s (3,403, 6,158 and 6,158 cfs). Ten percent of the flow exceeds 320.0 m^3/sec (11,300 cfs), 50 percent exceed SI 120.3 m^3/s (4,250 cfs), and 90 percent exceed 53.5 m^3/s (1,890 cfs) over this period (USGS, 2004).

2.4.1.4.3.2 Lakes and Reservoirs

Information Submitted by the Applicant

The applicant described the Monticello Reservoir as having a watershed area of 17.4 mi^2 and created by the construction of four dams, which drown Frees Creek. The crest elevation of all four dams is 434 ft NGVD29. The reservoir has a storage volume of 400,000 acre-feet and surface area of 6,800 acres at the normal maximum pool elevation of 425.0 ft NGVD29. The surface area is reduced to 6,500 acres when the pool elevation is 420.5 ft NVGD29. This represents a change in 29,000 acre-feet of storage which is the maximum daily withdrawal for power generating purposes.

The applicant stated that the Parr Reservoir was formed by the construction in 1914 of Parr Shoals Dam on the Broad River. The reservoir has a normal pool volume of 29,000 acre-feet. Normal pool elevation of the Parr Shoals Dam is 266 ft NGVD29. The Parr Shoals Dam is composed of concrete and earthen sections with the non-overflow sections with crest elevation 272.1 ft NVGD29 and 271.1 ft NGVD29 on the west and east respectively. The Parr Shoals Dam has a top-of-gate elevation of 266 ft NGVD29. Parr Reservoir receives inflow from the Broad River and from Monticello Reservoir via the FPSF. The dam has a surface area of about 4,400 acres and 29,000 acre-feet of usable storage at this top-of-gate elevation. At minimum pool elevation (256 ft NGVD29), the reservoir surface area is 1,400 acres and has a non-usable storage of 2,500 acre-feet.

The applicant described several reservoirs on the Broad River, both upstream and downstream of the VCSNS Units 2 and 3 site. The applicant reported the properties of these reservoirs in VCSNS COL FSAR Table 2.4-204 and their locations are shown in VCSNS COL FSAR Figure 2.4-207.

The applicant identified a future possible impoundment within the Broad River called Clinchfield Dam. The dam would be located in the upper reaches of the Broad River about 100 mi upstream of VCSNS as shown on FSAR Figure 2.4-208. The dam feasibility study was completed in 1969 by the U.S. Army Corps of Engineers (USACE). No further plans to build Clinchfield Dam were found by the applicant.

NRC Staff's Technical Evaluation

The staff relied on information provided by the applicant in the FSAR regarding the details of operation of the FPSF and the Monticello and Parr Reservoirs. The FPSF is used to exchange water between these two reservoirs under the Federal Energy Regulatory Commission (FERC) project 1894 (Dam Safety Analysis for FPSF) as described in VCSNS COL FSAR Section 2.4.1.2.2.

The Parr Reservoir is used to for hydropower generation. The staff's review of the Parr Reservoir is needed due to its proximity to the VCSNS Units 2 and 3 site and because the Parr Reservoir would impound water if upstream dams or storm events led to flooding in the Broad River. The Parr Reservoir will be further analyzed in subsequent sections of this SER Section 2.4.

The Monticello Reservoir is used as a source of cooling water for VCSNS Unit 1 and is proposed by the applicant as the source of the cooling water for VCSNS Units 2 and 3. The Monticello Reservoir is also used to store water for hydropower generation. The staff's review of the Monticello Reservoir is needed due to its proximity to the VCSNS Units 2 and 3 site and because it is operated with pool elevations that exceed the site grade elevation of the proposed units. The Monticello Reservoir will be further analyzed in subsequent sections of this SER Section 2.4.

2.4.1.4.3.3 Surface Water Users

Information Submitted by the Applicant

The applicant describes, using 2005 data received by the South Carolina Department of Health and Environmental Control (SCDHEC), the surface water users downstream from the VCSNS Units 2 and 3 site. The locations of these users are shown in VCSNS COL FSAR Figure 2.4-209. The nearest downstream user is the Columbia Canal Water Plant located 28 mi downstream of VCSNS Units 2 and 3.

NRC Staff's Technical Evaluation

Surface water use is described in the draft NRC ER for VCSNS Units 2 and 3. In the review of downstream water used, the staff identified the city of Columbia as the closest downstream large user of surface water. Other identified downstream surface water users were the town of Winnsboro, the city of Newberry, and the town of Whitmire. VCSNS Unit 1 and the Parr Shoal Dam are the other reported users.

2.4.1.4.3.4 Groundwater Users

Information Submitted by the Applicant

The applicant identified 16 public groundwater supply wells with 6 miles of the VCSNS site in the FSAR. The applicant noted that 15 of these wells are located on the opposite sides of either Parr or Monticello Reservoir from the Units 2 and 3 site. The remaining well is located near Parr Hydro. The applicant stated that no local groundwater is planned for use for the operation of VCSNS Units 2 and 3 and the nearest that water supply well could be placed to the site was about 0.75 mi.

NRC Staff's Technical Evaluation

The NRC staff relied on the information supplied in Section 2.3.2.2 of the VCSNS Draft Environmental Impact Statement (DEIS) for identification of local groundwater use. Table 2.3-26 of the VCSNS ER summarizes groundwater use for counties within an 80.5 km (50 mi) radius of the VCSNS site in 2004. Public water-supply wells within 9.7 km (6 mi) of the VCSNS site are listed in VCSNS COL FSAR Table 2.4-215 based on the SCDHEC database and Environmental Protection Agency's (EPA's) Safe Drinking Water Information System

(SDWIS) database for population served. The table lists 14 active public water-supply wells in the area screened in the Piedmont physiographic province bedrock aquifer. The ER states that "the nearest large groups of wells are located approximately 1.5 mi east of the site along SC 215 and in Jenkinsville approximately 2.5 miles southeast of the site" which serve "private residences and stores" (SCE&G 2009a). The ER also lists the Jenkinsville Water Company that has nine wells, three wells within 3.2 km (2 mi) of the VCSNS site.

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 confirmed that the applicant has demonstrated that the characteristics of the site fall within the site parameters specified in the design certification (DC) rule, and that no outstanding information is expected to be addressed in the VCSNS COL FSAR related to this section.

As set forth above, the applicant has presented and substantiated information to establish the site description. The staff has reviewed the information provided and, for the reasons given above, concludes that the applicant has provided sufficient details about the site description to allow the staff to evaluate, as documented in Section 2.4.1 of this SER, whether the applicant has met the relevant requirements of 10 CFR 52.79(a)(1)(iii) and 10 CFR Part 100 with respect to determining the acceptability of the site. This addresses COL Information Item 2.4-1. In conclusion, the applicant has provided sufficient information for satisfying 10 CFR Part 52 and 10 CFR Part 100.

2.4.2 Floods

2.4.2.1 *Introduction*

FSAR Section 2.4.2 of the VCSNS COL application 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.

Section 2.4.2 of this SER provides a review of the following specific areas: (1) local flooding on the site and drainage design; (2) stream flooding; (3) surges; (4) seiches; (5) tsunami; (6) dam failures; (7) flooding caused by landslides; (8) effects of ice formation on water bodies; (9) combined event criteria; (10) other site-related evaluation criteria; and (11) any additional information requirements prescribed in the "Contents of Application" sections of the applicable subparts to 10 CFR Part 52.

2.4.2.2 *Summary of Application*

This section of the VCSNS COL FSAR addresses information on site-specific flooding. The applicant addressed the information as follows:

<u>*AP1000 COL Information Item*</u>

- VCS COL 2.4-2

In addition, this section addresses the following COL Information Item 2.4-2 (COL Action Item 2.4.1-2) identified in Section 2.4.1.2 of the DCD.

> Combined License applicants referencing the AP1000 design will address the following site specific information on historical flooding and potential flooding factors, including the effects of local intense precipitation.
>
> - Probable Maximum Flood on Streams and Rivers – Site-specific information that will be used to determine design basis flooding at the site. This information will include the probable maximum flood on streams and rivers.
> - Dam Failures – Site specific information on potential dam failures.
> - Probable Maximum Surge and Seiche Flooding – Site-specific information on probable maximum surge and seiche flooding.
> - Probable Maximum Tsunami Loading – Site-specific information on probable maximum tsunami loading.
> - Flood Protection Requirements – Site-specific information on flood protection requirements or verification that flood protection is not required to meet the site parameter of flood level.
>
> No further action is required for sites within the bounds of the site parameter for flood level.

VCS COL 2.4-2 adds VCSNS COL FSAR Section 2.4.2 in its entirety.

This section of the SER relates to the historical flooding and local intense precipitation part of COL Information Item 2.4-2.

2.4.2.3 *Regulatory Basis*

The acceptance criteria associated with the relevant requirements of the Commission regulations for the identification of floods and flood design considerations are given in Section 2.4.2 of NUREG-0800.

The applicable regulatory requirements for identifying floods are:

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

- 10 CFR 52.79(a)(1)(iii), as it relates to the hydrologic 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.

The related acceptance criteria are as follows:

- RG 1.59, Revision 2, as supplemented by best current practices
- RG 1.102, Revision 1

2.4.2.4 *Technical Evaluation*

The NRC staff reviewed Section 2.4.2 of the VCSNS COL FSAR and checked the referenced DCD to ensure that the combination of the DCD and the COL application represents the complete scope of information relating to this review topic.[1] The NRC staff's review confirmed that the information in the application and incorporated by reference addresses the required information relating to the site-specific flooding description. The results of the NRC staff's evaluation of the information incorporated by reference in the VCSNS COL application are documented in NUREG-1793 and its supplements.

The staff reviewed the information in the VCSNS COL FSAR:

AP1000 COL Information Item

- VCS COL 2.4-2

2.4.2.4.1 Flood History

Information Provided by Applicant

The applicant stated that flooding near the VCSNS site from natural events can be caused by flooding in the Broad River, local intense precipitation, and dam and levee breaches.

The applicant stated that examination of the historical streamflow records at Alston and Richtex indicated a Broad River flood season in the spring and another in the fall. The floods in the fall were associated with hurricanes. Fall floods tended to be larger than spring floods. The applicant provided a table of the historical high flows and water elevations at Richtex. The largest observed flow at Richtex was 228,000 cfs on October 3, 1929. The water elevation of 215.5 ft NGVD29 at Richtex was observed on this date. The applicant estimated the flow and water elevation at the Parr Shoals Dam on this date to be 223,299 cfs and 266.2 ft NGVD29. These estimates assumed that the Parr Shoals Dam was operated in a manner consistent with the requirements for high flow conditions. The applicant stated that flood flow observations since 1977 may have been impacted by the operation of the FPSF.

The applicant stated that the Monticello Reservoir, an off-stream pond, has a historical pool elevation range of 420.5 to 425.0 ft NGVD29. The pool elevation in the Monticello Reservoir is controlled by the FPSF. Natural runoff into the Monticello Reservoir is limited due to the small watershed area.

NRC Staff's Technical Evaluation

The staff reviewed the data presented by the applicant in the VCSNS COL FSAR Section 2.4.2 regarding historical flooding. The staff independently obtained annual peak flow data for the Aston and Richtex USGS streamflow gauges. The historical peak flow data for the two gauges is plotted in SER Figures 2.4-1 and 2.4-2.

Based on this data, staff determined that the maximum historical annual peak discharges at the Aston and Richtex USGS gauges were 140,000 cfs and 228,000 cfs and occurred on June 7, 1903 and October 3, 1929, respectively. These discharge values were estimated based on recorded stages at each gauging station where the stages were 240.2 ft and 214.8 ft NAVD88 respectively. The ten highest peak discharge and water levels for Alston, Richtex and Carlisle are presented below.

Ten highest water levels recorded at the Alston USGS gauge 02161000

Water Year	Date	Peak Discharge (cfs)	Water Level (ft, NAVD88)
1903	Jun. 07, 1903	140,000	240.2
1991	Oct. 14, 1990	119,000	238.2
1987	Mar. 03, 1987	108,000	237.1
1995	Aug. 30, 1995	99,100	236.1
1901	May. 23, 1901	106,000	236.0
1902	Dec. 31, 1901	105,000	235.9
2003	Mar. 22, 2003	96,600	235.9
2004	Sep. 10, 2004	93,600	235.6
1900	Apr. 22, 1900	95,100	234.6
1990	Oct. 03, 1989	79,500	233.9

Ten highest water levels recorded at the Richtex USGS gauge 02161500

Water Year	Date	Peak Discharge (cfs)	Water Level (ft, NAVD88)
1930	Oct. 03, 1929	228,000	214.8
1928	Aug. 17, 1928	222,000	214.2
1936	Apr. 08, 1936	157,000	209.1
1977	Oct. 11, 1976	146,000	207.8
1940	Aug. 16, 1940	120,000	205.2
1933	Oct. 18, 1932	101,000	203.9
1965	Oct. 18, 1964	102,000	203.4
1964	Apr. 09, 1964	99,500	203.1
1945	Sep. 19, 1945	96,600	202.8
1949	Nov. 30, 1948	95,700	202.7

Ten highest water levels recorded at the Carlisle USGS gauge 02156500

Water Year	Date	Peak Discharge (cfs)	Water Level (ft, NAVD88)
1977	Oct. 10, 1976	123,000	321.6
1940	Aug. 15, 1940	103,000	319.5
1991	Oct. 14, 1990	78,200	316.7
1965	Oct. 18, 1964	79,900	315.9
1987	Mar. 02, 1987	72,100	315.9
1945	Sep. 19, 1945	78,500	315.8
2004	Sep. 10, 2004	71,200	315.4
2003	Mar. 21, 2003	69,400	315.1
1995	Jan. 16, 1995	65,800	314.5
1964	Apr. 08, 1964	69,500	314.0

2.4.2.4.2 Flood Design Considerations

Information Submitted by Applicant

The applicant stated that the design-basis flood elevation at the VCSNS site was determined from several scenarios, including the effects of local intense precipitation, probable maximum flood (PMF) on streams and rivers, potential dam failures, and ice effects. These flood scenarios are described in their respective VCSNS COL FSAR sections. Combinations of appropriate conditions with flooding scenarios, such as wind-generated waves, were considered.

The maximum flood water surface elevation at the VCSNS site was estimated from the effects of local intense precipitation and was determined to be the design-basis flood elevation at the site. The design-basis flood elevation of 399.4 ft NAVD88 is below ground-floor elevation of safety-related SSC at the VCSNS site.

NRC Staff's Technical Evaluation

The staff reviewed the description of flooding mechanisms provided by the applicant in VCSNS COL FSAR Sections 2.4.2, “Floods,” 2.4.3,”PMF [Probable Maximum Flood] on Streams and Rivers,” 2.4.4,”Potential Dam Failures,” 2.4.5, “Probable Maximum Surge and Seiche Flooding,” 2.4.6, “Probable Maximum Tsunami Hazards,” and 2.4.7, “Ice Effects.” The staff's review of these individual flooding mechanisms and their flooding potential is described in detail in the associated sections of the SER. The staff determined that the design basis flood is the flooding from local intense precipitation that is discussed in the following section.

2.4.2.4.3 Effects of Local Intense Precipitation

Information Submitted by the Applicant

Probable Maximum Precipitation (PMP) Depths

The applicant stated the design-basis for local intense precipitation is the all-season, 1-mi^2, PMP, which was obtained from the U.S. National Weather Service (NWS) Hydro-meteorological

Reports (HMR) No. 51 and 52 (Schreiner L.C. and J.T. Riedel, 1978 and Hansen et al., 1982). The values of PMP depths presented in VCSNS COL FSAR Table 2.4.2-207 are reproduced below.

Local Intense precipitation at the VCSNS Units 2 and 3 site
(adapted from FSAR Table 2.4.2-207)

Duration	PMP Depth cm(in)
5 minutes	15.7 (6.2)
15 minutes	24.6 (9.7)
30 minutes	35.8(14.1)
1 hour	48.3 (19.0)
6 hours	77.2 (30.4)

Local Drainage Components and Subbasins

The applicant divided the VCSNS Units 2 and 3 into four discrete subbasins, each of which has one or more distinct drainage outlets as shown in VCSNS COL FSAR Figure 2.4-210. Subbasin 1 covers the western part of the site including Unit 3. Subbasin 2 covers the eastern part of the site including Unit 2. Subbasin 3 covers the northern part of the site, including the parking lot. Subbasin 4 covers the southern part of the site including the cooling tower pad. Two additional drainage areas (i.e., Subbasin A to the east and Subbasin B to the north), located outside the main plant site area, may contribute runoff to the adjoining Subbasin 2 during an extreme storm event such as the PMP. For simplicity, the applicant assumed that during the PMP event, the entire runoff from Subbasin A flows into Subbasin 2 and that the culvert under the railroad to the south is blocked as in accordance with American National Standards Institute (ANSI)/American Nuclear Society (ANS) 2.8-1992, "Determining Design Basis Flooding at Power Reactor Sites." The runoff from Subbasin B may be blocked by the road coming out of the site and going towards the north so that it does not contribute to Subbasin 2. The applicant stated that only Subbasins 1, 2 and 3 cover areas near safety-related structures.

Peak Discharges

The applicant stated that PMP peak discharges were computed using the Rational Method for each of four subbasins. Subbasin 1 drains the southern portion of the site, Subbasin 2 drains the northern section of the site, Subbasin 3 drains the western portion of the site, and Subbasin 4 drains the eastern portion of the site. Subbasin 4 lies to the east of the safety related structures. The applicant estimated peak runoff flows for Subbasins 1 to 4 were 56.5, 128.7, 53.3, 135.8 m^3/s (1996, 4546, 1883 and 4796 cfs), respectively.

Hydraulic Model Setup

The applicant delineated discharge channels and divided each into 5 to 15 cross-sections having the peak discharges at each cross-section in each of the four subbasins. The applicant assumed critical depth at the reach outlets. The applicant assumed the Manning's n equal to 0.04 and contraction/expansion coefficient equal to 0.1/0.3. The input parameters used by the applicant for the HEC model were provided electronically in a letter dated January 4, 2010 in response to a verbal request for additional information (RAI 2.4.13-13).

Flood Elevations

The applicant stated that the highest estimated water surface elevation at the site was less than the proposed site grade of 121.92 m (400 ft) NAVD88. The maximum water surface elevation for each case was 121.86 m (399.8 ft) NAVD88. The highest water surface elevation near safety-related structures (Subbasins 1, 2 and 3) was 121.74 m (399.4 ft) NAVD88.

An accurate description of flooding mechanisms and combinations of these is required for staff to perform its safety assessment. The staff reviewed the description of flooding mechanisms provided by the applicant in VCSNS COL FSAR Section 2.4.2. The staff's review of these individual flooding mechanisms and their flooding potential is described in appropriate sections of the SER Section 2.4.

NRC Staff's Technical Evaluation

Probable Maximum Precipitation Depths

The staff reviewed the description of the local PMP performed by the applicant. The staff determined that the method used by the applicant is acceptable as this method is recommended in NUREG-0800 Section 2.4.2. The staff performed an independent estimation of the local PMP from HMR 51 and 52 and obtained values comparable to the values presented by the applicant in VCSNS COL FSAR Section 2.4.2. The staff agrees with the applicant-estimated local PMP depths.

Local Drainage Components and Subbasins

Staff verbally requested additional information (RAI 2.4.13-13) from the applicant related to obtaining the HEC-RAS cross-sections, the rationale for characterization of flow paths, and a description of the 121.92 m (400 ft) NAVD88 elevation contour at the VCSNS Units 2 and 3 site. The applicant provided a response on January 4, 2010, which:

- Provided an electronic file of the cross-section geometry data and locations of the channel cross-sections used in the HEC-RAS hydraulic models.

- Clarified that the VCSNS site is divided into north and south sides by an owner-controlled railroad line, which follows the crest of the site and runs from west to east across the site at an elevation of 400 feet. No runoff crosses the railroad, which acts as a watershed divide. The VCSNS Units 2 and 3 site area has been divided into four subbasins. Subbasin 2 drains into Storm Water Basin 1, which is located in the north-central part of this subbasin. Storm Water Basin 1 drains off the project site to the north. Subbasin 4 drains into Storm Water Basin 3, which is located in the southeastern Part of this subbasin. Storm Water Basin 3 drains off the project site to the southeast. Specifically, Subbasins 2 and 4 are located on opposite sides of the site drainage divide defined by the railroad embankment and the 400-ft contour. Therefore, since Subbasins 2 and 4 drain in different directions via different routes, it is not appropriate to combine their runoff at any of the drainage outlets or storm water basins.

- Clarified that the 400-ft elevation contour appears in several locations on the VCSNS Units 2 and 3 site. It encloses an area at the southwest end of the site, to the west of the cooling towers, south of the railroad, a narrow area along the cooling tower access road, and borders a part of the site to the east of the cooling towers. It also parallels each side of the railroad grade from west to east across most of the Units 2 and 3 site. In addition, near the eastern side of the site, it branches to the north and south away from the railroad grade. Finally, the 400-ft contour also traverses the northern edges of the parking lot at the north end of the site.

Since the applicant provided the requested HEC-RAS files, provided a detailed description of the flow paths, and clarified the location of the 400-ft contour at the site, the NRC staff finds the applicant's response acceptable and, therefore, considers RAI 2.4.13-13 closed.

Peak Discharges

The NRC staff used the peak precipitation rates from the PMP analysis to estimate the peak discharges using the Rational Method. The equation in the Rational Method has the form of

$$Q=C_f \cdot C \cdot i \cdot A$$

where Q = peak rate of flow (cfs), C_f = frequency factor, C = runoff coefficient, i = intensity of precipitation (in/hr), and A = drainage area (acres). The applicant used the conservative coefficient value (C_f C = 1). A conservative application of the Rational Method is to assume that all precipitation immediately runs off at a rate indicated by the rainfall intensity. The staff used this method and produced PMP peak flows from Subbasins 1 to 4 of 56.5 m^3/s, 128.7 m^3/s, 53.3 m^3/s, and 135.8 m^3/s(1996 cfs, 4546 cfs, 1883 cfs, and 4796 cfs), respectively. Since these discharges are the same as those calculated by the applicant, the NRC staff finds the applicant's peak discharges to be acceptable.

Hydraulic Model Setup

The staff reviewed the input parameters used by the applicant to set up the hydraulic model that were provided electronically and described in the applicant's January 4, 2010 response to RAI 2.4.13-13. The staff determined the hydraulic model was appropriately configured.

The staff, however, determined that the values of Manning's roughness coefficients for grass and for gravel used by the applicant in the HEC-RAS simulations did not represent the upper limit of what could be expected for the site. The applicant used a value of 0.04 for Manning's roughness coefficient in doing HEC-RAS modeling for the gravel and grass covered channels. In the reference, "Open Channel Hydraulics" (Chow 1959), it is suggested that the value of Manning's roughness coefficient range from 0.017-0.036 for gravel, from 0.025 to 0.035 for short grass, and from 0.030 to 0.050 for high grass. The staff conservatively selected a value of 0.05 and did a sensitivity analysis and found the maximum floodwater surface elevation near safety-related structures increased less than 1.5 cm (0.05 ft) (from 121.73 to 121.75 m (399.39 to 399.43 ft) NAVD88). The staff finds that the applicant's analysis of the local intense precipitation flooding is appropriate.

Flood Elevations

The staff's confirmatory analysis and independent sensitivity analysis yield maximum water surface elevation resulting from local intense precipitation to be 121.74 m (399.4 ft). This occurred at the upstream end of the channels draining Subbasins 1, 2, and 3. These estimates are lower than the design ground floor elevations for safety-related structures at the VCSNS Units 2 and 3 site.

No conceptual model is conceived where floods on the Broad River could rise to the level of the VCSNS Units 2 and 3 safety-related structures. Local intense precipitation events are conceived as potentially impacting the safety-related structures and so are further analyzed in detail in this technical evaluation. Flooding of the Broad River and the Frees Creek (which directly discharges into the Monticello Reservoir) due to PMP events is evaluated. Wind generated setup in the Monticello Reservoir is also considered as a potential flooding mechanism that could impact the safety-related structures. Flooding due to dam failures, either on the Broad River or on the Frees Creek is evaluated as a possible impact on the safety-related structures. These failures are also considered in terms of loss of water supply and operation of safety-related functions. The conceptual model for the site is that uncontrolled releases from the Monticello Reservoir would flow into high-capacity creeks between the reservoir and the VCSNS Units 2 and 3 and these waters would pass into the Broad River. No conceptual model is conceived where tsunamis or ice blockage of the Broad River could impact VCSNS Units 2 and 3 safety-related structures. The safe shutdown of the AP1000 does not rely on externally supplied water and so icing and other low water conditions do not pose safety-related risks.

The VCSNS safety-related structures are located at an elevation of 121.92 m (400 ft) NAVD88 approximately 45.7 m (150 ft) above the floodplain of the Broad River/Parr Shoals Reservoir.

The staff determined that a flood in the Broad River would need to raise the water level in Parr Shoal 45.7 m (150 ft) in order to reach site grade. VCSNS Units 2 and 3 site grade is 7.8 m (25.7 ft) below the normal pool level of the Monticello Reservoir. Local drainage paths indicated by topography suggest Frees Creek thalweg elevations surrounding the VCSNS site range from 91.4 to 109.7 m (300 to 360 ft). The design elevation of the VCSNS safety-related structures is 121.92 m (400 ft) NAVD88.

The staff confirmed that the VCSNS COL FSAR includes a complete scope of information relating to flood risk. In this technical evaluation, a flood risk due to local intense precipitation is further reviewed and analyzed by the staff.

The applicant provided the hydraulic model HEC-RAS files to be used for the staff's independent verification. VCSNS COL FSAR Section 2.4.2.3 describes the network of drainage ditches at the site that are designed to convey local surface water runoff away from the safety-related structures. The staff's review includes verification about whether the applicant's analysis was appropriate. The analyses of the local intense precipitation event and the routing of the floodwaters through the drainage system, described in the VCSNS COL FSAR, show the applicant's design basis for handling floodwaters in the vicinity of the power block. As such, the applicant must provide commitments in the VCSNS COL FSAR that the drainage system will function as designed throughout the operating life of the power station.

Key aspects for reviewing the applicant's hydraulic analyses that affect local intense precipitation flood included: (1) appropriate representation of the drainage system of the site in the HEC-RAS model setup; (2) estimation of local PMP peak runoff; and (3) sensitivity of hydraulic analysis to bed roughness, contraction and expansion coefficient, and boundary conditions, including regional flooding impact. Therefore, the NRC staff focused on these aspects to evaluate potential flood risk.

The staff's review of the HEC-RAS input files found them to conform to the applicant's statements in the VCSNS COL FSAR. The applicant identified the elevation of 121.92 m (400 ft) NAVD88 as the plant safety elevation. The applicant developed the HEC-RAS model cross-sections from topographic data for the overbank area and the proposed geometric configurations for the channels. The staff compared the HEC-RAS model cross-sections with the topographic information provided in the VCSNS COL FSAR.

In the VCSNS COL FSAR, the applicant included the overall site map of the VCSNS site showing the plant site drainage basins and flow paths (FSAR Figure 2.4-210). The applicant's analysis used the HEC-RAS model to determine water surface elevations at the site. An important aspect of the HEC-RAS model is that it uses cross sections to define the geometry of the drainage area. A map with the locations of these cross-sections was not provided to the staff in the VCSNS COL FSAR. Therefore, in RAI 2.4.13-14, the staff requested that the applicant provide a map with HEC-RAS cross-sections and clear identification of the safety-related structures and the design basis flood elevation. Based on the basin map identified in RAI 2.4.13-14, the staff confirmed that the applicant's HEC-RAS model cross-sections adequately represent the drainage system in the site. In response to RAI 2.4.13-14, the applicant committed to add the cross-section map to a future FSAR revision, therefore, this will be tracked as **Confirmatory Item 2.4.2-1**.

Resolution of Confirmatory Item 2.4.2-1

Confirmatory Item 2.4.2-1 is an applicant commitment to update its FSAR to include a cross-section map. The staff verified that the VCSNS COL FSAR was appropriately updated. As a result, this portion of Confirmatory Item 2.4.2-1 is now closed.

The HEC-RAS model for the site includes the following drainage areas as shown in VCSNS COL FSAR Figure 2.4-210:

- Subbasin A to the north of the site, which drains into Subbasin 2
- Subbasin B to the northwest of the site, which drains away from the site
- Subbasin 2 covering the north portion of the site, receiving flow from Subbasin A and discharging to the west of the site
- Subbasin 3 draining the southwest quadrant of the site and discharging along the west and south boundaries of the site
- Subbasin 1 covering the south central portion of the site and discharging along its southern boundary
- Subbasin 4 covering the southeastern portion of the site with discharge along the eastern boundary.

The railroad line coincides with the flow divide for Subbasins 1 and 4. The power block area forms another significant divide for subbasins 1 and 3 as well as Subbasins 2 and 3. An additional drainage area (Subbasin 5) was used by the NRC for the examination of flow effects at Storm Water Basin 3 within Subbasin 4. This additional drainage area is depicted in SER Figure 2.4-3, "Plant Site Drainage Basins and Flow Paths."

Culverts installed at the VCSNS site are conservatively treated using cross-sections aligned with the access roads and assuming that they are completely blocked. Culverts treated in this manner are found in the basin map provided by the applicant as a part of RAI 2.4.13-14. In response to RAI 2.4.13-14, the applicant committed to add the basin map to a future FSAR revision; therefore, this will be tracked as part of **Confirmatory Item 2.4.2-1**. Handling culvert cross-sections in this manner results in overflow of the plant access road in Subbasin 1. This particular access road is modeled with three cross-sections. This approach accounts for the effect of culvert blockage as a result of debris build-up resulting from a local-intense precipitation event.

Resolution of Confirmatory Item 2.4.2-1

Confirmatory Item 2.4.2-1 is an applicant commitment to update its FSAR to include a basin map. The staff verified that the VCSNS COL FSAR was appropriately updated. As a result, this portion of Confirmatory Item 2.4.2-1 is now closed.

The staff used the peak flows from the PMP analysis estimated using the Rational Method as described in the technical evaluation for peak discharges. This method produced PMP peak flows from Subbasins 1 to 4 of 56.5 m^3/s, 128.7 m^3/s, 53.3 m^3/s, 135.8 m^3/s(1996 cfs, 4546 cfs, 1883 cfs, and 4796 cfs), respectively. These flows were input into the HEC-RAS hydraulic model assuming a steady-state. These flows were distributed in proportion to drainage area upstream of each cross-section in the HEC-RAS model. The steady state approach produces a conservative result.

The staff conducted a series of sensitivity analysis on bed roughness, contraction/expansion coefficients, and boundary conditions to determine their effect on the maximum water levels from the HEC-RAS model. These parameters were selected based on a review of the VCSNS COL FSAR and the applicant's HEC-RAS model. Summary results showing the impact of these sensitivity tests on flood levels are shown in SER Table 2.4-1.

According to VCSNS COL FSAR Section 2.4.2.3, the applicant set up the HEC-RAS model using Manning's roughness coefficient (n) of 0.04 for areas associated with main channel and overbank sections. This value is typical for coarse cobbled natural channels and flood plains covered with light brush. The staff confirmed that the VCSNS COL FSAR and the HEC-RAS input file were consistent with regard to the roughness characterization.

The staff conducted a sensitivity test for the model inputs including systematic variations of the channel and overbank roughness Increasing Manning's n to 0.075 (heavy brush) in all cross-sections increased the water surface elevations within each drainage area. The maximum water surface elevation at the upstream end was more dependent on the flow regime change due to combination of bed roughness variation and channel slope. The water surface elevation remained below the safety-related elevation of 121.92 m (400 ft) for Subbasins 1, 2, and 3, with a maximum water surface elevation of 121.77 m (399.5) ft. For Subbasin 4, the maximum water surface elevation was 122.20 m (400.91 ft), which slightly exceeded the elevation of the railroad embankment (121.92 m (400 ft) NAVD88). The staff's analysis indicates the importance of site maintenance and ensuring that the drainage channels are able to convey floodwaters for the design basis storm through the operational life of the plant. As discussed in the next paragraph, the applicant has made commitments that resolve this issue.

RAI 2.4.2-1 and RAI 2.4.13-14 requested the applicant to provide a description of the VCSNS program to ensure drainage channels remain free from obstructions in the event of a heavy precipitation event. The applicant provided a description of the administrative controls and surveillance requirements in response to RAI 2.4.2-1; therefore, RAI 2.4.2-1 is closed. In response to RAI 2.4.13-14, the applicant committed to perform a walk-down prior to heavy rain events to look for potential sources of blockage or other inhibitors to proper storm water drainage. The incorporation of this commitment in a future VCSNS COL FSAR revision is being tracked as part of **Confirmatory Item 2.4.2-1**

Resolution of Confirmatory Item 2.4.2-1

Confirmatory Item 2.4.2-1 is an applicant commitment to update its FSAR to include a commitment to perform a walk-down prior to heavy rain events to look for potential sources of blockage or other inhibitors to proper storm water drainage. The staff verified that the VCSNS COL FSAR was appropriately updated. As a result, this portion of Confirmatory Item 2.4.2-1 is now closed.

The staff conducted a sensitivity test for the increased contraction and expansion coefficients to assess the effect of debris causing hydraulic energy loss, which generally resulted in increased water surface elevation. The applicant used contraction and expansion coefficients of 0.1 and 0.3 typical for gradual transition of channel. Typical coefficient values for abrupt transitions are 0.6 to 1.0. The Manning's n values were unchanged from the value used by the applicant. The staff's analyses assuming the abrupt transition produced no significant change of the maximum water surface elevation. The highest water surface elevation of 121.88 m (399.88 ft) in Subbasin 4 remained below the railroad elevation.

The staff confirmed the validity of the downstream boundary conditions. The applicant's HEC-RAS model used critical depth as the downstream boundary condition. The staff considered this a suitable boundary condition as long as runoff exits in the subbasins through a highly-sloped (i.e., 3:1) fill, which forces the flow into a supercritical regime.

The impact on the downstream boundary condition along Mayo Creek due to flooding from a potential dam break of the Monticello Reservoir was also examined. The estimated potential flood level near the discharge point of Subbasin 4 from the dam break was 119.44 m (391.85 ft) NAVD88. After applying this water surface elevation as the downstream boundary condition of Subbasin 4 in the HEC-RAS model, the staff found that the maximum water surface elevation remained unchanged. The effect of the high water surface elevation at the boundary does not propagate upstream due to the supercritical flow region at the downstream cross-sections of the model (30.48 m (100 ft) NAVD88~91.44 m (300 ft) from the downstream boundary). Consequently, the Mayo Creek flooding will not affect the flood level at the site.

The applicant did not consider the runoff from the drainage (northeast portion of plant site) adjoined with Subbasins 2 and 4. The topography map of the drainage area indicates flooding water drains into a storm water basin (SWB 3) that also receives the runoff from Subbasin 4. The staff considered whether the combined runoff might affect the storage and discharge capacity of the storm water basin, by increasing the downstream water surface elevation and potentially affect the upstream water surface elevation. The staff investigated the effect of PMP runoff from the unaccounted drainage area on the flood level in Subbasin 4. Conservatively, the PMP runoff (Q = i A = 57.1 m^3/s (2015 cfs)) estimated by the staff for the drainage was added to the cumulative inflow (4796 cfs) at the downstream cross-section in the HEC-RAS analysis of Subbasin 4. The result showed the maximum water surface elevation unchanged from the applicant's estimation. Therefore, no risk was associated with the effect of the additional drainage flow on the maximum water surface elevation in Subbasin 4. This is attributed to the supercritical flow occurring at the downstream cross-sections of the model due to the relatively high bed slope.

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 confirmed that the applicant has addressed the information related to 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 information also covered the potential effects of local intense precipitation. The staff also confirmed that no outstanding information is expected to be addressed in the COL FSAR related to this section.

As set forth above, the applicant has presented and substantiated information to establish the site description. The staff has reviewed the information provided and, for the reasons given above, concludes that the applicant has provided sufficient details about the site description to allow the staff to evaluate, as documented in Section 2.4.2, of this SER, whether the applicant has met the relevant requirements of 10 CFR 52.79(a)(1)(iii) and 10 CFR Part 100 with respect to determining the acceptability of the site. This addresses COL information item VCS COL 2.4-2. In conclusion, the applicant has provided sufficient information for satisfying 10 CFR Part 52 and 10 CFR Part 100.

2.4.3 Probable Maximum Flood on Streams And Rivers

2.4.3.1 *Introduction*

VCSNS COL FSAR Section 2.4.3 describes the hydrological site characteristics affecting any potential hazard to the plant's safety-related facilities as a result of the effect of the PMF on streams and rivers.

Section 2.4.3 of this SER provides a review of the following specific areas: (1) design basis for flooding in streams and rivers; (2) design basis for site drainage; (3) consideration of other site-related evaluation criteria; and (4) any additional information requirements prescribed in the "Contents of Application" sections of the applicable subparts to 10 CFR Part 52.

2.4.3.2 *Summary of Application*

This section of the VCSNS COL FSAR addresses the site-specific information on PMF on streams and rivers. The applicant addressed the information as follows:

<u>*AP1000 COL Information Item*</u>

- VCS COL 2.4-2

In addition, this section addresses the following COL Information Item 2.4-2 (COL Action Item 2.4.1-2) identified in Section 2.4.1.2 of the DCD.

> Combined License applicants referencing the AP1000 design will address the following site specific information on historical flooding and potential flooding factors, including the effects of local intense precipitation.
>
> - Probable Maximum Flood on Streams and Rivers – Site-specific information that will be used to determine design basis flooding at the site. This information will include the probable maximum flood on streams and rivers.
> - Dam Failures – Site specific information on potential dam failures.
> - Probable Maximum Surge and Seiche Flooding – Site-specific information on probable maximum surge and seiche flooding.
> - Probable Maximum Tsunami Loading – Site-specific information on probable maximum tsunami loading.
> - Flood Protection Requirements – Site-specific information on flood protection requirements or verification that flood protection is not required to meet the site parameter of flood level.
>
> No further action is required for sites within the bounds of the site parameter for flood level.

VCS COL 2.4-2 adds VCSNS COL FSAR Section 2.4.3 in its entirety.

This section of the SER relates to the PMFs on streams and rivers part of COL Information Item 2.4-2.

2.4.3.3 *Regulatory Basis*

The acceptance criteria associated with the relevant requirements of the Commission regulations for the identification of floods and flood design considerations are given in Section 2.4.3 of NUREG-0800.

The applicable regulatory requirements for identifying probable maximum flooding on streams and rivers are:

- 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 siting 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 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 are as follows:

- RG 1.59, Revision 2, as supplemented by best current practices.
- RG 1.102, Revision 1

2.4.3.4 *Technical Evaluation*

The NRC staff reviewed Section 2.4.3 of the VCSNS COL FSAR and checked the referenced DCD to ensure that the combination of the DCD and the COL application represents the complete scope of information relating to this review topic.[1] The NRC staff's review confirmed that the information in the application and incorporated by reference addresses the required information relating to the site-specific PMF on streams and rivers. The results of the NRC staff's evaluation of the information incorporated by reference in the VCSNS COL application are documented in NUREG-1793 and its supplements.

The staff reviewed the information in the VCSNS COL FSAR:

AP1000 COL Information Item

- VCS COL 2.4-2

2.4.3.4.1 Probable Maximum Precipitation

Information Submitted by the Applicant

The PMP was estimated on the Broad River and Frees Creek watersheds. These estimates were based on HMRs 51, 52, and 53. The characteristics used to develop the estimates are tabulated below.

	Broad River	**Frees Creek**
Drainage Area (sq mi)	4,850	17.4
72-hr PMP (in)	22.1	48.6

The 72-hr PMP are given above but these are provided in 6-hr increments with VCSNS COL FSAR Tables 2.4-209 and 2.4-210.

<u>NRC Staff's Technical Evaluation</u>

For Broad River (Parr Reservoir), the staff independently estimated the PMP over the Broad River basin using the HMR 52 software developed by the USACE (1991) and confirmed the applicant's PMP estimate of 56.1 cm (22.1 in) and the watershed area (4850 sq mi).

The area of the Frees Creek watershed is 45.1 sq km (17.4 sq mi) of which 27.5 sq km (10.6 sq mi) is the Monticello Reservoir leaving 17.6 sq km (6.8 sq mi) to drain into the Monticello Reservoir. The staff estimated the 72-hr PMP for the watershed area of 25.9 sq km (10 sq mi) to be between 121.9 and 127.0 cm (48 and 50 in) (HMR 51, Figure 22). By examining the location of the Frees Creek watershed, the staff was able to confirm the applicant's 123.4 cm (48.6 in) 72-hr PMP estimate by linear interpolation but decided to use the larger number (127.0 cm (50 in)) as a more conservative approach.

2.4.3.4.2 Precipitation Losses

<u>Information Submitted by the Applicant</u>

For the Broad River (Parr Reservoir), the applicant developed the flood hydrograph of the PMF at Richtex using the rainfall-runoff model HEC-HMS. The applicant modeled precipitation losses using the "Initial and Constant" method in HEC-HMS. The applicant set the initial rainfall loss equal to zero and used a constant rainfall loss rate of 0.06 in/hr in the model. For the Frees Creek (Monticello Reservoir), the 0.06 in/hr rainfall loss rate was also used and no initial rainfall loss was considered.

<u>NRC Staff's Technical Evaluation</u>

The staff reviewed the method followed by the applicant to estimate precipitation loss for the PMF estimate in the Broad River basin (Parr Reservoir) and the Frees Creek basin (Monticello Reservoir). The staff determined that no initial loss applied to the PMP storm was a conservative approach, the method used to estimate loss rate is an approach that is commonly used in practice, and using the 0.15 cm/hr (0.06 in/hr) rainfall loss rate is appropriate.

2.4.3.4.3 Runoff and Stream Course Models

<u>Information Submitted by the Applicant</u>

Based on the 1940 unit hydrograph (based on a storm hydrograph recorded for two storms that occurred on August 16, 1940 and October 14, 1990), the applicant developed the PMP Broad River unit hydrograph with adjustments to the peak flow and the time to peak (increasing the hydrograph peak by 20 percent, from 1,789 to 2,146 m^3/s (63,175 to 75,800 cfs) and decreasing the time to peak by 25 percent from 48 to 36 hours). The applicant set the base flow in the Broad River equal to the average flow.

For the Frees Creek (Monticello Reservoir), the applicant used a simpler and more conservative method than the unit hydrograph based on a rainfall-runoff approach to determine the PMF flood elevation in the reservoir. The applicant calculated the PMF flood stage by adding the volume associated with the direct 72-hour PMP depth over the reservoir area (27.5 sq km

(10.6 sq mi)) and the surface runoff volume of total PMP depth less 0.06 in/hr loss rate from the remaining watershed area (6.8 sq mi) of the Frees Creek. This volume was then added to the full-pool volume of 397,000 acre-feet to yield a total of 440,500 acre-feet.

NRC Staff's Technical Evaluation

The staff found the adjustments made by the applicant to the unit hydrograph developed from the recorded storms to be acceptable. The increase of 20 percent in the peak flow and the reduction in the time to peak of 25 percent is within the range of current practice for these adjustments.

The staff agreed the method used by the applicant is a simpler and more conservative method than the unit hydrograph-based rainfall-runoff approach used to determine the PMF flood elevation in the reservoir and confirmed the applicant's 72-hour PMP estimate of 123.4 cm (48.6 in).

2.4.3.4.4 Probable Maximum Flood Flow

Information Submitted by the Applicant

Using HEC-HMS with an antecedent flow conditions of a 40 percent 72-hour PMP followed by 3 days without precipitation, the applicant estimated the PMP peak flow to be 1,132,879 cfs at Richtex and the corresponding peak flow at Parr Reservoir to be 1,109,521 cfs by multiplying the peak PMF discharge of 1,132,879 cfs at Richtex with the ratio of the two drainage areas (4,750/4,850).

NRC Staff's Technical Evaluation

For the Broad River (Parr Reservoir), in RAI 2.4.2-2, the staff requested that the applicant provide additional details about the flow calculations used to estimate PMP flood flows over Parr Shoals Dam. A response was provided on October 9, 2009. The response included the specific weir equations appropriate for use at the Parr Shoals Dam. The staff determined that the applicant has provided sufficient information for staff to proceed with its review.

The gates of the Parr Shoals Dam on the Broad River have a top elevation of 81.08 m (266 ft) when raised and 78.33 m (257 ft) when lowered (NGVD29). The staff used the higher of the two as the downstream condition, and treated the dam as a set of three weirs yielded PMF levels of 88.85 m (291.5 ft) NGVD29. The applicant used the following weir equation to estimate the flow over sections of the dam:

$$Q = C_d L H^{2/3}$$

where Q is discharge (cfs), L is the length of the dam sections (ft), H is the Head above crest of weir, and C_d is the weir coefficient.

Three sections of the dam were identified for discharge points on Parr Reservoir, as follows:

- lengths of 609.6, 91.4, and 27.4 m (2000, 300, and 90 ft)
- weir base elevations of 81.8, 82.9, and 82.6 m (266, 272.1, and 271.1 ft) (NGVD29)
- weir coefficients (no units) of 3.9, 3.1, and 3.1.

The weir equations were used for these three dam sections along with the PMF peak elevation of 88.85 m (291.5 ft) NGVD29 to confirm the total discharge of these three locations as reported in the VCSNS COL FSAR. For water surface elevation of 88.85 m (291.5 ft) NGVD29, the discharge estimates for each of the three weirs was estimated to be 28,441, 2,250, 728 m^3/s (1,004,396 cfs, 79,467 cfs, and 25,707 cfs), respectively. The total discharge was estimated to be 31,419 m^3/s (1,109,569 cfs), which confirms the applicant's estimate of 31,418 m^3/s (1,109,521 cfs).

The watershed area above the Parr Reservoir is 12,561 sq km (4850 mi^2). The 72-hour PMP is 56.1 cm (22.1 in). The NRC staff conservatively assumed that the entire flow passes through Parr Reservoir in 72 hours without any infiltration. The staff examined the hydrographs presented for the storms identified as 1940, 1976, and 1990 in VCSNS COL FSAR Figures 2.4.3-211, 2.4.3-212, and 2.4.3-213. Based upon the observed shape of these hydrographs, the staff determined that representing the PMP hydrograph as having a duration of 72 hours with symmetric rising and falling arms was reasonable. The staff used the 72-hour runoff volume and this shape of the hydrograph to estimate the PMP peak flow through Parr Shoals Dam and produced peak PMP flow estimate of 54,408 m^3/s (1,921,390 cfs). While this peak flow value exceeds that reported by the applicant, it is designed to determine whether more detailed analysis was warranted and not refute the more detailed assessment described in the VCSNS COL FSAR.

2.4.3.4.5 Water Level Determinations

Information Submitted by the Applicant

Using weir equations to represent flow over the Parr Shoals Dam with the standard weir equation, the applicant calculated a PMF elevation of 291.5 ft NGVD29 at the Parr Reservoir.

Using the stage-volume relationship for the Monticello Reservoir, the applicant estimated the PMF still water surface elevation in the Monticello Reservoir to be 431 ft NGVD29.

NRC Staff's Technical Evaluation

Using the same weir equations but replacing the applicant's peak discharge value with the one estimated by staff yields a peak water surface elevation estimate of 92.35 m (303 ft) NGVD29. A rough doubling of the peak flow value yields an increase in peak water surface elevation from 88.85 m to 92.35 m (291.5 ft to 303 ft) NGVD29. Both the staff's and applicant's estimates show that the PMF elevation at Parr Reservoir is about 30.48 m (100 ft) below the design site grade elevation of 121.92 m (400 ft) NAVD88 (122.13 m (400.7 ft) NGVD29). For the Frees Creek (Monticello Reservoir), the staff conservatively assumed that no water would be released by the FPSF during the PMP event and that the pool would rise due to direct PMP delivery to the Monticello Reservoir and by runoff from the Frees Creek watershed upstream.

The staff used an infiltration rate of 0.15 cm/hr (0.06 in/hr) in the Frees Creek watershed area not covered by the Monticello Reservoir. The net total runoff into the Monticello Reservoir represented an effective 72-hour PMP of 127 cm (50 in). The staff combined this effective PMP with the PMP on the non-reservoir watershed area of 17.6 sq km (6.8 mi^2) after subtracting infiltration to compute a rise in the Monticello Reservoir of 74.4 cm (29.3 in). This was added to the full PMP amount delivered directly to the surface of the Monticello Reservoir. The staff estimated that runoff from the watershed and direct precipitation to the Monticello Reservoir would increase the pool elevation by 201.4 cm (79.3 in) or 2.01 m (6.6 ft). Assuming a normal pool elevation of 129.54 m (425 ft) NGVD29 prior to the PMP event, the staff estimated the post-event pool elevation to be 131.55 m (431.6 ft) NGVD29. Although this elevation exceeds the proposed site grade of 122.13 m (400.7 ft) NGVD29, the proposed VCSNS Units 2 and 3 are located outside the watershed of the Monticello Reservoir and are protected.

2.4.3.4.6 Coincident Wind Wave Activity

Information Submitted by the Applicant

For the Broad River (Parr Reservoir), using a 2-year wind speed of 50 miles per hour (mph), measured 30 ft above the ground surface over land as the design wind speed and the fetch length of 15,820 ft, the applicant estimated the maximum wave height to be 5.16 ft and the wave run-up to be 6.68 ft. The applicant also calculated a wind setup to be 0.17 ft for the reservoir site using the calculation procedures described in USACE Design Guideline EM 1110-2-1420. The total PMF elevation is estimated to be 431 + 6.68 + 0.17 ft or 437.85 ft NGVD29. According to the applicant, this elevation value is below a 438-ft NGVD29 dike crest elevation for the Monticello Reservoir, which will protect VCSNS Units 2 and 3 from water spilled from the Monticello Reservoir.

Because the PMF elevation at Parr Reservoir is well below the design site grade elevation of 400 ft NAVD88, the applicant conducted no analysis for wave action coincident with the PMF peak elevation for the Frees Creek (Monticello Reservoir).

NRC Staff's Technical Evaluation

For the Broad River (Parr Reservoir), the staff used a 22.4-m/s 9.1-m (50-mph 30-ft) elevation wind speed, a PMP modified average depth, and a fetch length of 27.4 km (17 mi), and estimated a combined wind setup and wave run-up water level rise to be 4.42 m (14.5 ft), which yields a maximum water elevation of 96.77 m (317.5 ft) NGVD29 (303 + 14.5 ft)—well below the minimum slab elevation of 121.92 m (400 ft) NAVD88.

For the Frees Creek (Monticello Reservoir), using the Coastal Engineering Manual (EM-1110-2-1100), a 22.4-m/s 9.1-m (50-mph 30-ft) elevation wind speed, a PMP modified average depth, and a fetch length of 9.7 km (6 mi), the staff calculated the combined wind setup and wave runup to be 1.92 m(6.3 ft) for the Monticello Reservoir. Adding this value to the PMP elevation for the Monticello Reservoir yields a maximum elevation of 131.55 + 1.92 m (431.6 + 6.3 ft) NGVD29 or 133.47 m (437.9 ft) NGVD29, slightly more than the applicant's estimate of 133.46 m (437.85 ft) NGVD29 and still below the 133.50 m (438 ft) NGVD29 dike crest elevation for the Monticello Reservoir. By examining the site topography, the staff agreed with the applicant that the VCSNS site will be protected by the dike (north berm) along the shoreline of the Monticello Reservoir north of VCSNS Unit 1, which is located between the VCSNS Units 2 and 3 site and the Monticello Reservoir.

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 confirmed that the applicant has addressed the information relevant to PMF on streams and rivers, and that there is no outstanding information required to be addressed in the VCSNS COL FSAR related to this section.

As set forth above, the applicant has presented and substantiated information to establish the site description. The staff has reviewed the information provided and, for the reasons given above, concludes that the applicant has provided sufficient details about the site description to allow the staff to evaluate whether the applicant has met the relevant requirements of 10 CFR 52.79(a)(1)(iii) and 10 CFR Part 100 with respect to determining the acceptability of the site. This addresses the part of COL Information Item 2.4-2 related to PMFs on streams and rivers.

2.4.4 Potential Dam Failures

2.4.4.1 *Introduction*

FSAR Section 2.4.4 of the VCSNS COL application addresses potential dam failures to ensure that any potential hazard to safety related structures due to failure of onsite, upstream, and downstream water control structures is considered in the plant design.

Section 2.4.4 of this SER presents a review of the specific areas related to dam failures. The specific areas of review are as follows: (1) flood waves resulting from severe dam breaching 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 non-seismic data on the postulated design bases and how they relate to dam failures in the vicinity of the site and the site region; and (8) any additional information requirements prescribed in the “Contents of Application” sections of the applicable subparts to 10 CFR Part 52.

2.4.4.2 *Summary of Application*

This section of the VCSNS COL FSAR addresses the site-specific information on potential dam failures. The applicant addressed the information as follows:

<u>*AP1000 COL Information Item*</u>

- VCS COL 2.4-2

In addition, this section addresses the following COL Information Item 2.4-2 (COL Action Item 2.4.1-1) identified in Section 2.4.1.2 of the DCD.

> Combined License applicants referencing the AP1000 design will address the following site specific information on historical flooding and potential flooding factors, including the effects of local intense precipitation.
>
> - Probable Maximum Flood on Streams and Rivers – Site-specific information that will be used to determine design basis flooding at the site. This information will include the probable maximum flood on streams and rivers.
> - Dam Failures – Site specific information on potential dam failures.
> - Probable Maximum Surge and Seiche Flooding – Site-specific information on probable maximum surge and seiche flooding.
> - Probable Maximum Tsunami Loading – Site-specific information on probable maximum tsunami loading.
> - Flood Protection Requirements – Site-specific information on flood protection requirements or verification that flood protection is not required to meet the site parameter of flood level.
>
> No further action is required for sites within the bounds of the site parameter for flood level.

VCS COL 2.4-2 adds VCSNS COL FSAR Section 2.4.4 in its entirety.

This section of the SER relates to the dam failures part of COL Information Item 2.4-2.

2.4.4.3 *Regulatory Basis*

The acceptance criteria associated with the relevant requirements of the Commission regulations for the identification of floods, flood design considerations and potential dam failures are given in Section 2.4.4 of NUREG-0800.

The applicable regulatory requirements for identifying the effects of dam failures are:

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

- 10 CFR 100.23(d) sets forth the criteria to determine the siting 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 area and with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.

Appropriate sections of the following Regulatory Guides are used by the staff for the identified acceptance criteria:

- RG 1.59, Revision 2, as supplemented by best current practices
- RG 1.102, Revision 1

2.4.4.4 *Technical Evaluation*

The NRC staff reviewed Section 2.4.4 of the VCSNS COL FSAR and checked the referenced DCD to ensure that the combination of the DCD and the COL application represents the complete scope of information relating to this review topic.[1] The NRC staff's review confirmed that the information in the application and incorporated by reference addresses the required information relating to the potential dam failure. The results of the NRC staff's evaluation of the information incorporated by reference in the VCSNS COL application are documented in NUREG-1793 and its supplements.

The staff reviewed the information in the VCSNS COL FSAR:

AP1000 COL Information Item

- VCS COL 2.4-2

In Section 2.4.4 of the FSAR, the applicant described an assessment of the maximum flood water elevation of a multiple dam failure scenario on the Broad River. The staff in their independent review also considered a breach of the levee on the Monticello Reservoir and subsequent flows on the Mayo Creek adjacent to the site. The staff determined that both of these scenarios were conservative and neither scenario would exceed the design basis flood elevation. The design basis flood elevation was determined to result from the locally intense precipitation scenario discussed in Section 2.4.2 of this SER. The applicant and the staff used the guidance provided in ANSI/ANS-2.8-1992 to quantify flood water elevations at the site resulting from postulated dam failures.

2.4.4.4.1 Dam Failure on Broad River

Information Submitted by the Applicant

The applicant provided rating curves that related the Parr Reservoir pool elevations to storage and weir equations that relate the Parr Reservoir pool elevations to flood flows over the Parr Shoals Dam. The applicant provided the postulated storage capacity of the proposed Clinchfield Dam.

NRC Staff's Technical Evaluation

The staff used a conservative approach to independently estimate the depth behind the Parr Shoals Dam after potential dam failures. The Parr Shoals Dam was assumed to not release any water and to be held at the 88.85 m (291.5 ft) NGVD29 PMF pool level established in Section 2.4.3.4 of this SER. Then all of the significant water impounded on the main stem of the Broad River above the Parr Shoals Dam was assumed to fail with timing, such that the total volume is transferred to the Parr Shoals Dam at the same time. The staff used the storage-pool elevation relationship provided by the applicant for the Parr Shoals Dam to then estimate the associated pool elevation for the dam failure water volume (VCSNS COL FSAR Figure 2.4-216). The water volumes used to develop the dam failure total water volume are given in VCSNS COL FSAR Table 2.4-211. These volumes generally agree with the information independently obtained from the National Inventory of Dams (NID), as briefly discussed below. When the storage associated with the PMF pool elevation was used (instead of the normal pool elevation the dam failure water volume is 1.885 km^3 (1,528,513 acre-feet)), the still water pool elevation was estimated to be 110.3 m (362 ft) NGVD29 or a maximum depth of 33.8 m (111 ft). The PMF storage on the Parr Reservoir and the storage associated with the Clinchfield Dam account for 97 percent of this volume estimate, and including this volume in the staff's assessment is conservative. The staff identified no plans to build the Clinchfield Dam.

Using the NID database, the staff independently determined that the maximum combined storage for dams, including and upstream of the Parr Shoal Dam, is 0.986 km^3 (799,572 acre-feet) as compared to the VCSNS COL FSAR total of 0.846 km^3 (685,516 acre-feet). The staff determined that use of the Clinchfield Dam storage volume of 1.573 km^3 (1,275,000 acre-feet) represented a plausible upper limit of upstream storage for the dam failure analysis.

Wind setup and wave run-up were estimated using 22 m/s (50 mph) and a maximum fetch distance of 27 km (17 mi) (ANS/ANSI-2.8-1992 and VCSNS COL FSAR Figure 2.4-217, respectively). Based upon the staff's independent review of the topography, the staff found that the fetch distance was conservatively estimated by the applicant. Under the dam break case, the maximum depth of the Parr Reservoir under these conditions is 33.8 m (111 ft). Using the wind speed, fetch distance, and reservoir depth, the wind setup was estimated to be 9 cm (0.3 ft) and wave run-up was estimated to be 4.4 m (14.5 ft). The combined dam break peak water surface elevation at the Parr Reservoir is 114.8 m (376.8 ft) NGVD29. Based on the staff's review, there is no indication that a breach of the Parr Reservoir would produce a water surface elevation approaching the site grade elevation. Therefore, the staff finds that a breach of the Parr Reservoir would not flood the VCSNS Units 2 and 3 site.

2.4.4.4.2 Levee Failure on Monticello Reservoir

Information Submitted by the Applicant

The applicant did not consider the levee failure as a plausible potential flooding event. The pool elevations and bathymetric information on the Monticello Reservoir were provided in the VCSNS ER and FSAR. Additionally, the storage volume and pool elevation information was provided by the applicant in the VCSNS COL FSAR.

NRC Staff's Technical Evaluation

The staff analyzed the impact of the potential failure of the levee at the south of the Monticello Reservoir, which can introduce flood water into the Mayo Creek located on the east side of the VCSNS site. The Monticello Reservoir has an estimated still water elevation of 131.4 m (431 ft) NGVD29 and total storage volume of 0.543 km^3 (440,500 acre-feet) under PMP conditions as described in Section 2.4.3. If the portion of the berm surrounding the Monticello Reservoir near the intake structure for VCSNS Unit 1 were to fail, water would enter the Mayo Creek drainage and flow southward from the Monticello Reservoir to the east of the VCSNS Units 2 and 3 site before it turns to the west to discharge into the Broad River downstream of the Parr Shoals Dam.

The staff estimated the peak discharge from the postulated breach of the berm at this location. The bed elevation in the Monticello Reservoir near the intake structure is about 109.7 m (405 ft) NAVD88. The total storage of the Monticello Reservoir at this water surface elevation is about 0.308 km^3 (250,000 acre-feet). The storage difference between the PMP pool elevation and the 405-ft storage elevation is 0.235 km^3 (190,500 acre-feet). The peak discharge range for observations of embankment and dam failure that would spill this volume of water is about 24,777 m^3/s (875,000 cfs) according to data presented in Figure 14 of DSO-98-004, "Prediction of Embankment Dam Breach Parameters: A Literature Review and Needs Assessment" (DSO-980-004 Wahl, T. L. 1998. Prediction of Embankment Dam Breach Parameters: A Literature Review and Needs Assessment. Dam Safety Office Water Resource Research Laboratory. U.S. Department of the Interior. Bureau of Reclamation).

The staff calculated the maximum water elevation at the site using the HEC-RAS hydraulic model and cross-section data extracted by the staff from digital topographic datasets. The staff assumed that the upstream boundary condition was a steady-state reservoir elevation based on the Monticello pool elevation at PMP. The staff assumed the downstream boundary conditions was the elevation of the Broad River during PMF flooding.

The approach was to conduct a bounding scenario analysis that assumed steady upstream boundary conditions. To evaluate the flood level due to failure, the staff conducted the following steps of analysis:

- Extract the cross-sectional information from the topography data covering the Mayo Creek valley, which contributes to the routing and storage of flood waters.

- Set up the HEC-RAS hydraulic model using the extracted cross-sectional information. The upstream boundary was located at the upstream valley of the Mayo Creek near the south levee of the Monticello Reservoir. The downstream boundary was extended to the Parr Reservoir.

- Assume the maximum possible amount of spilling water to be about the maximum storage capacity (0.555 km^3 (450,000 acre-feet)) of the Monticello Reservoir.

- Assume that the total amount of reservoir water would be spilled over a 12-hr period. Assume the peak flow to be 3 times of the average flow rate (12,849 m^3/s (453,750 cfs)). The estimated peak flow rate was 38,546 m^3/s (1,361,250 cfs), which is conservatively set to be larger than that suggested by the Dam Safety Office and discussed above.

- Assume a steady-state hydraulic using the peak flow rate at the upstream boundary.

- Set Manning's roughness value to 0.1 (dense brush or tree logs) and use the normal depth downstream boundary condition using the estimated bed slope.

The 3-times average flow scenario (38,546 m^3/s (1,361,250 cfs)) produced a flood level of 391.85 ft NAVD88 near the VCSNS Unit 2 location. The estimated flood level is 8.15 ft below the design safety grade level. A sensitivity analysis showed that an approximate flow rate of 2,000,000 cfs is required to reach the design safety grade level. This amount of water spill due to the levee failure is unrealistically high.

Based on the staff's review, none of the cases evaluated indicated that a breach of the Monticello Reservoir would produce a water surface elevation approaching the site grade elevation.

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 application and confirmed that the applicant has addressed the information relevant to potential dam failures, and that no outstanding information is expected to be addressed in the VCSNS COL FSAR related to this section.

As set forth above, the applicant has presented and substantiated information to establish the site description. The staff has reviewed the information provided and, for the reasons given above, concludes that the applicant has provided sufficient details about the site description to allow the staff to evaluate, as documented in Section 2.4.4 of this SER, whether the applicant has met the relevant requirements of 10 CFR 52.79(a)(1)(iii) and 10 CFR Part 100 with respect to determining the acceptability of the site. This addresses the part of COL Information Item 2.4-2 related to dam failures.

2.4.5 Probable Maximum Surge and Seiche Flooding

2.4.5.1 *Introduction*

FSAR Section 2.4.5 of the VCSNS COL application addresses the probable maximum surge and seiche flooding to ensure that any potential hazard to the safety-related SSCs at the proposed site has been considered in compliance with the Commission's regulations.

Section 2.4.5 of this SER presents evaluation of the following topics based on data provided by the applicant in the VCSNS COL FSAR and information available from other sources: (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 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 non-seismic information on the postulated design bases and how they relate to a surge and seiche in the vicinity of the site and the site region; (7) any additional information requirements prescribed in the "Contents of Application" sections of the applicable subparts to 10 CFR Part 52.

2.4.5.2 *Summary of Application*

This section of the VCSNS COL FSAR addresses the site-specific information on probable maximum surge and seiche flooding in terms of impacts on structures and water supply. The applicant addressed these issues as follows:

AP1000 COL Information Item

- VCS COL 2.4-2

In addition, this section addresses the following COL Information Item 2.4.2 (COL Action Item 2.4.1-2) identified in Section 2.4.1.2 of the DCD.

> Combined License applicants referencing the AP1000 design will address the following site specific information on historical flooding and potential flooding factors, including the effects of local intense precipitation.
>
> - Probable Maximum Flood on Streams and Rivers – Site-specific information that will be used to determine design basis flooding at the site. This information will include the probable maximum flood on streams and rivers.
> - Dam Failures – Site specific information on potential dam failures.
> - Probable Maximum Surge and Seiche Flooding – Site-specific information on probable maximum surge and seiche flooding.
> - Probable Maximum Tsunami Loading – Site-specific information on probable maximum tsunami loading.
> - Flood Protection Requirements – Site-specific information on flood protection requirements or verification that flood protection is not required to meet the site parameter of flood level.

No further action is required for sites within the bounds of the site parameter for flood level.

VCS COL 2.4-2 adds VCSNS COL FSAR Section 2.4.5 in its entirety.

This section of the SER relates to the surge and seiche part of COL Information Item 2.4.2.

2.4.5.3 *Regulatory Basis*

The acceptance criteria associated with the relevant requirements of the Commission regulations for consideration of the effects of probable maximum surge and seiche are given in Section 2.4.6 of NUREG-0800.

The applicable regulatory requirements for identifying surge and seiche hazards are:

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

- 10 CFR 100.23(d) sets forth the criteria to determine the siting factors for plant design bases with respect to water levels 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 area and with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.

2.4.5.4 *Technical Evaluation*

The NRC staff reviewed Section 2.4.5 of the VCSNS COL FSAR and checked the referenced DCD to ensure that the combination of the DCD and the COL application represents the complete scope of information relating to this review topic.[1] The NRC staff's review confirmed that the information in the application and incorporated by reference addresses the required information relating to the probable maximum surge and seiche flooding. The results of the NRC staff's evaluation of the information incorporated by reference in the VCSNS COL application are documented in NUREG-1793 and its supplements.

The staff reviewed the information in the VCSNS COL FSAR:

AP1000 COL Information Item

- VCS COL 2.4-2

Information Submitted by the Applicant

In the VCSNS COL FSAR, the applicant provided information related to the probable maximum surge and seiche flooding on the Monticello Reservoir. The applicant described the Monticello Reservoir in terms of location relative to VCSNS Unit 1 and VCSNS Units 2 and 3, and in terms of elevation and surrounding local topography. The applicant determined that the topography between the Monticello Reservoir and the VCSNS Units 2 and 3 site made it implausible for surges and seiches on the reservoir to inundate the VCSNS site.

NRC Staff's Technical Evaluation

The staff reviewed the topography of the site and confirmed that, if a surge or seiche was to occur in the Monticello Reservoir, it would be implausible for water that overtops the dam on the Monticello Reservoir to inundate the VCSNS Units 2 and 3 site. The staff independently verified topographic information in Section 2.4.1. The staff further examined the capacity of the Mayo Creek to carry a substantial portion of the volume of the Monticello Reservoir in the event of dike failure and found that such an event would not inundate VCSNS Units 2 and 3. The staff's determination is discussed in Section 2.4.3. The staff determined that the release of water from the Monticello Reservoir due to surge or seiches would be minimal in comparison and, therefore, finds that VCSNS Units 2 and 3 site flooding from these phenomena is implausible. The normal pool elevation in the Parr Reservoir is about 40.8 m (134 ft) and the Parr Shoals Dam is about 39.0 m (128 ft) below the VCSNS Units 2 and 3 safety-related site grade. The staff determined that any surge or seiches in the Parr Reservoir would not overtop the Parr Shoals Dam. Based on the maximum recorded surge and seiche heights from around the world, the staff determined that it was implausible for surges and seiches on the Parr Reservoir to flood the VCSNS Units 2 and 3 site.

The staff also determined that the proposed plant design does not rely on safety-related water for safe shutdown and, therefore, low water events caused by a surge or seiches in the Parr Reservoir or the Monticello Reservoir would not affect the safety of the plant.

2.4.5.5 *Post Combined License Activities*

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

2.4.5.6 *Conclusion*

The staff reviewed the application and confirmed that the applicant has addressed the information relevant to probable maximum surge and seiche flooding, and that there is no outstanding information required to be addressed in the VCSNS COL FSAR related to this section.

As set forth above, the applicant has presented and substantiated information to establish the site description. The staff has reviewed the information provided and, for the reasons given above, concludes that the applicant has provided sufficient details about the site description to allow the staff to evaluate, as documented in Section 2.4.5, of this SER, whether the applicant has met the relevant requirements of 10 CFR 52.79(a)(1)(iii) and 10 CFR Part 100 with respect to determining the acceptability of the site. This addresses the part of COL Information Item 2.4-2 related to probable maximum surge and seiche flooding.

2.4.6 Probable Maximum Tsunami Hazards

2.4.6.1 *Introduction*

FSAR Section 2.4.6 of the VCSNS COL application addresses the probable maximum tsunami hazards to ensure that any potential tsunami hazard to the safety-related SSCs at the proposed site has been considered in compliance with the Commission's regulations.

Section 2.4.6 of this SER presents an evaluation of the following topics based on data provided by the applicant in the VCSNS COL FSAR and information available from other sources: (1) historical tsunami data, including paleotsunami mappings and interpretations, regional records and eyewitness reports, and more recently available tide gauge and real-time bottom pressure gauge data; (2) probable maximum tsunami (PMT) that may pose hazards to the site; (3) tsunami wave propagation models and model parameters used to simulate the tsunami wave propagation from the source toward the site; (4) extent and duration of wave run-up during the inundation phase of the PMT event; (5) static and dynamic force metrics including the inundation and drawdown depths, current speed, acceleration, inertial component, and momentum flux that quantify the forces on any safety-related SSCs that may be exposed to the tsunami waves; (6) debris and water-borne projectiles that accompany tsunami currents and may impact safety-related SSCs; (7) effects of sediment erosion and deposition caused by tsunami waves that may result in blockage or loss of function of safety-related SSCs; (8) potential effects of seismic and non-seismic 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.

2.4.6.2 *Summary of Application*

This section of the VCSNS COL FSAR addresses the site-specific information on PMT hazards in terms of impacts on structures and water supply. The applicant addressed the information as follows:

<u>AP1000 COL Information Item</u>

- VCS COL 2.4-2

In addition, this section addresses the following COL Information Item 2.4.2 (COL Action Item 2.4.1-1) identified in Section 2.4.1.2 of the DCD.

> Combined License applicants referencing the AP1000 design will address the following site specific information on historical flooding and potential flooding factors, including the effects of local intense precipitation.
>
> - Probable Maximum Flood on Streams and Rivers – Site-specific information that will be used to determine design basis flooding at the site. This information will include the probable maximum flood on streams and rivers.
> - Dam Failures – Site specific information on potential dam failures.
> - Probable Maximum Surge and Seiche Flooding – Site-specific information on probable maximum surge and seiche flooding.
> - Probable Maximum Tsunami Loading – Site-specific information on probable maximum tsunami loading.

- Flood Protection Requirements – Site-specific information on flood protection requirements or verification that flood protection is not required to meet the site parameter of flood level.

No further action is required for sites within the bounds of the site parameter for flood level.

VCS COL 2.4-2 adds VCSNS COL FSAR Section 2.4.6 in its entirety.

This section of the SER relates to the tsunamis part of COL Information Item 2.4.2.

2.4.6.3 *Regulatory Basis*

The acceptance criteria associated with the relevant requirements of the Commission regulations on consideration of the effects of probable maximum tsunami hazards are given in Section 2.4.6 of NUREG-0800.

The applicable regulatory requirements for tsunami hazards are:

- 10 CFR Part 100, as it relates to identifying and evaluating hydrological features of the site. The requirement to consider physical site characteristics in site evaluations is specified in 10 CFR 100.20(c).
- 10 CFR 100.23(d) sets forth the criteria to determine the siting factors for plant design bases with respect to water levels 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 area and with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.

2.4.6.4 *Technical Evaluation*

The NRC staff reviewed Section 2.4.6 of the VCSNS COL FSAR and checked the referenced DCD to ensure that the combination of the DCD and the COL application represents the complete scope of information relating to this review topic. The NRC staff's review confirmed that the information in the application and incorporated by reference addresses the required information relating to the probable maximum tsunami hazards. The results of the NRC staff's evaluation of the information incorporated by reference in the VCSNS COL application are documented in NUREG-1793 and its supplements.

The staff reviewed the information in the VCSNS COL FSAR:

AP1000 COL Information Item

- VCS COL 2.4-2

Information Submitted by the Applicant

In the VCSNS COL FSAR the applicant assessed the potential for oceanic tsunamis to flood the VCSNS Units 2 and 3 site and concluded that none existed due to the distance from and elevation of the site relative to the ocean. The applicant provided the floor elevation for the safety-related structures at VCSNS Units 2 and 3 and the location of the site to support this determination (SCE&G 2010). The applicant did not assess the potential for tsunami-like phenomena to flood safety-related structures at the VCSNS Units 2 and 3 site.

The applicant described the normal pool and dam crest elevations for the Monticello Reservoir; the difference in these elevations is 9 ft (SCE&G 2010).

NRC Staff's Technical Evaluation

The NRC staff reviewed the applicant-provided information about potential flooding at VCSNS Units 2 and 3 site as a result of tsunamis. The staff's determined that given the site's distance from the Atlantic Ocean and the site grade elevation (as discussed in Section 2.4.1), it is implausible for an oceanic tsunami to cause flooding at the VCSNS site.

The staff queried the National Oceanic and Atmospheric Administration (NOAA) Tsunami Event and Runup Database maintained by NOAA/NGDC for historical tsunami events on the east coast of the United States between 1800 and 2010. Of the 22 events found, the closest one to the VCSNS site occurred in Charleston, South Carolina, in 1886 and was associated with an earthquake. No tsunami run-up value was given for this event in the database. However, the maximum run-up associated with this event was 51 cm (20 in) above mean sea level (South Carolina Emergency Management Division 2009), which is over 119 m (390 ft) below the site grade elevation.

The staff determined that a tsunami or a tsunami-like wave in the vicinity of the site is an implausible event. Therefore, a more detailed tsunami analysis is not needed. Hazards related to high water or flooding from a tsunami or a tsunami-like wave at the site are also unlikely.

The staff also considered the occurrence of two tsunami-like events in the Monticello Reservoir. The first event considered was a landslide in the reservoir triggering a tsunami-like phenomenon. The staff determined that this is not a plausible conceptual model because the majority of the Frees Creek watershed is already covered by the reservoir and the staff found no evidence of a saturation-induced slide. The second event considered was a landslide of the embankment around the FPSF. The staff determined that this is not a plausible concept model for flooding of the VCSNS site because the postulated slide would cause the Monticello Reservoir to drain into the Parr Reservoir (i.e., away from VCSNS site).

Tsunami-like waves are amplified as they pass from deep water to shallow water. The amplification of the wave height is inversely proportional to the quarter-root of the water depth (Knauss 1978). This relationship neglects the loss of wave energy due to frictional losses and so yields higher wave heights than would be obtained by including frictional effects. The maximum depth of the Monticello Reservoir is 38 m, and a nominal nearshore depth of 2 m implies a rough doubling of the tsunami wave height as it passes from deep to nearshore areas. The staff estimated that a tsunami-like event would have to create a wave greater than 1.2 m (4 ft) high in the deepest part of the Monticello Reservoir to generate a wave that would overtop the Monticello Reservoir dams under normal pool elevations. Furthermore, this calculation is conservative because it neglects the friction and spreading of the wave as it propagates. The staff determined that there is no plausible conceptual model that would lead to flooding at VCSNS Units 2 and 3 due to tsunami-like events.

The staff also determined that the proposed plant design does not rely on safety-related water for safe shutdown and, therefore, low water events caused by a PMT or a tsunami-like wave in the Broad River, Parr Reservoir, or Monticello Reservoir would not affect the safety of the plant.

- The staff reviewed Section 2.4.6 of the VCSNS Units 2 and 3 COL FSAR. The staff's review confirmed that the information in the application and incorporated by reference addresses the relevant information related to PMT hazards with the exception of the assessment of tsunami-like events. The staff's independent technical review of this application included an assessment of the oceanic tsunamis and non-oceanic tsunami-like phenomena.

2.4.6.5 *Post Combined License Activities*

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

2.4.6.6 *Conclusion*

The staff reviewed the application and confirmed that the applicant has addressed the information relevant to PMT hazards, and that there is no outstanding information required to be addressed in the VCSNS COL FSAR related to this section.

As set forth above, the applicant has presented and substantiated information to establish the site description. The staff has reviewed the information provided and, for the reasons given above, concludes that the applicant has provided sufficient details about the site description to allow the staff to evaluate, as documented in Section 2.4.6, of this SER, whether the applicant has met the relevant requirements of 10 CFR 52.79(a)(1)(iii) and 10 CFR Part 100 with respect to determining the acceptability of the site. This addresses the part of COL Information Item 2.4-2 related to PMT hazards.

2.4.7 Ice Effects

2.4.7.1 *Introduction*

FSAR Section 2.4.7 addresses the ice effects to ensure that safety-related facilities and water supply are not affected by ice-induced hazards.

Section 2.4.7 of this SER presents an evaluation of the following topics based on data provided by the applicant in the VCSNS COL FSAR and information available from other sources: (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 non-seismic data on the postulated worst-case icing scenario for the proposed plant site; (6) any additional information requirements prescribed in the "Contents of Application" sections of the applicable subparts to 10 CFR Part 52.

2.4.7.2 *Summary of Application*

This section of the VCSNS COL FSAR addresses the site-specific information on ice effects. The applicant addressed the information as follows:

AP1000 COL Information Item

- VCS COL 2.4-3

In addition, this section addresses the following COL Information Item 2.4.3 (COL Action Item 2.4.2-1) identified in Section 2.4.1.3 of the DCD.

> Combined License applicants will address the water supply sources to provide makeup water to the service water system cooling tower.

VCS COL 2.4-3 adds VCSNS COL FSAR Section 2.4.7 in its entirety.

This section of the SER relates to ice potential to cause flooding.

2.4.7.3 *Regulatory Basis*

The acceptance criteria associated with the relevant requirements of the Commission regulations for the identification and evaluation of ice effects are given in Section 2.4.7 of NUREG-0800.

The applicable regulatory requirements for identifying ice effects are:

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

- 10 CFR 100.23(d) sets forth the criteria to determine the siting factors for plant design bases with respect to water levels 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 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 are provided in the following Regulatory Guides:

- RG 1.59, Revision 2, as supplemented by best current practices
- RG 1.102, Revision 1

2.4.7.4 *Technical Evaluation*

The NRC staff reviewed Section 2.4.7 of the VCSNS COL FSAR and checked the referenced DCD to ensure that the combination of the DCD and the COL application represents the complete scope of information relating to this review topic. The NRC staff's review confirmed that the information in the application and incorporated by reference addresses the required information relating to the site-specific ice effects. The results of the NRC staff's evaluation of the information incorporated by reference in the VCSNS COL application are documented in NUREG-1793 and its supplements.

The staff reviewed the information in the VCSNS COL FSAR:

AP1000 COL Information Item

- VCS COL 2.4-3

Information Submitted by the Applicant

The applicant evaluated the water temperatures in the river close to the VCSNS site and found the minimum recorded water temperature was 3.5 °C (38.3 °F) using the water temperature data between October 1959 and December 1975 at Carlisle, Alston, and Richtex stations on the Broad River. The applicant calculated the maximum Accumulated Freezing Degree Days to be 5.8 °C (42.5 °F) days and suggested that ice formation in the Monticello Reservoir is unlikely. In the unlikely event that thin ice forms at the surface of the Monticello Reservoir, it would not affect the water supply at the Units 2 and 3 intakes, which are located approximately 3.1 m (12.8 ft) below the lowest operating reservoir water surface elevation. The applicant suggested formation of frazil or anchor ice is considered highly unlikely because the water temperature never approaches the freezing point.

NRC Staff's Technical Evaluation

The staff examined daily water temperature records reported by the USGS for the Carlisle Station on the Broad River for the entire period when temperatures were reported from 1983 to 2009, and air temperature records for 1946 to 2009 reported by the NOAA/National Climatic Data Center (NCDC) for the Parr climate station. The data show a seasonal trend where winter low water temperatures are typically 0.56 °C (33 °F) or higher. The lowest daily minimum water temperature in the data set is 0.50 °C (32.9 °F) (January, 3, 2001 and January 4, 2001) and on both days the daily maximum water temperatures are 2.17 °C (35.6 °F). The staff agreed that no frazil or anchor ice would grow under such water temperature conditions. The lowest daily air temperature reported for the Parr Reservoir is -9.4 °C (15 °F) in the period from January 1948 to June 2009. There were 44 instances of three of more days when the average air temperature was below freezing and two instances of eight consecutive days at or below freezing when the average air temperatures were -1.67 °C (29 °F) (December 15-22, 1963) and -2.78 °C (27 °F) (January 17-24, 1977). The staff estimated the maximum accumulated freezing degree days to be around 40 °F days compared to the 5.83 °C (42.5 °F) days reported in the FSAR and the ice thickness to be less than 10.1 cm (4 in). The staff agreed with the applicant that with such a low number of accumulated freezing degree days, ice formation in large bodies of water, such as the Parr Reservoir and the Monticello Reservoir, is unlikely and in the unlikely event that thin ice forms at the surface of the Monticello Reservoir, the water supply at the VCSNS Units 2 and 3 intakes would not be affected.

Ice formation can block the plant site drainage system, which could cause flooding on safety-related structures. The staff has reviewed this issue in Section 2.4.2.4 and determined that no flooding will affect the safety-related structures. Therefore, the staff finds that there are no risks to safety-related facilities posed by ice effects.

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 confirmed that the applicant has addressed site characteristics and other hydrometeorological parameters related to ice formation at or near the plant site, and that there is no outstanding information required to be addressed in the VCSNS COL FSAR related to this section.

As set forth above, the applicant has presented and substantiated information to establish the site description. The staff has reviewed the information provided and, for the reasons given above, concludes that the applicant has provided sufficient details about the site description to allow the staff to evaluate, as documented in Section 2.4.7, of this SER, whether the applicant has met the relevant requirements of 10 CFR 52.79(a)(1)(iii) and 10 CFR Part 100 with respect to determining the acceptability of the site. This addresses COL Information Item 2.4-3 related to ice effects.

2.4.8 Cooling Water Canals and Reservoirs

2.4.8.1 *Introduction*

VCSNS COL FSAR Section 2.4.8 addresses the cooling water canals and reservoirs used to transport and impound water supplied to the safety-related SSCs.

Section 2.4.8 of this SER presents an evaluation of the following topics to verify their hydraulic design basis: (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 non-seismic 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*

AP1000 COL Information Item

- VCS COL 2.4-3

This section addresses the following COL Information Item 2.4.3 (COL Action Item 2.4.2-1) identified in Section 2.4.1.3 of the DCD.

> Combined License applicants will address the water supply sources to provide makeup water to the service water system cooling tower.

VCS COL 2.4-3 adds VCSNS COL FSAR Section 2.4.8 in its entirety.

2.4.8.3 *Regulatory Basis*

The acceptance criteria associated with the relevant requirements of the Commission regulations for the identification of design considerations for cooling water canals and reservoirs are given in Section 2.4.8 of NUREG-0800.

The applicable regulatory requirements for cooling water canals and reservoirs are:

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

- 10 CFR 100.23(d) sets forth the criteria to determine the siting factors for plant design bases with respect to water levels 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 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 are provided in the following Regulatory Guides:

- RG 1.59, Revision 2, as supplemented by best current practices
- RG 1.102, Revision 1

2.4.8.4 *Technical Evaluation*

The NRC staff reviewed Section 2.4.8 of the VCSNS COL FSAR and checked the referenced DCD to ensure that the combination of the DCD and the COL application represents the complete scope of information relating to this review topic. The NRC staff's review confirmed that the information in the application and incorporated by reference addresses the required information relating to the cooling water canals and reservoirs. The results of the NRC staff's evaluation of the information incorporated by reference in the VCSNS COL application are documented in NUREG-1793 and its supplements.

The staff reviewed the information in the VCSNS COL FSAR:

AP1000 COL Information Item

- VCS COL 2.4-3

Information Submitted by the Applicant

In Section 2.4.8 of the VCSNS COL FSAR, the applicant described the data for and analysis of the cooling water canals and reservoirs. The applicant asserted that there were no cooling water canals or reservoirs that supply safety-related cooling in the VCSNS Units 2 and 3 design; therefore, no further related safety-risk assessment was warranted.

NRC Staff's Technical Evaluation

The staff independently determined that there is no plausible conceptual model including cooling canals and reservoirs that pose flooding to or low water for safety-related facilities. The staff based its determination on the fact that VCSNS Units 2 and 3 are not supplied with safety-related water from the canals and reservoirs, but rather from storage tanks that are designed according to specifications described in the AP1000 DCD.

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 application and confirmed that the scope of 2.4.8 is not relevant to the VCSNS COL.

2.4.9 Channel Diversions

2.4.9.1 *Introduction*

VCSNS COL FSAR Section 2.4.9 addresses channel diversions. It evaluates plant and essential water supplies used to transport and impound water supplies to ensure that they will not be adversely affected by stream or channel diversions. The evaluation 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, it must be ensured that alternate water supplies are available to safety-related equipment.

Section 2.4.9 of this SER presents an evaluation of the following specific areas: (1) historical channel migration phenomena including cutoffs, subsidence, and uplift; (2) regional topographic evidence that suggests a future channel diversion may or may not occur (used in conjunction with evidence of historical diversions); (3) thermal causes of channel diversion, such as ice jams, which may result from downstream ice blockages that may lead to flooding from backwater or upstream ice blockages that can divert the flow of water away from the intake; (4) potential for forces on safety-related facilities or the blockage of water supplies resulting from channel migration-induced flooding (flooding not addressed by hydrometeorological-induced flooding scenarios in other sections); (5) potential of channel diversion from human-induced causes (i.e., land-use changes, diking, channelization, armoring, or failure of structures); (6) alternate water sources and operating procedures; (7) potential effects of seismic and nonseismic information on the postulated worst-case channel diversion scenario for the proposed plant site; (8) any additional information requirement prescribed in the “Contents of Application” sections of the applicable subparts to 10 CFR Part 52.

2.4.9.2 *Summary of Application*

<u>*AP1000 COL Information Item*</u>

- VCS COL 2.4-3

This section addresses the following COL Information Item 2.4.3 (COL Action Item 2.4.2-1) identified in Section 2.4.1.3 of the DCD.

> Combined License applicants will address the water supply sources to provide makeup water to the service water system cooling tower.

VCS COL 2.4-3 adds VCSNS COL FSAR Section 2.4.9 in its entirety.

2.4.9.3 *Regulatory Basis*

The acceptance criteria associated with the relevant requirements of the Commission regulations for the identification and evaluation of channel diversions are given in Section 2.4.9 of NUREG-0800.

The applicable regulatory requirements for identifying and evaluating channel diversions are:

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

- 10 CFR 100.23(d) sets forth the criteria to determine the siting factors for plant design bases with respect to water levels 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 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 are provided in the following Regulatory Guides:

- RG 1.59, Revision 2, as supplemented by best current practices
- RG 1.102, Revision 1

2.4.9.4 *Technical Evaluation*

The NRC staff reviewed Section 2.4.9 of the VCSNS COL FSAR and checked the referenced DCD to ensure that the combination of the DCD and the COL application represents the complete scope of information relating to this review topic. The NRC staff's review confirmed that the information in the application and incorporated by reference addresses the required information relating to the channel diversions. The results of the NRC staff's evaluation of the information incorporated by reference in the VCSNS COL application are documented in NUREG-1793 and its supplements.

The staff reviewed the information in the VCSNS COL FSAR:

AP1000 COL Information Item

- VCS COL 2.4-3

Information Submitted by the Applicant

In Section 2.4.9 of the VCSNS COL FSAR, the applicant described the data for and analysis of channel diversions. The applicant considered the local geology and topography of the Broad River and the Monticello Reservoir. The Monticello Reservoir was determined to not be subject to upstream channel diversions because the formation of the reservoir drowned much of the small watershed and little of the Frees Creek remains. For the Broad River, the applicant examined historical charts of the river course by comparing the USGS geographical information system (GIS) digital elevation maps files of the topography with an 1838 map by Bradford and a 1773 map by Cook. The applicant found no significant channel diversions, leading to the applicant's conclusion that the Broad River is stable and, therefore, a channel diversion is unlikely to affect the supply of water to the site.

Based on the examination of historical water and air temperatures, the applicant determined that ice build-up is not a viable scenario leading to the diversion of water from the existing channel.

The applicant reviewed plans for further significant diversions of water upstream on the Broad River from the VCSNS site. One study concluded that only one location for an additional dam was feasible on the Broad River. The Clinchfield Dam was proposed at this site in 1969, but has not yet been built. If it were built at the former proposed location, it would be well upstream of the VCSNS site and would not pose a risk for diversion of the Broad River near the VCSNS site.

NRC Staff's Technical Evaluation

The NRC staff reviewed Section 2.4.9 of the VCSNS COL FSAR and checked the referenced DCD to ensure that the combination of the DCD and the COL application represents the complete scope of information related to this review topic. Given that the AP1000 does not require makeup water from offsite for safety-related equipment, the staff determined that the scope of Section 2.4.9 is not relevant for the VCSNS COL.

2.4.9.5 *Post Combined License Activities*

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

2.4.9.6 *Conclusion*

The staff reviewed the application and confirmed that the applicant has addressed the information to demonstrate that the characteristics of the site fall within the site parameters specified in the DC rule, and that there is no outstanding information required to be addressed in the VCSNS COL FSAR related to this section.

As set forth above, the applicant has presented and substantiated information to establish the site description ensuring that the plant and essential water supplies will not be adversely affected. The staff has reviewed the information provided and, for the reasons given above, concludes that the applicant has provided sufficient details about the site description to allow the staff to evaluate, as documented in Section 2.4.9, of this SER, whether the applicant has met the relevant requirements of 10 CFR 52.79(a)(1)(iii) and 10 CFR Part 100 with respect to determining the acceptability of the site. This addresses the part of COL Information Item 2.4-3 related to channel diversions.

2.4.10 Flooding Protection Requirements

2.4.10.1 *Introduction*

VCSNS COL FSAR Section 2.4.10 addresses 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.

Section 2.4.10 of this SER presents an evaluation of the following specific areas: (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 non-seismic information on the postulated flooding protection for the proposed plant site; and (5) any additional information requirements prescribed in the "Contents of Application" sections of the applicable subparts to 10 CFR Part 52.

2.4.10.2 *Summary of Application*

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

AP1000 COL Information Item

- VCS COL 2.4-2

In addition, this section addresses the following COL Information Item 2.4.2 (COL Action Item 2.4.1-2) identified in Section 2.4.1.2 of the DCD)

> Combined License applicants referencing the AP1000 design will address the following site specific information on historical flooding and potential flooding factors, including the effects of local intense precipitation.

- Probable Maximum Flood on Streams and Rivers – Site-specific information that will be used to determine design basis flooding at the site. This information will include the probable maximum flood on streams and rivers.

- Dam Failures – Site specific information on potential dam failures.

- Probable Maximum Surge and Seiche Flooding – Site-specific information on probable maximum surge and seiche flooding.

- Probable Maximum Tsunami Loading – Site-specific information on probable maximum tsunami loading.

- Flood Protection Requirements – Site-specific information on flood protection requirements or verification that flood protection is not required to meet the site parameter of flood level.

No further action is required for sites within the bounds of the site parameter for flood level.

This section of the SER relates to the flood protection requirements part of COL Information Item 2.4.2.

- VCS COL 2.4-6

In addition, this section addresses the following COL Information Item 2.4.6 (COL Action Item 2.4.1-1) identified in Section 2.4.1.6 of the DCD.

> Combined License applicants referencing the AP1000 certified design will address any flood protection emergency procedures required to meet the site parameter for flood level.

VCS COL 2.4.6 adds VCSNS COL FSAR Section 2.4.10 in its entirety.

2.4.10.3 *Regulatory Basis*

The acceptance criteria related to the relevant requirements of the Commission regulations for the identification and evaluation of flooding protection requirements are given in Section 2.4.10 of NUREG-0800.

The applicable regulatory requirements for identifying and evaluating flooding protection requirements are:

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

- 10 CFR 100.23(d) sets forth the criteria to determine the siting factors for plant design bases with respect to water levels 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 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 are provided in the following:

- RG 1.59, Revision 2, as supplemented by best current practices
- RG 1.102, Revision 1

2.4.10.4 *Technical Evaluation*

The NRC staff reviewed Section 2.4.10 of the VCSNS COL FSAR and checked the referenced DCD to ensure that the combination of the DCD and the COL application represents the complete scope of information relating to this review topic. The NRC staff's review confirmed that the information in the application and incorporated by reference addresses the required information relating to the flood protection requirements. The results of the NRC staff's evaluation of the information incorporated by reference in the VCSNS COL application are documented in NUREG-1793 and its supplements.

The staff reviewed the information in the VCSNS COL FSAR:

AP1000 COL Information Items

- VCS COL 2.4-2
- VCS COL 2.4-6

Information Submitted by the Applicant

In Section 2.4.10 of the VCSNS COL FSAR, the applicant performed an analysis of a postulated tank failure that supports the conclusion that the site is dry and flood protection is not required. The applicant also states in Section 2.4.3 of the VCSNS COL FSAR that the site is dry and flood protection is not required.

NRC Staff's Technical Evaluation

The staff independently estimated the maximum flood elevation from the postulated tank failure and has established that the design basis flood for the site is from the local intense precipitation discussed in Section 2.4.2 of this SER, and has determined that flood protection is not required.

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 application and confirmed that the applicant has addressed the information to demonstrate that the characteristics of the site fall within the site parameters specified in the DC rule, and that there is no outstanding information required to be addressed in the VCSNS COL FSAR related to this section.

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 finds that the applicant has considered the appropriate site phenomena in establishing the flood protection measures for SSCs. The staff has reviewed the information provided and, for the reasons given above, concludes that the applicant has provided sufficient details about the site description to allow the staff to evaluate, as documented in Section 2.4.10, of this SER, whether the applicant has met the relevant requirements of 10 CFR 52.79(a)(1)(iii) and 10 CFR Part 100 with respect to determining the acceptability of the site. This addresses the part of COL Information Item 2.4-2 related to flood protection requirements and COL Information Item 2.4.6.

2.4.11 Low Water Considerations

2.4.11.1 *Introduction*

VCSNS COL FSAR Section 2.4.11 addresses 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.

Section 2.4.11 of this SER presents an evaluation of the following specific areas: (1) low water conditions due to the 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 of low water on the intake structure and pump design bases in relation to the events described in safety analysis report (SAR) Sections 2.4.7, 2.4.8, 2.4.9, and 2.4.11, which consider the range of water supply required by the plant (including minimum operating and shutdown flows during anticipated operational occurrences and emergency conditions) compared with availability (considering the capability of the ultimate heat sink [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 non-seismic information on the postulated worst-case low water scenario for the proposed plant site; and (6) any additional information requirements prescribed in the "Contents of Application" sections of the applicable subparts to 10 CFR Part 52.

2.4.11.2 *Summary of Application*

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

<u>*AP1000 COL Information Item*</u>

- VCS COL 2.4-3

In addition, this section addresses the following COL Information Item 2.4.3 (COL Action Item 2.4.1-1) identified in Section 2.4.1.3 of the DCD.

> Combined License applicants will address the water supply sources to provide makeup water to the service water system cooling tower.

VCS COL 2.4-3 adds VCSNS COL FSAR Section 2.4.11 in its entirety.

2.4.11.3 *Regulatory Basis*

The acceptance criteria associated with the relevant requirements of the Commission regulations for the low water considerations are described in Section 2.4.11 of NUREG-0800.

The applicable regulatory requirements for identifying the effects of low water are:

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

- 10 CFR 100.23(d) sets forth the criteria to determine the siting 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 area and with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.

2.4.11.4 *Technical Evaluation*

The NRC staff reviewed Section 2.4.11 of the VCSNS COL FSAR and checked the referenced DCD to ensure that the combination of the DCD and the COL application represents the complete scope of information relating to this review topic. The NRC staff's review confirmed that the information in the application and incorporated by reference addresses the required information relating to the low water considerations. The results of the NRC staff's evaluation of the information incorporated by reference in the VCSNS COL application are documented in NUREG-1793 and its supplements.

The staff reviewed the information in the VCSNS COL FSAR:

AP1000 COL Information Item

- VCS COL 2.4-3

Information Submitted by the Applicant

The applicant stated that the passive cooling system of the AP1000 design does not rely on the Broad River as a source of water and, therefore, no safety-related facilities of the VCSNS would be affected by low water conditions in the river.

For nonsafety-related uses, which are reported to have a maximum demand of 137.2 cfs, the applicant determined they can be adequately supplied by the 10-year, 7-day average low flow (850 cfs) or the 100-year, 7-day average low flow (430 cfs) at the Parr Shoals Dam combined with the storage at the Monticello and Parr Reservoirs. Using a more conservative assessment, the applicant estimated that the Monticello Reservoir could supply makeup water for VCSNS

Units 2 and 3 for 42 days if the FPSF is unavailable and there is no inflow of water to the Monticello Reservoir from direct precipitation or runoff.

The applicant stated that the effects of surges, seiches, and tsunami are not applicable to this site (as discussed in FSAR Sections 2.4.5 and 2.4.6) and no ice conditions are expected to affect flows in either the Broad River or the Monticello Reservoir (as described in FSAR Section 2.4.7.)

The applicant used 149 cfs at Richtex on October 13, 1935 and on September 2, 1957 and 156 cfs at Alston on August 13, 2002 (excluding the 1.4 m^3/s (48 cfs) record on September 12, 2002, because it was influenced by the upstream flow diversion from the Parr Reservoir to the FPSF) as the lowest flow in the low flow analysis.

The applicant reported that there are no future uses or controls planned for the Monticello Reservoir water and none of the identified future uses of the Broad River above the Parr Shoals Reservoir would affect VCSNS Units 2 and 3 safely-related facilities.

NRC Staff's Technical Evaluation

The staff reviewed the AP1000 DCD to evaluate the impact of low water conditions in the vicinity of the VCSNS site on the safety of the VCSNS units. Since no external water source (for VCSNS this is the Parr or Monticello Reservoirs) is required for safe emergency shutdown, the staff determined that low water conditions would have no impact on the safety of the VCSNS units. There are no site characteristics in the DCD associated with low water conditions.

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 confirmed that the applicant has addressed the information required and that no site characteristic related to low water conditions apply to the AP1000 design.

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 finds that the applicant has considered the appropriate site phenomena in establishing the design bases for SSCs. The staff has reviewed the information provided and, for the reasons given above, concludes that the applicant has provided sufficient details about the site description to allow the staff to evaluate, as documented in Section 2.4.11, of this SER, whether the applicant has met the relevant requirements of 10 CFR 52.79(a)(1)(iii) and 10 CFR Part 100 with respect to determining the acceptability of the site. This addresses COL Information Item 2.4-3 related to low water considerations.

2.4.12 Groundwater

2.4.12.1 *Introduction*

VCSNS COL FSAR Section 2.4.12 describes the hydrogeological characteristics of the site. The most significant objective of groundwater investigations and monitoring at this site is to evaluate the effects of groundwater on plant foundations. The evaluation is performed to assure that the maximum groundwater elevation remains below the DCD site parameter value. The other significant objectives are to examine whether groundwater provides any safety-related water supply; to determine whether dewatering systems are required to maintain groundwater elevation below the required level; and to measure characteristics and properties of the site needed to develop a conceptual site model of groundwater movement, and to estimate the direction and velocity of movement of potential radioactive contaminants.

Section 2.4.12 of this SER presents an evaluation of the following specific areas: (1) identification of the aquifers, types of onsite groundwater use, sources of recharge, present withdrawals and known and likely future withdrawals, flow rates, travel time, gradients (and other properties that affect the movement of accidental contaminants in groundwater), groundwater levels beneath the site, seasonal and climatic fluctuations, monitoring and protection requirements, and manmade changes that have the potential to cause long-term changes in local groundwater regime; (2) effects of groundwater levels and other hydrodynamic effects of groundwater on design bases of plant foundations and other SSCs important to safety; (3) reliability of groundwater resources and related systems used to supply safety-related water to the plant; (4) reliability of dewatering systems to maintain groundwater conditions within the plant's design bases; (5) potential effects of seismic and non-seismic information on the postulated worst-case groundwater conditions for the proposed plant site[9]; and (6) any additional information requirements prescribed in the "Contents of Application" sections of the applicable subparts to 10 CFR Part 52.

2.4.12.2 *Summary of Application*

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

AP1000 COL Information Item

- VCS COL 2.4-4

In addition, this section addresses the following COL Information Item 2.4.4 (COL Action Item 2.4.1-1) identified in Section 2.4.1.4 of the DCD.

> Combined License applicants referencing the AP1000 certified design will address site-specific information on groundwater. No further action is required for the sites within the bounds of the site parameter for ground water.

VCS COL 2.4-4 adds VCSNS COL FSAR Section 2.4.12 in its entirety.

Potential safety impacts resulting from on-site groundwater conditions were also considered in other sections of the FSAR and resultant SER. These are summarized below.

[9] See Section 2.4.1.1 for a discussion of why seismic effects on groundwater conditions were not discussed.

- VCS COL 3.4-1

COL Information Item 3.4-1 in Sections 3.4.1.3 and 3.4.3 of the DCD discussed the need for a permanent dewatering system and protective measures to prevent flooding based on site specific maximum operational groundwater levels.

To address this COL item, VCSNS FSAR Section 3.4.1.3 added the following text to the end of DCD Section 3.4.1.3:

> No permanent dewatering system is required because site groundwater levels are 20 feet below site grade level as described in FSAR Section 2.4.12.5.

And the following text was added to the end of DCD Section 3.4.3:

> VCSNS site-specific water levels provided in FSAR Section 2.4 satisfy the AP1000 site interface requirements described in DCD Section 2.4.

- VCS COL 2.5-8

COL Information Item 2.5-8 was provided to resolve COL Action Item 2.4.1-1. This addresses the groundwater conditions relative to the foundation stability of the safety-related structures at the site. The applicant performed an analysis of foundation stability using the maximum groundwater level (380 ft) and maximum differential water head and this analysis was confirmed by NRC staff and found to be acceptable.

- VCS COL 2.5-11

COL Information Item 2.5-11 was provided to resolve COL Action Item 2.5.2-2. This addresses the impact of hydrostatic groundwater pressures on the safety-related structures at the site. The applicant performed an analysis of uplift forces on foundation and buried piping due to groundwater levels at the maximum operational groundwater level (380 ft) and at plant grade (400 ft) and this analysis was confirmed by NRC staff and found to be acceptable.

The conclusions related to these COL information items rely on the characterization of groundwater levels across the site and the assumption that maximum operational groundwater level for the site will be 380 ft. The technical validity of this characterization and assumption was independently evaluated and the results are presented in Section 2.4.12.4 of this SER.

2.4.12.3 *Regulatory Basis*

The acceptance criteria associated with the relevant requirements of the Commission regulations for groundwater are described in Section 2.4.12 of NUREG-0800.

The applicable regulatory requirements are:

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

- 10 CFR 100.23(d) sets forth the criteria to determine the siting 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 area and with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.

2.4.12.4 *Technical Evaluation*

The NRC staff reviewed Section 2.4.12 of the VCSNS COL FSAR and checked the referenced DCD to ensure that the combination of the DCD and the COL application represents the complete scope of information relating to this review topic. The NRC staff's review confirmed that the information in the application and incorporated by reference addresses the required information relating to groundwater. The results of the NRC staff's evaluation of the information incorporated by reference in the VCSNS COL application are documented in NUREG-1793 and its supplements.

The staff reviewed the information in the VCSNS COL FSAR:

AP1000 COL Information Items

- VCS COL 2.4-4
- VCS COL 3.4-1
- VCS COL 2.5-8
- VCS COL 2.5-11

Information Submitted by the Applicant

In Section 2.4.12 of the VCSNS COL FSAR, the applicant presented information and data describing the regional hydrology, groundwater sources and usage, site hydrogeology, monitoring and safeguards, and the design bases for dewatering and hydrostatic loading. The applicant described the VCSNS site as being within the Piedmont physiographic province, which consists of metamorphic and igneous rock overlain by a layer of saprolite. The saprolite layer is a mixture of sand and clay that is essentially the weathered remains of the Piedmont bedrock. The applicant identified two zones of bedrock. The upper zone is the shallow bedrock, which is partially weathered and may have some fracturing. Groundwater in the partially weathered rock is associated with the groundwater conditions in the saprolite. The lower zone is the deep bedrock, which may have some fracturing that decreases with depth. Groundwater wells in the deep bedrock aquifers of the Piedmont typically only provide 5 to 15 gpm. In contrast, wells in the Coastal Plain province to the southeast can sustain pumping rates as high as 3,000 gpm (South Carolina Department of Natural Resources [SCDNR] 2004).

The applicant provided data from the SCDHEC that showed South Carolina used groundwater to provide only 17.3 percent of its consumptive water use in 2005. In Fairfield County, groundwater provides only 10 percent. In VCSNS COL FSAR Table 2.4-215, the applicant provided data for groundwater use for public water supply within 6 mi of the VCSNS site. All of the water systems extracted groundwater from the deep bedrock aquifer. The design yields for the wells ranged from 5 to 29 gpm. The populations served ranged from 25 to 1969.

The applicant characterized the hydrogeology of the VCSNS Units 2 and 3 site using groundwater observations, well tests, laboratory tests, and site topography and geology.

The applicant installed 31 observation wells (22 wells in the saprolite/shallow bedrock zone and 9 in the deep bedrock) and monitored water levels monthly from June 2006 to June 2007. The applicant used the data to construct groundwater surface maps that show that groundwater in the saprolite/shallow bedrock flows in all directions away from the ridgetop where Units 2 and 3 will be constructed. The applicant noted that the surface of the groundwater in the saprolite/shallow bedrock aquifer is similar to the topographic surface and that the topographic data show that all surface water drainages lead to the Broad River. The applicant stated that the deep bedrock aquifer was recharged from the shallow aquifer and that the deep aquifer flows directly to the Broad River.

Using the groundwater levels observed during the 13-month monitoring period, the applicant calculated horizontal gradients of 0.001 to 0.003 on top of the ridge and 0.037 to 0.05 on the ridge flanks. In the deep bedrock, the applicant reported horizontal gradients of 0.011 to 0.012 on top of the ride and 0.06 to 0.08 on the ridge flanks.

The applicant estimated vertical gradients between the saprolite/shallow bedrock aquifer and the deep bedrock aquifer using 10 of the observation wells. The applicant installed the 10 wells in a configuration of five well pairs so that each pair would provide an observation of water level in both aquifers at each of the five pair locations. The applicant determined that the two aquifers were directly connected on the ridgetop and the gradient was nearly zero. Away from the ridgetop, the vertical gradient increased. The applicant calculated vertical downward gradients of 1.58 and 2.07 in the drainage swale.

The applicant conducted slug tests in most of the observation wells to determine saturated conductivity. The values for the saprolite/shallow bedrock ranged from 0.0017 to 18 ft/day. The values for the deep bedrock ranged from 0.0088 to 0.38 ft/day. The applicant also conducted packer tests in two zones of each of four geotechnical borings in the deep bedrock. The results of the packer tests ranged from 0 to 1.14 ft/day.

The applicant analyzed seven samples of residual soil and 23 samples of saprolite to determine porosity, grain size, moisture content and specific gravity. The porosity of the residual soil ranged from 0.465 to 0.631. The porosity of the saprolite ranged from 0.401 to 0.632. The applicant assumed that the porosity of saprolite could be used to represent the porosity of the saprolite/shallow bedrock zone.

The applicant indicated that regional bedrock geology yields calcium carbonate-type groundwater. According to SCDHEC (2005), the dominant cations in the regional aquifer are calcium and sodium. Analyses reported by SCDHEC (2005) indicate that the water samples from 2004 display great similarity in composition, and are suitable for most purposes, with minor exceptions (related to the levels of iron, manganese, and total dissolved solids). The applicant indicated that the Jenkinsville Water Company reported the presence of naturally occurring radionuclides radium-226 and its daughter products in several of its wells, which the water company subsequently abandoned. The company is located 10 mi northeast of the Monticello Reservoir, and thus, hydraulically isolated from the VCSNS site.

The applicant stated that groundwater is not used for VCSNS Unit 1 and would not be used for the proposed Units 2 and 3.

The applicant stated that the existing monitoring program for VCSNS Unit 1 will be evaluated with respect to the addition of Units 2 and 3 to determine if modifications are needed to the existing radioactive effluent and environmental monitoring program for Unit 1 to also monitor the effect of Units 2 and 3 on groundwater. This is discussed further in Section 11.5 of this SER.

The applicant estimated the maximum groundwater level would be 380 ft, which is 20 ft below site grade. For the estimation, the applicant used the maximum level of 375.1 ft observed during the 13-month preconstruction monitoring period and the maximum seasonal groundwater fluctuation of 2.3 ft observed during the same period. By doubling the observed fluctuation, adding it to the maximum observed level, and rounding up, the applicant calculated the maximum water level to be 380 ft. The applicant examined well data collected from VCSNS Unit 1 between 1998 and 2006 and determined the fluctuations were less than the value used for the maximum water level calculation. Based on this estimated maximum groundwater level, the applicant determined that no permanent dewatering system is required.

NRC Staff's Technical Evaluation

The NRC staff issued RAI 2.4.12-1, RAI 2.4.12-2, and RAI 2.4.12-3 to obtain additional information on current and future groundwater use in the vicinity of the VCSNS site. In its response, the applicant explained the source of the groundwater supply data, provided private well data for the towns of Jenkinsville, Peak, Monticello, and Pomaria, which are the towns that are located nearest to the VCSNS site, and provided information on potential future groundwater use in the vicinity of the VCSNS site.

The applicant obtained population data from the EPA's SDWIS database and the remainder of the information from the SCDHEC database. The applicant noted that half of the water systems showed population values that differed from the SDWIS, but the applicant was unable to identify the source of those different numbers. The applicant stated that because the differences were small and the groundwater withdrawals were small, the impact to groundwater was minimal.

In regards to private well data, the applicant noted that the data do not include pumping rates and do not include data for private wells that do not have permits. The applicant also noted that the permitted private well data are maintained by the SCDHEC and can only be viewed on a "need to know" basis.

The applicant provided information on potential future groundwater use in the vicinity of the VCSNS site using information from Butler (2007). According to the applicant, population in Fairfield County is predicted to increase 12 percent by 2025 and groundwater use will increase in a similar fashion. The applicant stated that there are no plans to use local groundwater for construction or operation of VCSNS Units 2 and 3. The applicant plans to obtain water for construction from the Monticello Reservoir and the Jenkinsville Water Company. The applicant also plans to construct a water treatment plant to treat water from the Monticello Reservoir to provide the plant with potable water in the future.

The staff checked the SWDIS database on March 1, 2010. Some of the values match those in VCSNS COL FSAR Table 2.4-215 and some do not. For 10 of the 11 water systems, the population numbers are less than 50 regardless of the source. The 11th system, the Jenkinsville Water system, serves a population of either 1969 (FSAR Table 2.4-215) or 2217 (SDWIS); the SDWIS number is 13 percent higher. In either case, the population numbers are small and would not affect the analysis.

The staff reviewed the well data and examined the location of each town relative to the site. Monticello, Peak, and Pomaria are more than 3.2 km (2 mi) from the site and in alternate environmental settings. Peak and Pomaria are on the west side of the Parr Reservoir; the VCSNS site is located east of the reservoir. Monticello is on the eastern side of the Monticello Reservoir; the VCSNS site is on the south side. The staff concluded that groundwater at the VCSNS site would not be affected by the water systems in these towns because the Broad River and the Monticello Reservoir hydraulically isolate the VCSNS site from the water supply systems. The fourth town, Jenkinsville, is about 3.2 km (2 mi) southeast and at a nominal elevation of 141 m (463 ft), which is 19 m (63 ft) above the VCSNS site grade of 118 m (400 ft). The area between the plant site and Jenkinsville is drained by the Mayo Creek, which flows north to south. At its closest approach, the Mayo Creek passes the reactor buildings at a distance of 0.8 km (0.5 mi) to the east. The information provided in response to RAI 2.4.13-10 is consistent with the conceptual model; wherein the flow in Mayo Creek is essentially over bedrock. Because the VCSNS site is separated from Jenkinsville by the Mayo Creek, flow in the Mayo Creek is over bedrock, and bedrock in the area has a low conductivity. The staff concludes that wells in Jenkinsville will not impact the VCSNS site, nor will wells in Jenkinsville be impacted by groundwater changes onsite.

The staff reviewed the South Carolina Water Use Report 2006 Summary, South Carolina, Department of Environmental Control, Bureau of Water, dated July 2007, Butler (2007) reference cited by the applicant and confirmed that the population growth projection for Fairfield County between 2005 and 2025 is 12 percent. Butler (2007) also reported that groundwater in Fairfield County is used solely for water supply, thus, future use is expected to increase 12 percent to match the population increase. Overall, groundwater provided only 9 percent of the total water supply needs of Fairfield County in 2006. Because the applicant will not use groundwater for construction or operation of Units 2 and 3, and because no local well can be sited any closer than 1.2 km (0.75 mi) to the southeast, the staff concluded that the projected increase in groundwater use in Fairfield County will have no impact on Units 2 and 3. The staff reviewed VCSNS COL FSAR and confirmed that Sections 2.4.12.2.2 and 2.4.12.3.3 were revised as described in the responses to RAIs 2.4.12-2 and 2.4.12-3. Accordingly, the staff considers RAI 2.4.12-1, RAI 2.4.12-2, and RAI 2.4.12-3 closed. Section 2.4.13 of this SER further discusses RAI 2.3.13-10.

The NRC staff issued RAI 2.4.12-4 to obtain well test data and examine the analysis used by the applicant to calculate hydraulic conductivity. In a letter dated May 1, 2009, the applicant provided 34 input/output files for the aquifer test analysis model AQTESOLV. The applicant noted a transcription error for one well and identified the appropriate corrections for that error, which have been incorporated in the VCSNS COL FSAR.

The staff reviewed the AQTESOLV files to confirm the applicant's analysis. Slug-test data provided by the applicant showed good reproducibility between the rising and falling test responses as indicated by similar saturated hydraulic conductivity values for both the rising and falling head tests. When the rising and falling test values did not agree, the applicant used the larger more conservative estimate. For two well tests in the saprolite/shallow bedrock, the staff analysis yielded saturated hydraulic conductivity values that were 20 percent higher than the applicant's values. Although the staff values increased the geometric mean Ks value by 2 percent, the staff values did not affect the transport analysis in VSCNS COL FSAR Section 2.4.13 because the applicant used the 75th percentile Ks value of 1.7 ft/day, which was not affected by the updated Ks values. The staff reviewed VCSNS COL FSAR and confirmed that the applicant made the proposed changes. Accordingly, the staff considers RAI 2.4.12-4 closed.

The NRC staff issued RAI 2.4.12-5 to obtain local precipitation data for the period covering the groundwater monitoring program. In its response, the applicant provided precipitation data from the Parr climate station for the months of October 2006 through December 2007, which covers the period of groundwater monitoring. The applicant also provided groundwater elevation data for 8 wells for the period of July 2007 to November 2008.

The staff reviewed the precipitation data and the well responses. From January to May 2006, precipitation was 18 cm (7.1 in) below average for the Parr climate station (averages are for the period 1946 to 2009). From June to December 2006, which coincides with the first half of the monitoring period, precipitation was 39.1 cm (15.4 in) above average. The highest monthly precipitation, 29.8 cm (11.74 in), occurred in June 2006. From January to June 2007, precipitation was 9.7 cm (3.8 in) below average. Overall, precipitation from January 2006 through June 2007 was about 11.2 cm (4.4 in) above average. During the monitoring period (June 2006 to June 2007), there was very little response to seasonal changes in precipitation; in most wells, the response was less than 0.9 m (3 ft). This result is consistent with the significant depth below ground surface (about 15 m (50 ft)) in the vicinity of the reactor buildings. In all wells, the highest water table recorded was 114.3 m (375.1 ft). The data provided by the applicant showed that the existing groundwater was not sensitive to seasonal precipitation extremes. Accordingly, the staff considers RAI 2.4.12-5 closed.

The NRC staff issued RAI 2.4.12-6 to obtain a description of the impact of post-construction and operations on water table elevations and subsurface pathways. The information sought included site grading, land cover, recharge rates, and fill material properties. In its response, the applicant provided specifications for the common and structural fill for the foundation and for the drainage on the east that will be filled to provide an area for the cooling towers. The applicant acknowledged the uncertainty of recharge conditions and suggested the impacts will be local and that existing groundwater pathways will not be significantly impacted. The applicant confirmed that alternate flow paths to the east will be evaluated and presented in responses to RAIs related to VCSNS COL FSAR Section 2.4.13. The NRC staff held a conference call with the applicant on April 7, 2010, to discuss the nature of the surface conditions around the reactors that would affect recharge rates and thus groundwater levels. Subsequent to the call, the applicant provided detailed information in a letter dated May 27, 2010, on how precipitation falling on structures will be captured in gutters and routed to the surface water drainage system, such that it would not become recharged near the reactor buildings. On June 7 and 10, 2010, the NRC staff held two conference calls with the applicant to discuss the issue. The applicant explained that no topsoil would be used (it would just be fill material). The applicant described the fractional area occupied by the four main surface features within the protected zone (which is primarily the fenced area that surrounds the reactor buildings): a) buildings on the reactor basemat; b) buildings, roads, and pavement not above the basemat; c) grass-covered soil; and d) graveled compacted soil. The applicant described the graveled compacted soil as impervious so that it promotes runoff and minimizes plant growth. The applicant identified the maximum water level possible in the storm water basins and explained that the basins would be subject to South Carolina storm water management regulations and would be emptied within 72 hr of a storm event. The applicant provided a supplemental letter dated June 22, 2010, that documented the information provided on the phone calls. The applicant proposed to update the FSAR with a summary of this information as described in its June 22, 2010, letter. This is being tracked as **Confirmatory Item 2.4.12-1**.

Resolution of Confirmatory Item 2.4.12-1

Confirmatory Item 2.4.12-1 is an applicant commitment to update its FSAR consistent with its discussion in a June 22, 2010, letter. The staff verified that the VCSNS COL FSAR was appropriately updated. As a result, Confirmatory Item 2.4.12-1 is now closed.

The staff reviewed the applicant's response by examining VCSNS COL FSAR Figures 2.5.4-119 to 2.5.4-223, which show the cross-sections of the fill placement, and VCSNS COL FSAR Figure 2.4.5-245, which is the site grading plan. The grading plan shows that the final grade in the vicinity of the reactor complex slopes down from a plant grade elevation of 122 m (400 ft) to an elevation of 121 m (396 ft) on all four sides of the complex within about 46 m (150 ft) of the nearest structure.

VCSNS COL FSAR states that the maximum groundwater elevation will be 116 m (380 ft). This value was derived from well observations between June 2006 and June 2007. The maximum observed level was 114 m (375 ft) and the maximum observed fluctuation was 0.7 m (2.3 ft). A value of 1.5 m (5 ft) (roughly twice the observed fluctuation) was added to the maximum observed level to arrive at the maximum expected elevation of 115.8 m (380 ft). All of these values were derived for conditions before the site is constructed. They do not account for construction related changes to the site that could determine what the maximum operational groundwater levels will be. These include the large scale manipulations of the topography (e.g., losing up to 7.6 m (25 ft) in some locations and gaining up to 18.3 m (60 ft) in other areas), installation of massive infrastructure, removal of vegetation, and alteration of soil and fill surrounding the reactor buildings.

The site grading plan shows what appears to be a surface drainage swale at the 46-m (150-ft) distance. Such a feature could convey surface water away quickly, such that groundwater at that location would not exceed 121 m (396 ft). What happens to the water table elevation adjacent to the reactor buildings depends on the soil, vegetation, topography, and facility conditions (e.g., catch basins; drainage pipes) between the buildings and the drainage swale at 46 m (150 ft). As an example, the applicant estimated the hydraulic conductivity of the structural fill to be 1.0E-3 cm/second (s) (3.3E-5 feet per second (fps)) and the common fill to be 5.0E-5 cm/s (1.6E-6 fps). Figures 2.5.4-120 to 2.5.4-123 indicate that common fill would surround the structural fill. If precipitation infiltrates the structural fill, lateral flow away from the facility would be impeded by the common fill (because of its much lower conductivity).

Following construction, runoff will be significantly reduced as slopes are lowered from 3-10 percent to 1 percent and transpiration will be significantly reduced by the removal of trees and shrubs (and potentially grasses in the case of graveled surfaces). Reductions in runoff or transpiration could lead to significantly increased recharge rates depending on the nature of the post-construction surfaces. But the staff finds that the procedure described by the applicant for collecting all precipitation that falls on buildings and routing it to the surface water collection system will convey the water offsite and preclude the enhancement of recharge to groundwater around the reactor buildings that could cause the groundwater level to rise above the DCD level.

According to the applicant, the storm water basins would not hold water except during the period (up to 72 hr) following a storm event. Because the basins would generally be dry, the staff concludes that the basins would not be constant contributors to recharge that could raise the groundwater level higher than expected.

The applicant explained that the surface features within the protected area are not conducive to recharge. The buildings, roads, and pavement will route precipitation to the drainage swales and on to the storm water management system. The grassed area will be confined to the perimeter of the protected area and coincide with the drainage system. The graveled compacted soil will be emplaced to maximize runoff to the drainage system. The staff concludes that conditions within the protected area, which surrounds the reactor buildings, will not be conducive to recharge rates that could raise the groundwater level above the DCD level. Given the actions proposed by the applicant to reduce recharge, the staff concludes that the maximum groundwater level will likely not exceed the applicant's estimate of 380 ft. As a result, the staff concludes that 380 ft is an acceptable estimation of maximum groundwater levels to use in calculations performed in related SER sections (2.5 and 3.4) and that no permanent dewatering system will be required to maintain groundwater levels below the DCD requirement of 2 feet below site specific plant grade (400 ft).

The applicant proposed to provide information on the land cover details in the protected areas. This is identified as **Confirmatory Item 2.4.12-1**. Once the expected information is received, the staff will be able to consider RAI 2.4.12-6 closed.

Resolution of Confirmatory Item 2.4.12-1

Confirmatory Item 2.4.12-1 is an applicant commitment to update its FSAR to provide information on the land cover details in the protected areas. The staff verified that the VCSNS COL FSAR was appropriately updated. As a result, this part of Confirmatory Item 2.4.12-1 is now closed. Closing Confirmatory Item 2.4.12-1 also closes RAI 2.4.12-6.

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 has reviewed the application and has confirmed that the applicant addressed the information relevant to groundwater, and that no outstanding information is expected to be addressed in the VCSNS COL FSAR related to this section. As set forth above, the applicant presented and substantiated information to establish the site description. The staff has reviewed the information provided and, concludes that the applicant has provided sufficient details about the site description to allow the staff to evaluate, as documented in Section 2.4.12, of this SER, whether the applicant has met the relevant requirements of 10 CFR 52.79(a)(1)(iii) and 10 CFR Part 100 with respect to determining the acceptability of the site. This addresses COL information item VCS COL 2.4-4, VCS COL 2.5-8, VCS COL 2.5-11, and VCS COL 3.4-1. In conclusion, the applicant has provided sufficient information for satisfying 10 CFR Part 52 and 10 CFR Part 100.

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

2.4.13.1 *Introduction*

VCSNS COL FSAR Section 2.4.13 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, FSAR Section 2.4.13 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 of existing uses of groundwater and surface water and their 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 NUREG-0800 Section 11.2 following the guidance in Branch Technical Position (BTP) 11-6, "Postulated Radioactive Releases Due to Liquid-containing Tank Failures." The source term is determined from a postulated release from a single tank outside of the containment.

Section 2.4.13 of this SER presents an evaluation of the following specific areas: (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) ability of the groundwater and surface water environments to delay, disperse, dilute, or concentrate accidentally released radioactive liquid effluents during transport; and (4) assessment of scenarios wherein an accidental release of radioactive effluents is combined with potential effects of seismic and non-seismic events[2].

2.4.13.2 *Summary of Application*

This section of the VCSNS COL FSAR addresses the accidental release of radioactive liquid effluents in ground and surface waters. The applicant addressed these issues as follows:

AP1000 COL Information Items

- VCS COL 2.4-5 and VCS COL 15.7-1

In addition, this section addresses the following COL Information Item 2.4.5 (COL Action Item 2.4.1-1) identified in Section 2.4.1.5 of the DCD.

> Combined License applicants referencing the AP1000 certified design will address site-specific information on the ability of the ground and surface water to disperse, dilute, or concentrate accidental releases of liquid effluents. Effects of these releases on existing and known future use of surface water resources will also be addressed.

VCS COL 2.4-5 adds VCSNS COL FSAR Section 2.4.13 in its entirety.

Also, VCSNS COL FSAR Section 15.7.6 states that VCS COL 15.7-1 is addressed in FSAR Section 2.4.13. In FSAR Section 2.4.13, the applicant performed the consequence analysis of a postulated liquid waste tank failure to address COL Information Items 2.4-5 and 15.7.1. This is also evaluated in SER Section 11.2.

The staff does not limit its review to just surface water. The staff considers both surface water and groundwater resources in their independent review.

2.4.13.3 *Regulatory Basis*

The acceptance criteria associated with the relevant requirements of the Commission regulations for the pathways of liquid effluents in ground and surface waters are described in Section 2.4.13 of NUREG-0800.

The applicable regulatory requirements for liquid effluent pathways for groundwater and surface water are as follows:

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

- 10 CFR 100.23(d) sets forth the criteria to determine the siting 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 area and with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.

Appropriate sections of the following documents are used for the related acceptance criteria:

- 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.

- RG 1.113, "Estimating Aquatic Dispersion of Effluents from Accidental and Routine Reactor Releases for the Purpose of Implementing Appendix I," Revision 1.

2.4.13.4 *Technical Evaluation*

The NRC staff reviewed Section 2.4.13 of the VCSNS COL FSAR and checked the referenced DCD to ensure that the combination of the DCD and the COL application represents the complete scope of information relating to this review topic. The NRC staff's review confirmed that the information in the application and incorporated by reference addresses the required information relating to accidental releases of radioactive liquid effluents in ground and surface waters. The results of the NRC staff's evaluation of the information incorporated by reference in the VCSNS COL application are documented in NUREG-1793 and its supplements.

The staff reviewed the information in the VCSNS COL FSAR:

AP1000 COL Information Item

- VCS COL 2.4-5 and VCS COL 15.7-1

The technical evaluation addresses four issues: conceptual model, alternative pathways, effective porosity, behavior of well OW-627a, and the dilution factor for the Mayo Creek.

Information Supplied by the Applicant

In Section 2.4.13 of the VCSNS COL FSAR, the applicant presented information and data describing a postulated accidental release of radioactive liquid effluents in groundwater and surface water. In addition to describing the accidental release, the applicant described the conceptual models of the site, the modeling approach, the screening process, accidental release to surface water, and meeting the acceptance criteria in BTP 11-6.

The applicant selected the tank that failed in the accidental release scenario based on information in Table 11.2-2 of the AP1000 DCD. According to the applicant, the scenario is an instantaneous release from one of the two effluent holdup tanks located in the lowest level of the AP1000 auxiliary building. Each effluent holdup tank holds 28,000 gallons. The applicant assumed the contents would be 101 percent of the reactor coolant concentrations of tritium, corrosion products, and other radionuclides identified by the reactor vendor and in accordance with guidance provided in BTP 11-6. The applicant provided the expected concentrations in VCSNS COL FSAR Table 2.4-225. The applicant described the effluent holdup tanks as having the highest potential radionuclide concentration and the largest volume and, therefore, release from one of those tanks would lead to the most adverse contamination of groundwater.

The applicant described the conceptual model of the release. In accordance with BTP 11-6, 80 percent (22,400 gallons) of the tank volume is released instantaneously and flows through floor drains to the sump. The applicant assumed the sump pumps would not work and that a pathway would exist through either the 6-ft-thick concrete floor or the 3-ft-thick concrete walls. The slab of the room containing the effluent tanks is 5 to 7 ft below the groundwater levels measured during the monitoring period and would be 17 ft below the maximum groundwater level. Although groundwater pressure outside the structure would likely cause an influx of groundwater into the structure, the applicant assumed groundwater would not enter and assumed it would not impede the exodus of the leaked effluent tank liquid.

The applicant assumed the leaked liquid would enter the saprolite/shallow bedrock zone and flow down gradient to the nearest discharge points. The applicant identified the primary discharge points as the unnamed creek to the north-northwest of Unit 2 and the unnamed creek to the south-southwest of Unit 3. The two pathways are illustrated in VCSNS COL FSAR Figure 2.4.252.

The applicant considered alternative pathways. In the case of bedrock pathways, the applicant decided that much lower conductivity would yield longer travel times. In the case of discharge to other nearby creeks, the applicant decided that the longer travel pathways would yield longer travel times. The applicant did not consider the alternative pathways in the transport analysis because the longer travel times would yield lower impacts than the primary pathways.

The applicant stated that there were no water supply wells between the release points and the groundwater discharge points. The applicant identified surface water uses on the Broad River downstream of the VCSNS site. The applicant noted that potable water resources exist on SCE&G property, are under the control of SCE&G, and will be monitored and controlled in the event of an accidental tank rupture. The applicant did not include the SCE&G potable water supply in the accident release analysis.

For the transport calculation, the applicant used an analytical solution based on the advection-dispersion-reaction equation (Javandel, et al. 1984). The applicant included all progeny that were important from a dose perspective. The applicant used a linear sorption model to represent sorption of contaminants to sediments. With this model, the contaminant-specific K_d parameter relates sorption linearly to groundwater concentration. The applicant neglected hydrodynamic dispersion (which reduces concentrations) to yield a more conservative result.

The applicant identified the parameters used to calculate transport along the primary pathway for each unit. SER Table 2.4-2 summarizes both the parameters and the resulting calculated values of groundwater velocity and travel time.

The applicant analyzed the results in three steps. In the first step, the applicant considered only radioactive decay. Of the original 57 constituents, only 8 exceeded 1 percent of the maximum permissible concentration for the Unit 2 pathway and only 7 for the Unit 3 pathway.

In the second step, the applicant considered both decay and adsorption. The applicant measured K_d values for cobalt, strontium, and cesium on multiple saprolite samples from the VCSNS site. For the transport analysis, the applicant assigned the lowest measured K_d values for cobalt, strontium, and cesium. For the remaining radionuclides (H-3, I-129, Fe-55, and Y-90), the applicant assigned K_d values of zero. The applicant used a bulk density value of 1.41 g/cm3 and an effective porosity value of 0.39 to translate the adsorption values in retardation values. Of the radionuclides evaluated, only Hydrogen (H)-3, Iron (Fe)-55, Manganese (Mn)-54, Silver (Ag)-110, Cerium (Ce-144) and Iodine(I)-129 exceeded 1 percent of the permissible concentrations for Unit 2 and only H-3 and I-129 exceeded 1 percent for Unit 3.

In the third step, the applicant calculated the groundwater flow rate into the unnamed creeks. The applicant assumed the plume was 10 ft thick and square (in plan view). The applicant assumed the effluent liquid filled the entire effective porosity of 0.39. Using those assumptions and the hydraulic gradients in SER Table 2.4-2, the applicant calculated the flow rate to the unnamed creeks. The applicant noted that uncontaminated flow in the creeks would dilute the effluent, but the applicant did not include this dilution in the analysis. Once flow reached the Broad River, the applicant assumed the effluent would be diluted further. The applicant used the 100-year daily mean low flow value of 125 cfs to calculate a conservative dilution factor. Table 2.4-2 shows that the dilution factor for each unit was roughly 10^{-6}. Conservatively, the applicant did not consider the additional dilution that would occur in the existing water impounded in the Parr Reservoir.

The applicant stated that in the AP1000 design, there are no outdoor tanks containing radioactivity. The unstated conclusion is that there would be no accidental release to surface water. However, most of the groundwater pathways evaluated eventually reach surface water, and it is as surface water concentrations that the radionuclides are considered relative to 10 CFR Part 20, Appendix B, “Annual Limits on Intake (ALIs) and Derived Air Concentrations

(DACs) of Radionuclides for Occupational Exposure; Effluent Concentrations; Concentrations for Release to Sewerage," limits as described in BTP 11-6.

The applicant assessed compliance with 10 CFR Part 20, Appendix B limits using the sum-of-fractions approach in which the sum must not exceed 1.0, as explained in BTP 11-6. For each radionuclide, the applicant calculated the ratio of the concentration of that radionuclide at the compliance point to the concentration permitted. The applicant provided those ratios in VCSNS COL FSAR Tables 2.4-235 and 2.4-236. The applicant summed all ratios (i.e., fractions) for each unit and determined the sum was 5.32×10^{-4} for Unit 2 and 3.01×10^{-3} for Unit 3. For both units, the sums are well below the limit of 1.0. The applicant concluded that an accidental release of effluents to groundwater would not exceed the criteria in BTP 11-6.

<u>NRC Staff Technical Evaluation</u>

The NRC staff issued RAIs 2.4.13-2, 2.4.13-7, and 2.4.13-10 to obtain conceptual model information on the subsurface environment, a statement about the use of chelates and complexants, and a description of the Mayo Creek bed.

In response to RAI 2.4.13-2, the applicant provided a description of the process used to define the conceptual site model of the subsurface environment. The applicant used that conceptual site model to postulate two primary pathways and eight plausible alternative pathways. The applicant calculated the travel time along all ten pathways and identified the pathway with the shortest travel time (7.7 years through the saprolite/shallow bedrock from Unit 2 to the unnamed creek to the northwest). The applicant proposed to make changes to the VCSNS COL FSAR to address all ten alternative pathways.

In response to RAI 2.4.13-7, the applicant stated that "Chelates & complexants are not planned to be used for Units 2 and 3."

In response to RAI 2.4.13-10, the applicant provided the results of a field survey of the Mayo Creek where it passes the outlet of the main eastern surface drainage for the saprolite/shallow bedrock pathway from Units 2 and 3. Over a distance of about 1100 ft, the applicant used visual inspection and hand auguring to characterize stream sediments and substrate. The applicant identified specifics for seven locations. At the three most upstream locations, the augur penetrated some sand and clay, but met resistance and outright hard rock within a couple of feet. At the four locations on the downstream end, rock ledges and outcrops were directly observed. The applicant provided a picture showing water flowing over rock ledges at about the point where the surface drainage from the VCSNS site enters the Mayo Creek. The applicant also provided a USGS topographic map of the Mayo Creek basin showing that the creek is perennial in the section that was sampled and intermittent about 1750 ft upstream.

The staff reviewed the proposed conceptual site model, primary and alternate pathways, and transport calculations. The pathways include transport from Unit 2 and Unit 3 and through the shallow aquifer and the deep bedrock. Endpoints include the Broad River, the Mayo Creek, and a hypothetical private well. The parameters used by the applicant to calculate flow and transport are reasonable. For some parameters, the applicant used conservative values as a means to overcome variability and uncertainty. Examples are the use of the 75th percentile hydraulic conductivity and the lowest of all K_d values measured for each radionuclide.

The staff determined that the applicant's estimation of an effective porosity for the saprolite/shallow bedrock was not conservative with respect to travel time. The applicant estimated an effective porosity of 0.27 based on grain size information. In response to RAI 2.4.13-2, the applicant corrected the estimate to 0.18 to represent the field value assuming the particle size estimate exceeded the field estimate by a factor of 1.50 based on data reported by Stephens et al. (1998). In that reference, the particle-size based estimate exceeded the field estimate by a factor of 1.82. For the VCSNS site, that means the original estimate of 0.27 should be reduced to 0.146. This corrected value is a better estimate of the nominal value and is not necessarily conservative. The staff determined that a conservative value of effective porosity would be something less than 0.146. To demonstrate the impact of a reasonably conservative effective porosity, the nominal value was reduced by 25 percent to yield a conservative effective porosity value of 0.11 (a lower effective porosity value is conservative because it yields a shorter travel time). Using this value, staff calculated travel times that are 39 percent shorter in the saprolite/shallow bedrock than reported by the applicant. The staff determined that using the shorter and more conservative travel time would increase the sum of fractions, but for all pathways, the sum would be less than 0.1, which is well below the allowable limit of 1.0 as described in acceptance criteria in BTP 11-6.

Another parameter value that the staff considered nonconservative was the post-construction water table, which affects groundwater gradients. As discussed in the response to RAI 2.4.12-6, the applicant's post-construction water table does not address post-construction recharge conditions. To be conservative, the staff considered one possibility to be that the water table could be as high as 398 ft, which is the maximum allowable groundwater elevation. Using that elevation to calculate groundwater gradients, the staff determined that the travel times for the two primary pathways would decrease by 53 percent for Unit 2 and 31 percent for Unit 3. For the pathway from either reactor to the Mayo Creek, the travel time reduction would be about 34 percent. The higher groundwater gradients shorten travel times but do not change the ranking of pathways. Using the conservative gradient for the primary pathway (the one with the shortest travel time) yields a travel time of 3.6 years (versus the 7.7 years reported by the applicant). Even though the travel time would be shorter, the dilution by the Broad River lowers concentrations well below the limits identified in 10 CFR Part 20, Appendix B, Table 2, Column 2. For the pathways to the Mayo Creek, the dilution factor is lower by a factor of 2000 relative to the Broad River, which means the sum of fractions will be higher. The applicant reports the highest sum of fractions is 0.054 and it occurs for the pathway through saprolite/shallow bedrock between Unit 3 and the Mayo Creek (in contrast, the sum of fractions for the primary pathway is 0.00011). The staff determined that the larger and more conservative groundwater gradient would increase the sum of fractions to a value just below 0.1, which is still far below the acceptance criteria of 1.0.

The staff considered the possibility that the groundwater level could be somewhat higher than expected based on preconstruction levels (although not exceed the DCD level; see discussion of the applicant's response to RAI 2.4.12-6 in Section 2.4.12.4.4 of this SER). A higher water table could lead to the formation of seeps and springs. Such features could shorten the travel time of contaminants to a surface water body. Pathways that end in the Broad River would still yield sums of fractions below the regulatory limit because of the dilution potential of the river. Pathways toward the Mayo Creek could be shortened significantly. The staff reviewed the site grade plan in VCSNS COL FSAR Figure 2.5.4-245 and determined that common fill material would make up approximately 70 percent of the distance between either Unit 2 or 3 and the Mayo Creek. In response to RAI 2.4.12-6, the applicant stated the hydraulic conductivity of the common fill would be 5.0 x 10-5 cm/s (0.1417 ft/day). This value is 12 times lower than the hydraulic conductivity of the saprolite/shallow bedrock material that comprises the shallow pathways to the Mayo Creek. Because the fill has a much lower value, any seeps and springs that do appear will be from points that are down slope of the fill area. If so, the travel distance, and thus, travel time, to the Mayo Creek would only be shortened by up to 30 percent. The staff determined that the reduced travel time would increase the sum of fractions to a value just below 0.1, which is still far below the acceptance criteria of 1.0.

The staff concluded that because chelating agents and complexants will not be used, there will be no impact to sorption of radionuclides in the groundwater.

The staff reviewed the field observations relative to the Mayo Creek, the locations of the observations relative to the eastern drainage, the picture of the streambed, and the USGS map. The staff concluded that the Mayo Creek is likely a gaining stream fed by groundwater that flows on top of bedrock.

In summary, the conceptual model questions were addressed. The staff confirmed that the proposed changes to the VCSNS COL FSAR were incorporated. Accordingly, the staff considers RAIs 2.4.13-2, 2.4.13-7 and 2.4.13-10 closed.

The NRC staff issued RAIs 2.4.13-3, 2.4.13-4, 2.4.13-5, and 2.4.13-12 to identify and evaluate alternative pathways and parameters. In response, the applicant referred to its response to RAI 2.4.13-2. In that response, the applicant described 10 possible pathways: four in saprolite/shallow bedrock and six in the deep bedrock.

The staff reviewed the 10 alternate pathways and associated parameters. Six bedrock pathways were examined. For each unit, one pathway was west to the Broad River, one was east to the Mayo Creek, and one was east to a hypothetical private well. For all pathways, the hydraulic conductivity of the deep bedrock was 0.4 ft/day. This value is higher than seven of the eight values measured onsite and the staff considers it to be conservative. For all pathways, the effective porosity was set equal to 0.04, which was estimated to be 80 percent of the porosity value of 0.05, which was itself estimated from regional values. The staff considers these values to be reasonable. Travel times for all bedrock pathways ranged from 35 to 69 years. These times are much greater than the 7.7 years for the primary pathway, which is through the saprolite/shallow bedrock between Unit 2 and the unnamed creek to the northwest. The staff considered a more conservative effective porosity value of 0.02, which is half the value used by the applicant. With the conservative value, the travel times for the deep bedrock pathways were reduced by half. Even so, the times were still more than double the travel time of the primary pathway. Because conservative values of conductivity and effective porosity yielded travel times longer than the primary pathway, the staff concluded that the deep bedrock pathways would not yield the most conservative accidental release scenario.

The staff reviewed the eastern pathways in the saprolite/shallow bedrock from Units 2 and 3 toward the Mayo Creek. Even when using more conservative values of effective porosity and hydraulic gradients, travel times are longer than the primary pathway. Because the travel times are longer, the staff concluded that the saprolite/shallow bedrock pathways to the Mayo Creek would not yield the most conservative accidental release scenario.

The staff reviewed the eastern pathway in the deep bedrock from Units 2 and 3 toward the Mayo Creek and the impact to possible receptors at the Mayo Creek and a hypothetical private well. Even when using conservative values of conductivity and effective porosity, travel times are longer than the primary pathway. Because the travel times are longer, the staff concluded the deep bedrock pathways would not yield the most conservative accidental release scenario.

In summary, the staff considered the ten alternative pathways that covered multiple directions and the two primary geologic units and confirmed that the primary pathways identified by the applicant are the primary pathways. The staff confirmed that the proposed changes to the VCSNS COL FSAR were incorporated. Accordingly, the staff considers RAIs 2.4.13-3, 2.4.13-4, 2.4.13-5 and 2.4.13-12 closed.

The NRC staff issued RAI 2.4.13-8 to obtain a description of the conservativeness of the effective porosity parameter. In response, the applicant referred to its response to RAI 2.4.13-2, in which the applicant described the estimation of the effective porosity estimate.

In the staff's evaluation of the applicant's response to RAI 2.4.13-2, the staff noted that the effective porosity for the saprolite/shallow bedrock was reasonable but not necessarily conservative. The staff evaluated a conservative value (half the nominal value) and determined that the result would not change the outcome of the accident release scenario, which is that the site meets criteria identified as 10 CFR Part 20, Appendix B, Table 2, Column 2. In its evaluation of the applicant's response to RAI 2.4.13-3, the staff examined the effective porosity value used for the deep bedrock pathways. Based on that examination, the staff determined that a more conservative value of effective porosity for the deep bedrock pathways would not change the outcome of the accident release scenario, which is that the site meets criteria identified as 10 CFR Part 20, Appendix B, Table 2, Column 2. Accordingly, the staff considers RAIs 2.4.13-2 and 2.4.13-8 closed.

The NRC staff issued RAI 2.4.13-11 to obtain any additional data on bedrock well OW-627a that might explain its anomalous behavior. In its response, the applicant provided one additional water level measurement taken on January 27, 2009, in wells OW-627a (316.3 ft) and OW-627b (315.3 ft) as part of a well abandonment effort. The applicant stated that the measurements by the well abandonment contractor were not conducted under quality control protocol, so those measurements should be considered approximate. The applicant also provided Figure RAI 2.4.13-11-1 that shows the hydrographs for both wells from June 2006 to January 2009.

The staff reviewed the well data and examined MACTEC (2007). Geotechnical borehole B-627 and groundwater monitoring wells OW-627a and OW-627b are located within 15 ft of each other. The water table at this location is approximately 12 to 15 ft below ground surface. The shallow aquifer material is alluvium to a depth of 16.7 ft, saprolite from 16.7 to 46 ft, and partially weathered rock from 46 to 57.5 ft. The top of sound rock is at 61.5 ft (an elevation of 264.8 ft). Well OW-627b is screened across the interface of the saprolite and partially weathered rock. Well OW-627a is screened within sound rock. The water level elevation in this borehole (OW-627a) rose from 250 ft to 316.3 ft between October 2006 and January 2009. The January 2009 level is consistent with the water level in the shallow aquifer. The change in water level in the deep borehole could be caused by either equilibration with the local bedrock aquifer or by communication with the upper shallow aquifer. Either way, the slow response (about 2.5 years) indicates a very low hydraulic conductivity (the applicant estimates it to be 3.0×10^{-8} cm/s) and likely a low fracture density. Because of the low conductance and higher travel times that result, the staff concludes that the deep bedrock pathway to the east, although plausible, is not the most conservative pathway. Accordingly, the staff considers RAI 2.4.13-11 closed.

The NRC staff issued RAI 2.4.13-9 to obtain a description of the process used to estimate the dilution factor for the Mayo Creek. In its response, the applicant described the method used to calculate the 100-year low annual mean flow in the Mayo Creek where it passes beneath Parr

Road. The Mayo Creek is not gauged, so the applicant developed a regression equation relating annual flow to drainage area. The equation was based on data from nine gauged watersheds with areas less than 50 sq mi in similar piedmont settings and at least 17 years of data. Two estimates of the 100-year low annual mean flow were derived. Using all the data yielded an estimate of 0.54 cfs. Deleting one outlier datum from the regression improved the regression fit R2 from 0.51 to 0.73. The resulting 100-year low flow was 0.39 cfs. The applicant used the lower estimate of 0.39 cfs for the analysis because it was the more conservative of the two estimates.

The staff reviewed the method and results. Relating annual flow conditions in an ungauged watershed to data from gauged watersheds is an acceptable method for estimating low-flow statistics. As a check, the staff considered a conservative low-flow value of 0.195 cfs, which is half the applicant's value. As a result, the dilution factor for Mayo Creek would be reduced by half and the sum of fractions would be increased to 0.11, which is still well below the maximum allowable value of 1.0. Accordingly, the staff considers RAI 2.4.13-9 closed.

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 has reviewed the application and has confirmed that the applicant addressed the relevant information and there is no outstanding information expected to be addressed in the VCSNS COL FSAR related to this section. As set forth above, the applicant presented and substantiated information to establish the potential effects of accidental releases from the liquid waste management system. The staff has reviewed the information provided and, for the reasons given above, concludes that the applicant has provided sufficient details about the site description, and about the design of the liquid waste management system, to allow the staff to evaluate, as documented in this section, whether the applicant has met the relevant requirements of 10 CFR 52.79(a)(1)(iii) and 10 CFR Part 100 with respect to determining the acceptability of the site, and with respect to 10 CFR Part 20 as it relates to effluent concentration limits. This addresses COL Information Items 2.4-5 and 15.7-1. In conclusion, the applicant provided sufficient information for satisfying 10 CFR Part 20, 10 CFR Part 52, and 10 CFR Part 100.

2.4.14 Technical Specification and Emergency Operation Requirements

2.4.14.1 *Introduction*

FSAR Section 2.4.14 of the VCSNS COL application describes the technical specifications and emergency operation requirements as necessary. The requirements described implement protection against floods for safety-related facilities to ensure that an adequate supply of water for shutdown and cool-down purposes is available.

Section 2.4.14 of this SER presents an evaluation of the following specific areas: (1) controlling hydrological events, as determined in previous hydrology sections of the FSAR, to identify bases for emergency actions required during these events; (2) the amount of time available to initiate and complete emergency procedures before the onset of conditions while controlling hydrological events that may prevent such action; (3) reviewing technical specifications related to all emergency procedures required to ensure adequate plant safety from controlling hydrological events by the organization responsible for the review of issues related to technical specifications; (4) potential effects of seismic and non-seismic information on the postulated technical specifications and emergency operations for the proposed plant site; and (5) any additional information requirements prescribed in the "Contents of Application" sections of the applicable subparts to 10 CFR Part 52.

2.4.14.2 *Summary of Application*

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

AP1000 COL Information Item

- VCS COL 2.4-6

In addition, this section addresses the following COL Information Item 2.4.6 (COL Action Item 2.4.1-1) identified in Section 2.4.1.6 of the DCD.

> Combined License applicants referencing the AP1000 certified design will address any flood protection emergency procedures required to meet the site parameter for flood level.

VCS COL 2.4-6 adds VCSNS COL FSAR Section 2.4.14 in its entirety.

2.4.14.3 *Regulatory Basis*

The acceptance criteria associated with the relevant requirements of the Commission regulations for consideration of emergency protective measures are described in Section 2.4.14 of NUREG-0800.

The applicable regulatory requirements are:

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

- 10 CFR 100.23(d) sets forth the criteria to determine the siting 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 area 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 technical specifications related to all emergency procedures required to ensure adequate plant safety from controlling hydrological events by the organization responsible for the review of issues related to technical specifications.

2.4.14.4 *Technical Evaluation*

The NRC staff reviewed Section 2.4.14 of the VCSNS COL FSAR and checked the referenced DCD to ensure that the combination of the DCD and the COL application represents the complete scope of information relating to this review topic. The NRC staff's review confirmed that the information in the application and incorporated by reference addresses the required information relating to technical specifications and emergency operation requirements. The results of the NRC staff's evaluation of the information incorporated by reference in the VCSNS COL application are documented in NUREG-1793 and its supplements.

The staff reviewed the information in the VCSNS COL FSAR:

AP1000 COL Information Item

- VCS COL 2.4-6

Information Submitted by the Applicant

The applicant states Section 2.4.3 of the FSAR establishes that the site is dry and flood protection is not required.

NRC Staff's Technical Evaluation

Based on the fact that the NRC staff has established that the design basis flood of the local intense precipitation discussed in Section 2.4.2 of this SER, the staff determined that flood neither protection technical specifications or emergency procedures are required.

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 confirmed that the applicant has addressed the information relevant to technical specification and emergency operations requirements, and there is no outstanding information required to be addressed in the VCSNS COL FSAR related to this section.

As set forth above, the applicant has presented and substantiated information to establish the site description. The staff has reviewed the information provided and, for the reasons given above, concludes that the applicant has provided sufficient details about the site description to allow the staff to evaluate, as documented in Section 2.4.14, of this SER, whether the applicant has met the relevant requirements of 10 CFR 52.79(a)(1)(iii) and 10 CFR Part 100 with respect to determining the acceptability of the site. This addresses COL Information Item 2.4.6.

2.5 Geology, Seismology, and Geotechnical Engineering

In Section 2.5, "Geology, Seismology, and Geotechnical Engineering," of the VCSNS COL FSAR, the applicant described geologic, seismic, and geotechnical engineering properties of the proposed COL site. Following NRC guidance in RG 1.206, "Combined License Applications for Nuclear Power Plants," and RG 1.208, "A Performance-Based Approach to Define Site-Specific

Earthquake Ground Motion," the applicant defined the following four zones around the VCSNS site and conducted investigations in those zones:

Site region – Area within a 320-km (200-mi) radius of the VCSNS site location
Site vicinity – Area within a 40-km (25-mi) radius of the VCSNS site location
Site area – Area within an 8-km (5-mi) radius of the VCSNS site location
Site location – Area within a 1-km (0.6-mi) radius of VCSNS Units 2 and 3

Since the COL site is located adjacent to VCSNS Unit 1, the applicant used information acquired during the previous site investigations for the Unit 1 facility as the starting point for characterization of the geologic, seismic, and geotechnical engineering properties of the COL site. As such, the material in Section 2.5 of the VCSNS COL FSAR focuses on information published since the VCSNS Unit 1 FSAR, which was issued in the 1970s. VCSNS COL FSAR Section 2.5 also presents information collected during geologic, seismic, geophysical, and geotechnical investigations performed specifically for the COL site.

The applicant used seismic source models published by EPRI, the Electric Power Research Institute (EPRI, 1986 and 1989), as the starting point for characterizing potential regional seismic sources and vibratory ground motion resulting from those sources. The applicant then updated the EPRI seismic source models in light of more recent data and evolving knowledge, particularly for the Charleston and New Madrid seismic source zones. The applicant also replaced the original EPRI ground motion models (EPRI, 1989) with the more recent EPRI ground motion models (EPRI, 2004; Abrahamson and Bommer, 2006). The applicant applied the performance-based approach described in RG 1.208 to develop the Ground Motion Response Spectra (GMRS) for the site.

This SER is divided into five main parts (SER Sections 2.5.1 through 2.5.5), which parallel the VCSNS COL application. The five main SER sections are Section 2.5.1, "Basic Geologic and Seismic Information"; Section 2.5.2, "Vibratory Ground Motion"; Section 2.5.3, "Surface Faulting"; Section 2.5.4, "Stability of Subsurface Materials and Foundations"; and Section 2.5.5, "Stability of Slopes." Evaluations made by the staff in regard to these five sections contribute to the staff's overall determination that the VCSNS COL site is acceptable based on geologic, seismic and geotechnical information presented in VCSNS COL FSAR Sections 2.5.1 through 2.5.5. Section 2.5.6 of the application includes information regarding embankments and dams. This information is evaluated in Section 2.5.5 of this report.

2.5.1 Basic Geologic and Seismic Information

2.5.1.1 *Introduction*

Section 2.5.1 of the VCSNS COL FSAR describes geologic, seismic and geotechnical information collected by the applicant during regional and local site investigations. This technical information results primarily from surface and subsurface investigations, performed in progressively greater detail closer to the site, within each of four circumscribed areas corresponding to the site region, site vicinity, site area, and site location, as previously defined. The primary purposes for conducting these investigations are to determine geologic and seismic suitability of the site, provide the bases for plant design, and determine whether there is significant new information on tectonic features or ground motion that could impact seismic design bases as determined by a probabilistic seismic hazard analysis (PSHA). VCSNS COL FSAR Section 2.5.1.1, "Regional Geology," describes the geologic and tectonic setting within the VCSNS site region. VCSNS COL FSAR Section 2.5.1.2, "Site Geology," describes the geology and tectonic setting within the site vicinity and site area and at the site location.

2.5.1.2 *Summary of Application*

Section 2.5.1 of the VCSNS COL FSAR, Revision 5, incorporates by reference Section 2.5.1 of the AP1000 DCD, Revision 19.

In addition, in VCSNS COL FSAR Section 2.5.1, the applicant provided the following information:

AP1000 COL Information Item

- VCS COL 2.5-1

The applicant provided additional information in VCS COL 2.5-1 to address COL Information Item 2.5-1 (COL Action Item 2.5.1-1). VCS COL 2.5-1 addresses regional and site-specific geologic, seismic, and geophysical information, including structural geology; site seismicity; geologic history; evidence of paleoseismicity; site stratigraphy and lithology; engineering significance of geologic features; site groundwater conditions; dynamic behavior during prior earthquakes; zones of alteration, irregular weathering, or structural weakness; unrelieved residual stresses in bedrock; materials that could be unstable because of mineralogy or unstable physical properties; and the effect of human activities in the area.

The applicant developed VCSNS COL FSAR Section 2.5.1 based on information derived from the review of previously prepared reports for VCSNS Unit 1, published geologic literature, interviews with experts in the geology and seismotectonics of the site region, and geologic field work performed specifically for Units 2 and 3, including new boreholes and geologic field reconnaissance. The applicant used recently-published geologic literature, reports, and maps to supplement and update the existing geologic and seismic information.

Based on the results of the geologic and seismic investigations performed for VCSNS Units 2 and 3, the applicant concluded that the Charleston, South Carolina area seismic source zone dominates the ground motion hazard for the VCSNS site and updated the seismic source for the Charleston area based on new information related to recurrence interval and source geometry. The applicant also concluded that no Quaternary age (i.e., 2.6 million years ago, or 2.6 Ma, to present) faults or capable tectonic sources occur in the site vicinity; that no evidence exists for Quaternary (2.6 Ma to present) deformation in the site area; and that the potential for tectonic and nontectonic deformation at the site is negligible. A summary of the geologic and seismic information provided by the applicant in VCSNS COL FSAR Section 2.5.1 is presented below.

2.5.1.2.1 Regional Geology

VCSNS COL FSAR Section 2.5.1.1 discusses the physiography, geomorphology, stratigraphy, geologic history, tectonic setting, and seismicity and paleoseismology of the site region, defined to include the area within a 320-km (200-mi) radius of the VCSNS site. The following sections summarize the information provided by the applicant in VCSNS COL FSAR Section 2.5.1.1.

Regional Physiography, Geomorphology, and Stratigraphy

VCSNS COL FSAR Section 2.5.1.1.1 describes the regional physiography, geomorphology and stratigraphy in relation to the five physiographic provinces which occur in the VCSNS site region. SER Figure 2.5.1-1, reproduced from VCSNS COL FSAR Figure 2.5.1-201, shows the location of the VCSNS site and its spatial relationship to those portions of the Appalachian Plateau, Valley and Ridge, Blue Ridge, Piedmont, and Coastal Plain physiographic provinces within the site region. The VCSNS site is located in the Piedmont physiographic province.

Appalachian Plateau, Valley and Ridge, Blue Ridge, Piedmont, and Coastal Plain Physiographic Provinces

The Appalachian Plateau province extends from New York State to Alabama. It is underlain by unmetamorphosed and slightly deformed sedimentary rocks of Permian (299-251 million years (Ma)) to Cambrian (542-488 Ma) age. The Valley and Ridge province extends from New York through Pennsylvania, Maryland and Virginia and is underlain by folded and faulted sedimentary rocks of Paleozoic (542-251 Ma) age. The Blue Ridge province extends from Pennsylvania into northern Georgia and consists of a strongly-deformed, metamorphosed basement and cover sequence containing igneous intrusive rock bodies. The Coastal Plain province extends southeastward from Massachusetts to south-central Georgia. It exhibits a low, gently rolling surface morphology and is made up of semi-consolidated sedimentary rocks of Cretaceous (145.5-65.5 Ma) age and younger, including Quaternary deposits (2.6 Ma to present).

The Piedmont physiographic province in which the VCSNS site is located comprises variably-deformed, metamorphosed igneous and sedimentary rocks of middle Proterozoic to Permian age (about 1600-251 Ma). The Piedmont province consists of the Western Piedmont to the west and the Carolina Zone to the east. The VCSNS site is situated in the Carolina Zone of the Piedmont province, specifically in the westernmost part of that zone referred to as the Charlotte Terrane. Rock units in the Charlotte Terrane are primarily plutonic igneous rocks greater than 490 Ma in age that intrude a suite of mainly metamorphosed igneous rock bodies, but including younger igneous intrusive rock bodies dated at about 300 Ma (e.g., the Winnsboro plutonic complex, which underlies the site). Carolina Zone rocks are unconformably overlain by sediments of the Coastal Plain physiographic province southeast of the VCSNS site.

Regional Tectonic Setting

VCSNS COL FSAR Section 2.5.1.1.2 describes the regional tectonic setting of the VCSNS site, including regional geologic history, tectonic stress in the midcontinent region, gravity and magnetic data for the site region and site vicinity, and principal regional tectonic structures. The applicant referenced the original 1986 EPRI seismic source models (EPRI, 1986) for the Central and Eastern United States (CEUS) in this FSAR section, and evaluated the site in regard to these source models in subsequent FSAR sections. The 1986 source models were developed for the CEUS using input from six independent earth science teams (ESTs) based on existing geologic, geophysical, and seismic data. Rather than attempting to characterize seismic potential of known faults or other specific tectonic features, the EPRI ESTs used areal source zones that encompassed areas of increased seismicity, microseismicity, and liquefaction, as well as postulated buried causative tectonic features. The applicant also reviewed additional geologic, seismic, and geophysical data acquired since the development of the1986 EPRI seismic source models, and concluded that updates to the previous source models were warranted only for the Charleston, South Carolina area and the New Madrid area seismic zones. The updates for these two seismic zones are briefly discussed below under the section on regional seismicity and paleseismology, with more detailed discussions in SER Section 2.5.2.

The applicant specifically assessed the major Paleozoic (542-251 Ma), Mesozoic (251-65.5 Ma) and Cenozoic (65.5 Ma to present) tectonic structures and concluded that none of these regional features represent capable tectonic structures. The applicant identified 14 potential Quaternary (2.6 Ma to present) tectonic features in the region based on the work of Crone and Wheeler (2000) and Wheeler (2005). Of these 14 features, the applicant concluded that the Pembroke faults may display Quaternary deformation, but only the Charleston, Bluffton and Georgetown liquefaction features unequivocally demonstrate evidence of Quaternary tectonic deformation.

Geologic History and Stress Field

The applicant stated that the VCSNS site is located within the southern part of the Appalachian orogenic belt, which extends from Alabama to New York and formed during the Paleozoic (542-251 Ma) as a result of multiple orogenic events related to the opening and closing of the proto-Atlantic Ocean. Subsequent closing of the proto-Atlantic and continental accretion during the Paleozoic was punctuated by four episodes of compressional deformation and related metamorphism and magmatism. The applicant defined these four compressional episodes sequentially from earliest to latest as the Penobscottian (Late Cambrian to Early Ordovician, > 472 Ma), Taconic (Ordovician, 461-444 Ma), Acadian (Late Devonian, 385-359 Ma), and Alleghanian (Carboniferous to Permian (<359 to 251 Ma) orogenic events.

The applicant stated that, since the earliest Paleozoic compressional deformation event (i.e., the Penobscottian orogeny) occurred mainly in the Northern Appalachians, the Taconic orogeny represents the earliest Paleozoic deformational event affecting the VCSNS site region. The applicant indicated that the most recent event, the Alleghanian orogeny at the end of the Paleozoic, is the most significant compressional deformation event in the Appalachian orogenic belt. This event resulted from closing of the proto-Atlantic Ocean basin, and was responsible for formation of the Valley and Ridge fold and thrust belt. The applicant noted that this compressional event also thrust a portion of the ancestral North American basement eastward to form the western part of the Blue Ridge province and the western Piedmont zone of the Piedmont physiographic province.

The applicant stated that ancestral North American basement rocks underlie the Valley and Ridge, Blue Ridge, and Inner Piedmont provinces at depths less than 10-14 km (6-9 mi) in the VCSNS site region. A basal detachment fault (i.e., a large-displacement, shallow-dipping to subhorizontal, regional shear zone that truncates all rock units above it) developed along the top of the basement and formed the structure from which Paleozoic (> 251 Ma) thrust faults in the Valley and Ridge, Blue Ridge and Inner Piedmont provinces were derived. The applicant stated that potential seismogenic sources may lie in the basement rocks below the detachment surface. Although Wheeler (1995 and 1996) suggested earthquakes that occur in the eastern part of the Piedmont beneath the Coastal Plain physiographic province may be spatially related to buried normal faults associated with Mesozoic (251-65.5 Ma) rifting and extension, the applicant stated that it was not possible to correlate seismicity with any of these faults in the site region.

The applicant stated that the northeast-southwest orientation of maximum horizontal compressive stress in the CEUS is statistically robust, and consistent with compressive forces exerted on the North America plate by seafloor spreading at the mid-Atlantic ridge as proposed by Zoback (1992). The applicant noted that analyses of regional tectonic stress in the CEUS since the original EPRI studies (EPRI, 1986) do not alter the proposed northeast-southwest orientation for maximum horizontal compressive stress in the site region. Therefore, the applicant concluded that no new data exist to significantly alter current interpretations of the potential for tectonic activity in the site region as a result of changes in the regional stress field.

Gravity and Magnetic Data

In VCSNS COL FSAR Section 2.5.1.1.2.3.1, the applicant discussed the regional gravity data for the site region and site vicinity, indicating that some gravity anomalies are directly associated with buried Paleozoic (> 251 Ma) igneous rock bodies. The applicant concluded that long wavelength anomalies at the VCSNS site are typical of parts of the Appalachian orogen, and that the gravity data show no evidence for Cenozoic (65.5 Ma to present) tectonic activity.

VCSNS COL FSAR Section 2.5.1.1.2.3.2 presents the regional magnetic data for the site region and site vicinity. The applicant stated that first-order magnetic anomalies are related primarily to Paleozoic terrains of the Appalachian orogen. The applicant concluded that the magnetic data show no evidence of Cenozoic structures in the site region and are not of a sufficient resolution to identify discrete faults.

Principal Regional Tectonic Structures

In VCSNS COL FSAR Section 2.5.1.1.2.4, the applicant discussed principal regional tectonic structures in the site region, including Paleozoic (> 251 Ma), Mesozoic (251-65.5 Ma), Cenozoic (65.5 Ma to present), and Quaternary (2.6 Ma to present) tectonic structures, as well as regional geophysical anomalies and lineaments. These principal regional tectonic features and geophysical anomalies and lineaments are discussed in the following SER sections.

Regional Paleozoic Tectonic Structures. In VCSNS COL FSAR Section 2.5.1.1.2.4.1, the applicant associated the rocks and structures of the physiographic provinces within the VCSNS site region with thrust sheets that formed during Paleozoic (> 251 Ma) compressional Appalachian orogenic events. The applicant stated that most of the tectonic structures dip eastward and shallow in depth in the subsurface as they approach the basal detachment fault. The applicant referenced previous researchers who established that most of the seismicity in eastern North America occurs below the detachment surface, and concluded that seismicity within the Appalachians is likely unrelated to the shallow thrust sheets mapped at the surface. The applicant did not attribute any seismicity to Paleozoic faults in the site region, and stated that published literature also does not report any evidence for late Cenozoic deformation. The applicant further concluded that none of the Paleozoic structures which occur in the site region are capable tectonic features.

Regional Mesozoic Tectonic Structures. VCSNS COL FSAR Section 2.5.1.1.2.4.2 describes Mesozoic (251-65.5 Ma) tectonic features in the VCSNS site region, including faults and extensional rift basins. The applicant cited previously published literature, which suggests some earthquakes in the eastern part of the Piedmont province and beneath the Coastal Plain province may be spatially related to buried normal faults associated with Mesozoic rifting. However, the applicant indicated that no definitive correlation of seismicity with any Mesozoic normal faults exists.

Regional Cenozoic Tectonic Structures. VCSNS COL FSAR Section 2.5.1.1.2.4.3 describes Cenozoic (65.5 Ma to present) tectonic features within the VCSNS site region. The applicant stated that only a few structures in the site region show evidence of possible Cenozoic activity, namely the Camden fault and the Cape Fear and Yamacraw arches. The Camden fault is located about 64 km (40 mi) east of the site. The Cape Fear arch is located east of the site in North Carolina, near the North Carolina-South Carolina state line. The Yamacraw arch lies south of the site, in South Carolina near the Georgia-South Carolina state line.

The applicant cited Knapp and others (2001), who interpreted the Camden fault to be covered by unfaulted Tertiary (65.5-2.6 Ma) sediments. This field relationship provides an upper age limit on fault movement, indicating that the fault is pre-Quaternary in age (i.e., > 1.8 Ma). Therefore, the applicant concluded that the Camden fault is not a capable tectonic feature.

The applicant indicated that the two arches and adjacent embayments controlled Coastal Plain sedimentation from late Cretaceous through Pleistocene time (i.e., from about 65 Ma to 10,000 years ago), suggesting the possibility of episodic differential tectonic movement. The applicant pointed out that Crone and Wheeler (2000) indicated there is no evidence for Quaternary (2.6 Ma to present) age faulting associated with these features, and concluded that no evidence exists to indicate the Cape Fear and Yamacraw arches are tectonically active at present, and that they are not capable tectonic features.

Regional Quaternary Tectonic Structures. In VCSNS COL FSAR Section 2.5.1.1.2.4.4, based on the catalogue of known or suggested Quaternary (2.6 Ma to present) tectonic structures in the CEUS compiled by Crone and Wheeler (2000) and Wheeler (2005), the applicant described Quaternary faults, liquefaction features, and other possible tectonic features in the site region. Crone and Wheeler (2000) and Wheeler (2005) classified potential tectonic features according to four categories based on strength of the evidence for Quaternary age faulting and related deformation features. The classification scheme of Crone and Wheeler (2000) and Wheeler (2005) is based on an evaluation of information currently available in the published literature, and not on direct examination of the actual geologic features. Their classification categories are as follows:

> Class A – Geologic evidence demonstrates the existence of a Quaternary fault of tectonic origin, whether exposed or inferred from liquefaction or other deformation features.
>
> Class B – Geologic evidence demonstrates the existence of a fault or suggests Quaternary deformation, but the fault may not be a potential source of significant earthquakes or available data are not strong enough to assign the feature to Class A.
>
> Class C – Geologic evidence is insufficient to demonstrate the existence of a tectonic fault or Quaternary deformation associated with the feature.
>
> Class D – Geologic evidence demonstrates that the feature is not a tectonic fault.

The applicant identified 14 potential Quaternary (2.6 Ma to present) tectonic features within the VCSNS site region. These features include the Class A Charleston area, Bluffton, and Georgetown liquefaction features; the Class B Pembroke faults; and the Class C Fall Lines of Weems (Weems, 1998), Belair fault zone, Pen Branch fault, Cooke fault, East Coast fault system (ECFS), Eastern Tennessee Seismic Zone (ETSZ), Cape Fear arch, Helena Banks fault, Hares Crossroads fault, and Stanleytown-Villa Heights faults. SER Figure 2.5.1-2 (reproduced from VCSNS COL FSAR Figure 2.5.1-215) shows the locations of these 14 potential Quaternary features.

The applicant discussed the Charleston area features (i.e., the Cooke fault, ECFS, and Helena Banks fault zone as potential source faults; and the Charleston, Bluffton, and Georgetown liquefaction features as seismically-induced liquefaction features) in VCSNS COL FSAR Section 2.5.1.1.3.2.1 ("Charleston Seismic Zone"); the ETSZ in FSAR Section 2.5.1.1.3.2.2 ("Eastern Tennessee Seismic Zone"); and the Cape Fear arch in FSAR Section 2.5.1.1.2.4.3 ("Regional Cenozoic Tectonic Structures"). The applicant discussed the remaining six potential Quaternary age (2.6 Ma to present) tectonic features (i.e., the Fall Lines of Weems and the Belair, Pen Branch, Hares Crossroads, Stanleytown-Villa Heights, and Pembroke faults) in FSAR Section 2.5.1.1.2.4.4. Information related to these six potential Quaternary faults provided by the applicant is summarized in the paragraphs immediately below.

Fall Lines of Weems

The applicant described the Fall Lines of Weems (Weems, 1998) as alignments of rapids or anomalously steep sections of rivers, which drain the Piedmont and Blue Ridge physiographic provinces of North Carolina and Virginia. The applicant stated that these alignment features are as close as about 80 km (50 mi) to the VCSNS site (SER Figure 2.5.1-2). Based on reviews of published literature, field reconnaissance, and the North Anna Early Site Permit (ESP) evaluation in NUREG-1835, "Safety Evaluation Report for an Early Site Permit (ESP) at the North Anna ESP Site," (USNRC, 2005), the applicant concluded that the Fall Lines of Weems are features which developed due to different resistance to erosion of rock masses involved, and are not tectonic in origin.

Belair Fault Zone

The applicant stated that that there is no reported geomorphic expression and no evidence of recent or historical seismicity associated with the Belair fault zone. This fault zone is located approximately 24 km (15 mi) southwest of the VCSNS site (SER Figure 2.5.1-2), and is at least 24 km (15 mi) in length. Crone and Wheeler (2000) classified the Belair fault as a Class C feature because existing data are insufficient to demonstrate that the most recent faulting is Quaternary (2.6 Ma to present) in age.

Pen Branch Fault

The applicant noted that the Pen Branch fault is more than 32 km (20 mi) in length and located 113 km (70 mi) south-southwest of the VCSNS site (SER Figure 2.5.1-2). The applicant stated that seismic reflection and borehole data collected at the Savannah River Site (Cumbest and others, 2000), as well as investigations performed for the Vogtle Electric Generating Plant (VEGP) ESP application (U.S. NRC, 2009), show no evidence of post-Eocene (i.e., < 33.9 Ma) deformation on the Pen Branch fault. Therefore, the applicant concluded that the Pen Branch fault is older than 33.9 Ma and is not a capable tectonic structure.

Hares Crossroads Fault

The applicant indicated that the Hares Crossroads fault was only recognized in a roadcut exposure approximately 320 km (200 mi) northeast of the VCSNS site (SER Figure 2.5.1-2). The applicant postulated that this feature likely resulted from land sliding, and is nontectonic in origin. Crone and Wheeler (2000) classified the Hares Crossroads fault as a Class C feature based on a lack of evidence for Quaternary (2.6 Ma to present) faulting.

Stanleytown-Villa Heights Faults

The applicant stated that the Stanleytown-Villa Heights faults are approximately 183 m (600 ft) long and comprise a set of features that juxtapose Quaternary (2.6 Ma to present) alluvium against rocks of Cambrian (542-488 Ma) age. These features are located approximately 241 km (150 mi) northeast of the VCSNS site (SER Figure 2.5.1-2). The applicant postulated that these features are likely the result of land sliding and are not of tectonic origin. Crone and Wheeler (2000) classified the Stanleytown-Villa Heights faults as a Class C feature based on a lack of evidence for Quaternary age faulting.

Pembroke Faults

The Pembroke faults occur in Quaternary alluvial deposits approximately 320 km (200 mi) north of the site. The applicant stated that these features exhibit no geomorphic expression, and it is unclear whether they are of tectonic origin or the result of dissolution collapse. Crone and Wheeler (2000) classified the Pembroke faults as a Class B feature based on evidence suggesting possible Quaternary (2.6 Ma to present) age faulting.

Regional Geophysical Anomalies and Lineaments

VCSNS COL FSAR Section 2.5.1.1.2.4.5 describes the geophysical anomalies and lineaments located within the site region. From southeast to northwest, these features are the East Coast Magnetic Anomaly (ECMA); the southeastern boundary of Iapetan (i.e., > 542 Ma) normal faulting; the Clingman, Ocoee and the New York-Alabama lineaments; the Appalachian gravity gradient; the northwest boundary of Iapetan normal faulting; the Appalachian thrust front; and the Grenville Front. The applicant documented an age of > 65.5 Ma for these anomalies and lineaments. The staff notes that these features were fully accounted for in the original EPRI seismic source models (EPRI, 1986).

Regional Seismicity and Paleoseismology

VCSNS COL FSAR Section 2.5.1.1.3 describes the seismicity and paleoseismicity of the VCSNS site region, including seismicity of the CEUS and seismic sources defined by regional seismicity. The applicant emphasized the description of the Charleston Seismic Zone because a currently unknown tectonic source in that zone produced one of the largest historical earthquakes in the CEUS in the Charleston, South Carolina area in August 1886.

Seismic Source Zones and Potential Source Faults

The applicant identified four principal areas of concentrated seismicity within the VCSNS site region, three of which (i.e., the Middleton Place-Summerville, Bowman, and Adams Run Seismic Zones) are located in the Charleston area as shown in SER Figure 2.5.1-3 (reproduced from VCSNS COL FSAR Figure 2.5.1-218) and bear a relationship to potential buried tectonic structures in the Charleston area, some of which have been postulated as the causative fault source for the 1886 Charleston earthquake. SER Figure 2.5.1-4 (reproduced from VCSNS COL FSAR Figure 2.5.1-216) shows the location of the fourth area of concentrated seismicity within the site region, the ETSZ. Figure 2.5.1-4 also locates three areas of concentrated seismicity (i.e., the New Madrid, Central Virginia, and Giles County Seismic Zones) which represent seismogenic and capable tectonic sources outside the site region.

Charleston Seismic Zone. VCSNS COL FSAR Section 2.5.1.1.3.2.1 discusses the 11 buried potential causative source faults and fault zones for the 1886 Charleston earthquake, which have been postulated to occur in the Charleston area; the three seismic source zones defined for the Charleston area (i.e., the Middleton Place-Summerville, Bowman, and Adams Run zones); and the seismically-induced liquefaction features found in the Charleston area. Locations of the seismic source zones and the potential causative source faults and fault zones are shown in SER Figure 2.5.1-3.

The applicant stated that the 1886 Charleston earthquake generated a Modified Mercalli Intensity (MMI) X shaking in the epicentral area, an intensity level resulting in the destruction of some well-built wooden structures, destruction of masonry and frame structures, and bent railroad rails. Liquefaction features related to the 1886 earthquake were also observed, and similar features found in and around the Charleston area suggest repeated earthquake activity in that area prior to the 1886 event as well. The applicant indicated that the most recent magnitude (**M**) estimates for this earthquake (i.e., **M** 7.3 by Johnston, 1996; **M** 6.9 with a 95 percent confidence level corresponding to a range of **M** 6.4-7.1 by Bakun and Hopper, 2004) are similar to the upper-bound Mmax values used in the original EPRI studies (1986 and 1989). The applicant incorporated significant new information on source geometry and earthquake recurrence interval for the Charleston earthquake into an updated Charleston seismic source (UCSS) model in VCSNS COL FSAR Section 2.5.2. The applicant stated that this updated model is the same as that used for the VEGP ESP site, and it has been reviewed and approved by the staff (U.S. NRC, 2009).

The 11 buried potential causative faults and fault zones include the southern segment of the ECFS; the Adams Run, Ashley River, Charleston, Cooke, Drayton, Gants, Sawmill Branch, Summerville, and Woodstock faults; and the Helena Banks fault zone. The applicant stated that, despite numerous investigations by multiple researchers, a specific tectonic source for the 1886 Charleston earthquake has not yet been directly related to any of these 11 buried postulated causative structures.

The applicant described the Middleton Place-Summerville Seismic Zone as an area of high microseismic activity located about 19 km (12 mi) northwest of Charleston, South Carolina (SER Figure 2.5.1-3). The Bowman Seismic Zone is located approximately 80 km (50 mi) northwest of Charleston and lies outside the meizoseismal area defined for the 1886 Charleston earthquake (SER Figure 2.5.1-3). The applicant identified the Adams Run Seismic zone, located in the meizoseismal area of the 1886 Charleston earthquake about 185 km (115 mi) from the VCSNS site, on the basis of four **M**<2.5 earthquakes reported by Tarr and Rhea (1983) which occurred in that zone in a 2-day period during December 1977.

Charleston Area Seismically-Induced Liquefaction Features. The applicant discussed liquefaction features found in the Charleston area related to the 1886 Charleston earthquake, as well as those which occur in coastal South Carolina and are interpreted to be related to moderate to large earthquakes that pre-date the 1886 Charleston event. No specific tectonic structure has been identified to which the development of any of these liquefaction features can be related.

1886 Charleston Earthquake Liquefaction Features

The applicant stated that the liquefaction features produced by the 1886 Charleston earthquake are most heavily concentrated in the meizoseismal area defined for this event. The applicant also indicated that some liquefaction features associated with the 1886 earthquake are reported as far away as Georgetown, South Carolina (Seeber and Armbruster, 1988) and Blufftown, South Carolina (Talwani and Schaeffer, 2001) northeast and southwest of the meizoseismal area, respectively.

Paleoliquefaction Features in Coastal South Carolina

The applicant reported that researchers analyzed seismically-induced liquefaction features found in the coastal region of South Carolina to constrain possible locations and recurrence rates for large earthquakes related to a Charleston area tectonic source, leading to the recognition that moderate to large earthquakes predating the 1886 Charleston event occurred in the Charleston area. New information related to distribution of observed liquefaction features and age dates constraining the timing of development of these features enabled a refined definition of source area geometries and estimated recurrence intervals of about 550 years and approximately 900-1000 years from two scenarios proposed by Talwani and Schaeffer (2001). Talwani and Schaeffer (2001) suggested a magnitude for the events located near Charleston of approximately **M** 7+. The 550-year recurrence interval is an order of magnitude less than that used in the original EPRI analyses (EPRI, 1986), and the applicant incorporated this recurrence interval into the UCSS for the VCSNS site as presented in detail in VCSNS COL FSAR Section 2.5.2.

<u>Eastern Tennessee Seismic Zone</u>. In VCSNS COL FSAR Section 2.5.1.1.3.2.2, the applicant described the ETSZ as one of the most active seismic zones in Eastern North America. The ETSZ is located approximately 282 km (175 mi) northwest of the VCSNS site (SER Figure 2.5.1-4). The applicant noted that Chapman and others (2002) reported a magnitude of 4.6, with the magnitude scale not specified, for the largest known earthquake associated with the zone. The applicant also indicated that earthquakes in this seismic zone occur at a mean focal depth of about 15 km (9 mi) and, therefore, are well below the regional basal detachment surface separating basement rocks from overlying Appalachian thrust sheets. The detachment surface occurs at a maximum depth of about 5 km (3 mi) based on Prowell and others (1994). The applicant indicated that structures responsible for seismicity in the ETSZ are likely deep-seated Cambrian (542-488 Ma) or Precambrian (> 542 Ma) normal faults reactivated in the present-day regional stress field.

<u>Seismogenic and Capable Tectonic Sources Beyond the Site Region</u>. The applicant discussed three seismogenic and capable tectonic sources which lie outside the site region, namely the New Madrid, Central Virginia, and Giles County Seismic Zones (SER Figure 2.5.1-4).

The New Madrid Seismic Zone (NMSZ) is located more than 724 km (450 mi) west of the VCSNS site. This zone is defined by post-Eocene (< 33.9 Ma) to Quaternary (2.6 Ma to present) faulting, including historical seismicity related to large magnitude earthquakes which occurred between December 1811 and February 1812. The Central Virginia Seismic Zone, located more than 402 km (250 mi) northeast of the VCSNS site, is characterized by persistent, low-level historical seismicity. The largest historical earthquake in this zone occurred on December 23, 1875, with a body-wave magnitude (m_b) of 5.0 (Bollinger and Sibol, 1985). The Giles County Seismic Zone is located about 322 km (200 mi) north-northeast of the VCSNS site in southwestern Virginia. The applicant reported that the second largest earthquake in the southeastern United States, an **M** 5.9 based on Johnston and others (1994), occurred in this zone in 1897.

2.5.1.2.2 Site Area Geologic Description

VCSNS COL FSAR Sections 2.5.1.2.1 through 2.5.1.2.7 describe the physiography, geomorphology, geologic setting and history, stratigraphy, structural geology, engineering geology, seismicity and paleoseismology, and groundwater conditions within an 8-km (5-mi) radius and, in some cases, a 40-km (25-mi) radius of the site (i.e., the site area and site vicinity, respectively). The following sections provide a summary of the information on these topics as presented in the FSAR.

Site Area Physiography and Geomorphology

The applicant stated that the VCSNS site lies in the Piedmont physiographic province of central South Carolina, wherein the topography is characterized by gently to moderately rolling hills and well-drained valleys with elevations ranging from about 67-158 m (220-520 ft) above mean sea level (amsl). The applicant noted the presence of local stream tributaries draining into the Broad River about 1.6 km (1 mi) east of the site, and stated that local drainage patterns are likely controlled by regional bedrock structures and joint systems.

The applicant reported that most of the site area is covered by residual soils and saprolite (soft, typically clay-rich, decomposed rock formed in place by chemical weathering and characterized by preservation of structures that existed in the unweathered rock), such that few natural bedrock outcrops exist. The applicant concluded that the saprolite indicates a long and stable weathering history for the Piedmont physiographic province and the site area.

Site Area Geologic Setting and Geologic History

The applicant stated that the site is located in the Charlotte Terrane, the westernmost subdivision of the Carolina Zone, and consists of Neoproterozoic to Early Paleozoic (900 to 543 Ma) plutonic rocks, which intrude a suite of predominantly metamorphosed igneous rocks. The applicant noted that younger plutonic intrusive rocks also occur in the site area. Based on radiometric dates, the applicant concluded that the Winnsboro plutonic complex, one of the younger plutonic intrusive rock bodies in the VCSNS site area, formed about 300 Ma. The applicant stated that igneous dikes intruded the Winnsboro complex around 227 Ma, and shearing along joint systems occurred later. Based on radiometric age dates, the applicant also concluded that the youngest shearing event observed in the site area, which is reflected as minor shear zones in the Unit 1 excavation, is not younger than 45 Ma.

Site Area Stratigraphy

The applicant indicated that the Winnsboro plutonic complex underlies the VCSNS site and consists primarily of granodiorite and quartz diorite intrusive igneous rock bodies. The Winnsboro complex intruded the metamorphic country rock units of the Charlotte Terrane, which are made up of complexly folded, metamorphosed igneous and sedimentary rocks. The applicant indicated that the Winnsboro complex is Carboniferous (359-299 Ma) in age, and the metamorphic country rock of the Carolina Zone is likely Cambrian (542-488 Ma) in age. The applicant reported that the youngest rocks in the site area are diabase dikes emplaced during Mesozoic (251-65.5 Ma) time and associated with opening of the present-day Atlantic Ocean basin.

Site Area Structural Geology

Shear Zones in the Unit 1 Excavation

The applicant summarized the detailed geologic mapping and age dating of three northeast-striking, oblique-slip shear zones exposed in bedrock in the Unit 1 foundation after removal of approximately 30 m (100 ft) of residual overburden. The applicant defined these shear zones as minor faults because they died out in the excavation, did not penetrate the overlying soil profile, and exhibited a maximum displacement along one of the three zones of about 2 m (7 ft). Based on radiometric dating of undeformed zeolite minerals collected from the shear zones, the applicant concluded that these structures are not younger than 45 Ma. Consequently, the applicant stated that these faults are not capable structures as defined in RG 1.208. The applicant also stated that such features are common throughout the Piedmont physiographic province and, consequently, may be found in excavations for Units 2 and 3. In addition, based on results of investigations performed for Unit 1 (Dames and Moore, 1974) and the seismic design bases presented by USAEC staff in the Safety Evaluation Report for Unit 1 (USAEC,1974), the applicant concluded that impoundment of the Monticello Reservoir will not adversely affect these bedrock shear zones if they do occur in Units 2 and 3.

Faults and Shear Zones in the Site Area

The applicant discussed three faults and one shear zone mapped within the site area: the Wateree Creek and the Summers Branch faults (Secor et al., 1982), the Chappells Shear Zone (Halpin et al., 2003; Halpin and Barker, 2004), and the unnamed postulated fault near Parr, South Carolina (Dames and Moore, 1972). The following paragraphs summarize these structures.

The applicant reported that, at their nearest points, the Wateree Creek fault is located about 3.2 km (2 mi) south of the VCSNS site, and the Summers Branch fault about 8 km (5 mi) southwest of the VCSNS site. Based on information from Secor et al. (1982), the applicant interpreted the Wateree Creek and Summers Branch faults to be at least Triassic (251-201.6 Ma) in age. The applicant indicated that the Chappells Shear Zone, located about 3.2 km (2 mi) south of the VCSNS site, is a Paleozoic (>251 Ma) structure based on the fact that it does not crosscut the 300 Ma unmetamorphosed Winnsboro plutonic complex. The applicant reported that no field evidence exists to suggest post-Paleozoic displacement along the Chappells Shear Zone. The applicant stated that the unnamed fault near Parr 4.8 km (3 mi) south-southwest of the VCSNS site, as postulated by Dames and Moore (1972) is a Paleozoic structure if it exists. The applicant indicated that more recent reconnaissance reported by Gore (1986) did not recognize any evidence of this unnamed fault.

In summary, the applicant concluded that the shear zones mapped in the Unit 1 excavation are no younger than 45 Ma; that the Wateree Creek and Summers Branch faults have a minimum age of Triassic (251-201.6 Ma); and that the Chappells Shear Zone and the postulated unnamed fault near Parr, if it exists, are Paleozoic (> 541 Ma) in age. The applicant further concluded that site area investigations showed no evidence for landslides, subsidence, uplift, collapse related to slope failures, tectonic activity, or dissolution related to karst. The applicant also concluded that a review of site physiography revealed no features which indicated any potential for such events in the future.

Site Area Engineering Geology

The applicant indicated that sound rock beneath the site is made up of hard, crystalline rock of the Winnsboro plutonic complex, and the site is classified as a hard-rock site because the shear wave velocities measured for the sound rock exceed the 2,440 m/s (8,000 feet per second (fps)) velocity required by the AP1000 DCD for that type of site. The applicant acknowledged that a relatively thick weathering profile also exists above bedrock in the site area. The applicant indicated that no mining operations or excessive extraction or injection of groundwater occur or have occurred within the site area that could detrimentally affect geologic conditions at the site, and that no petroleum or coal resources occur in the site area. The applicant also indicated that the Winnsboro plutonic complex is not susceptible to subsidence due to withdrawal of groundwater because it is crystalline igneous rock. Finally, although joints, fractures, and minor shear zones of the type mapped in the Unit 1 foundation excavation may be encountered within excavations for Units 2 and 3, the applicant concluded that these are not capable tectonic sources and do not represent either a ground motion or surface rupture hazard at the VCSNS site.

Site Area Seismicity and Paleoseismology

In regard to historical and instrumented seismicity, the applicant stated that only three earthquakes of $m_b \geq 3.0$ have occurred within a 40 km (25 mi) radius of the site, the largest of which was m_b 4.3. The applicant indicated that impoundment of water in the Monticello Reservoir resulted in minor seismicity. This reservoir-induced seismicity is discussed in detail in VCSNS COL FSAR Section 2.5.2, but the applicant noted that this type of seismicity was limited to the reservoir area and occurred at depths less than about 2 km (1.5 mi). The applicant further stated that these shallow earthquakes occurred in 1977 and 1978, that the largest recorded event was m_b 2.8, and that these earthquakes began to decrease after 1978.

The applicant indicated that the highest shaking intensities recorded for the VCSNS site occurred due to earthquakes located outside the site area, specifically the 1886 Charleston earthquake and the 1913 m_b 4.8 Union County, South Carolina earthquake. The applicant stated that the 1886 Charleston earthquake produced an estimated maximum MMI of VII to VIII shaking at the site, and the 1913 Union County earthquake produced a MMI of IV. The Union County earthquake epicenter was most likely located about 48-80 km (30-50 mi) from the VCSNS site. The applicant stated that no published reports suggest the presence of paleoseismology indicators in the site area by way of liquefaction features. Based on extensive outcrop studies, the applicant concluded that there is no evidence to indicate post-Miocene (i.e., < 5.3 Ma) earthquake activity within the site area.

Site Groundwater Conditions

VCSNS COL FSAR Section 2.5.1.2.7 references FSAR Section 2.4.12 for the detailed discussion of groundwater conditions at the VCSNS site.

2.5.1.3 *Regulatory Basis*

The regulatory basis of the information incorporated by reference is addressed in NUREG-1793 and its supplements.

In addition, the acceptance criteria associated with the relevant requirements of the Commission regulations for basic geologic and seismic information are given in Section 2.5.1 of NUREG-0800.

The applicable regulatory requirements for reviewing geologic and seismic information are:

- 10 CFR 52.79(a)(1)(iii), as it 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, "Geologic and Seismic Siting Criteria," for evaluating suitability of a proposed site based on consideration of geologic, geotechnical, geophysical, and seismic characteristics of the proposed site. Geologic and seismic siting factors must include the safe shutdown earthquake (SSE) for the site; and the potential for surface tectonic and non-tectonic deformation. The site-specific GMRS satisfies requirements of 10 CFR 100.23 with respect to development of the SSE.

The related acceptance criteria from Section 2.5.1 of NUREG-0800 are as follows:

- Regional Geology: In meeting the requirements of 10 CFR 100.23, VCSNS COL FSAR Section 2.5.1.1 will be considered acceptable if a complete and documented discussion is presented for all geologic (including tectonic and nontectonic), geotechnical, seismic, and geophysical characteristics, as well as conditions caused by human activities, deemed important for safe siting and design of the plant within the site region, defined as that area within a circle drawn around the site using a radius of 320 km (200 mi).

- Site Geology: In meeting the requirements of 10 CFR 100.23, and regulatory positions presented in RG 1.132, "Site Investigations for Foundations of Nuclear Power Plants," Revision 2; RG 1.138, "Laboratory Investigations of Soils and Rocks for Engineering Analysis and Design of Nuclear Power Plants," Revision 2; RG 1.198, "Procedures and Criteria for Assessing Seismic Soil Liquefaction at Nuclear Power Plant Sites"; RG 1.208, and RG 4.7, Revision 2, VCSNS COL FSAR Section 2.5.1.2 will be considered acceptable if it contains a description and evaluation of geologic (including tectonic and nontectonic) 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.

For evaluating completeness and acceptability of the application, the reviewer should use published and unpublished scientific information derived from various sources that present geologic, geotechnical, seismic, geophysical, and related data for the region in which the site is located. These sources include the United States Geological Survey (USGS); other Federal and State agencies; and academia, industry, and other nongovernmental and professional organizations.

In addition, the geologic characteristics should be consistent with appropriate sections from RG 1.132, Revision 2; RG 1.138, Revision 2; RG 1.198; RG 1.206; RG 1.208; and RG 4.7, Revision 2.

2.5.1.4 *Technical Evaluation*

The NRC staff reviewed Section 2.5.1 of the VCSNS COL FSAR and checked the referenced DCD to ensure that the combination of the DCD and the COL application represents the complete scope of information relating to this review topic.[1] The NRC staff's review confirmed that information in the application and incorporated by reference addresses the required information relating to basic geologic and seismic data. The results of the NRC staff's evaluation of the information incorporated by reference in the VCSNS COL application are documented in NUREG-1793 and its supplements.

The staff reviewed the following information in the VCSNS COL FSAR:

AP1000 COL Information Item

- VCS COL 2.5-1

The NRC staff reviewed VCS COL 2.5-1 in regard to evaluation of the geologic, seismic, and geophysical information included in Section 2.5.1 of the VCSNS COL FSAR. The COL information item in Section 2.5.1 of the AP1000 DCD states:

> Combined License applicants referencing the AP1000 certified design will address the following regional and site-specific geological, seismological, and geophysical information as well as conditions caused by human activities: (1) structural geology of the site, (2) seismicity of the site, (3) geological history, (4) evidence of paleoseismicity, (5) site stratigraphy and lithology, (6) engineering significance of geological features, (7) site groundwater conditions, (8) dynamic behavior during prior earthquakes, (9) zones of alteration, irregular weathering, or structural weakness, (10) unrelieved residual stresses in bedrock, (11) materials that could be unstable because of mineralogy or physical properties, and (12) effect of human activities in the area.

The technical information presented in VCSNS COL FSAR Section 2.5.1 resulted from the applicant's review of previous reports prepared for Unit 1; review of published geologic literature; interviews with experts in geology and seismology of the site region; and geologic field work performed specifically for Units 2 and 3, including new boreholes and geologic field reconnaissance. Through the review of VCSNS COL FSAR Section 2.5.1, the staff determined whether the applicant had complied with all applicable NRC regulations and conducted all investigations at the appropriate levels of detail within the four circumscribed areas designated in RG 1.208. These areas are defined by circles drawn around the site using radii of 320 km (200 mi), 40 km (25 mi), 8 km (5 mi) and 1 km (0.6 mi) to encompass the site region, site vicinity, site area, and site location, respectively.

VCSNS COL FSAR Section 2.5.1 describes geologic and seismic information collected by the applicant to support the vibratory ground motion analysis and site-specific GMRS discussed in VCSNS COL FSAR Section 2.5.2, which is evaluated in Section 2.5.2 of this SER. RG 1.208 recommends that applicants update the geologic, seismic, and geophysical database and evaluate new data to determine whether any revisions to the existing seismic source models are necessary. Consequently, the staff focused on review of geologic and seismic data published since the mid to late 1980s to assess whether these data indicated a need to update the existing seismic source models.

During the early site investigation stage in June 2006, the staff visited the site and interacted with the applicant and its consultants in regard to the geologic, seismic, and geophysical investigations being performed for the VCSNS COL application. On a second site visit in March 2009, the staff obtained assistance from experts at the USGS to enable a thorough evaluation of the geologic, seismic, and geophysical information presented by the applicant for confirming the interpretations, assumptions, and conclusions made about potential geologic and seismic hazards. The staff's evaluation of the information presented by the applicant in VCSNS COL FSAR Section 2.5.1 and in responses to RAIs on that FSAR section is presented below.

The NRC staff reviewed VCS COL 2.5-1, which addresses the provision of regional and site-specific geologic, seismic, and geophysical information, as well as information related to conditions caused by human activities (e.g., mining operations, excessive extraction or injection of groundwater, and oil and gas extraction) included under Section 2.5.1 of the VCSNS COL FSAR. Other important facets of VCS COL 2.5-1 related to seismology and geotechnical engineering are addressed in Sections 2.5.2 and 2.5.4 of this SER, respectively. Based on the regional and site-specific geologic descriptions provided by the applicant in VCSNS COL FSAR Section 2.5.1, the staff concludes that the applicant supplied the information required to satisfy VCS COL 2.5-1.

In addition to the RAIs addressing specific technical issues for regional and site geology of the VCSNS site, the applicant's responses to which are discussed in detail below under SER Sections 2.5.1.4.1 and 2.5.1.4.2, the staff also prepared several editorial RAIs to further clarify certain descriptive statements made by the applicant in the FSAR and to qualify geologic features illustrated in FSAR figures. These editorial RAIs are not discussed in this detailed technical evaluation because they are not important to the staff's safety determination. Also, RAIs related to geologic issues resolved in FSARs previously prepared for other sites in the CEUS are not discussed in detail in this technical evaluation for the VCSNS site, but rather addressed by a cross-reference to and a summary of the pertinent information used to satisfactorily resolve the issues as presented in those FSARs.

2.5.1.4.1 Regional Geology

The NRC staff focused the review of VCSNS COL FSAR Section 2.5.1.1, "Regional Geology," on the descriptions provided by the applicant for physiography, geomorphology, stratigraphy, geologic history, tectonic setting, seismicity, and paleoseismology of the site region, defined to include the area within a 320-km (200-mi) radius of the VCSNS site.

Regional Physiography, Geomorphology, and Stratigraphy

In VCSNS COL FSAR Section 2.5.1.1.1, the applicant described regional physiography, geomorphology, and stratigraphy in relation to the five physiographic provinces which occur in the site region (SER Figure 2.5.1-1, reproduced from FSAR Figure 2.5.1-201). The applicant stated that the VCSNS site is located in the Piedmont physiographic province approximately 32 km (20 mi) northwest of its boundary with the Coastal Plain province (SER Figure 2.5.1-1), lying specifically in the Charlotte lithotectonic terrain of the Carolina Zone of the Piedmont province.

The NRC staff focused the review of VCSNS COL FSAR Section 2.5.1.1.1 on the applicant's discussion of the relationships between lithotectonic terrains in the site region, the regional faults separating them, and the Carolina Zone in which the site lies. In RAI 2.5.1-3, the staff asked the applicant to incorporate information from more recently-published references into the description of the lithologic, stratigraphic, and structural characteristics of the Carolina Zone.

In the response to RAI 2.5.1-3, the applicant proposed revisions to VCSNS COL FSAR Section 2.5.1.1.1, which incorporated information from more recently published references, namely Hatcher and others (2007) and Hibbard and others (2007), into the description of the lithologic, stratigraphic, and structural characteristics of the Carolina Zone. The applicant also modified FSAR Figure 2.5.1-202 to include lithotectonic units defined by Hatcher and others (2007) and Hibbard and others (2007), and added FSAR Figure 2.5.1-232 to better illustrate the relationships between physiographic subdivisions, regional fault zones, and lithotectonic terrains.

Based on review of the response to RAI 2.5.1-3 and changes provided by the applicant in Revision 2 of VCSNS COL FSAR Section 2.5.1.1.1, including modified FSAR Figure 2.5.1-202 and new FSAR Figure 2.5.1-232, the staff concludes that the applicant properly clarified the relationships between physiographic subdivisions, regional fault zones, and lithotectonic terrains in the site region by incorporating pertinent descriptive information derived from more recently-published references. The staff makes this conclusion because the revisions to VCSNS COL FSAR Section 2.5.1.1.1, which incorporate this information and the two figures, fully clarify the relationships between physiographic subdivisions, regional fault zones, and lithotectonic terrains, including those terrains comprising the Carolina Zone in which the site lies. Consequently, the staff considers RAI 2.5.1-3 to be resolved.

Based on review of VCSNS COL FSAR Section 2.5.1.1.1 and the applicant's response to RAI 2.5.1-3, the staff concludes that the applicant provided a thorough and accurate description of regional physiography, geomorphology, and stratigraphy in support of the VCSNS COL application.

Regional Tectonic Setting

In VCSNS COL FSAR Section 2.5.1.1.2, the applicant discussed the regional tectonic setting of VCSNS site, including regional geologic history (Section 2.5.1.1.2.1), tectonic stress in the midcontinent region (Section 2.5.1.1.2.2), gravity and magnetic data of the site region and site vicinity (Section 2.5.1.1.2.3), and principal regional tectonic structures (Section 2.5.1.1.2.4). The staff's evaluation of VCSNS COL FSAR Section 2.5.1.1.2, including Sections 2.5.1.1.2.1 through 2.5.1.1.2.4, is presented below. The staff performed the most detailed evaluation on the 14 Quaternary (2.6 Ma to present) structures identified in the site region because these structures represent potentially capable tectonic features.

<u>Regional Geologic History</u>

In VCSNS COL FSAR Section 2.5.1.1.2.1, the applicant summarized the geologic history of the VCSNS site region. The applicant addressed both Paleozoic (> 251 Ma) evolution of the Appalachian orogenic belt and post-Paleozoic (i.e., Mesozoic, 251-65.5 Ma) extension of the eastern continental margin.

The NRC staff focused the review of VCSNS COL FSAR Section 2.5.1.1.2.1 on the applicant's discussion of Mesozoic age rift basins and their associated boundary faults. This focus was necessary because the applicant indicated that researchers (e.g., Wheeler, 1995) have suggested earthquakes in the eastern Piedmont and beneath the Coastal Plain may be spatially associated with buried normal faults related to Mesozoic extension of the eastern continental margin. Furthermore, FSAR Section 2.5.1.1.2.4.2 also states that Mesozoic basins have long been considered potential sources of earthquakes along the eastern seaboard, and so were included by most EPRI science teams in the definition of potential seismic sources (EPRI, 1986 and 1989). In RAI 2.5.1-4, the staff asked the applicant to summarize any published information which provides evidence to support the inference that the basin-bounding faults are either steeply-dipping and cut deeply into the crust, or listric and do not extend deeply into the crust. The requested information is important because, if the basin-bounding faults are high-angle structures that penetrate deeply into the crust, then these structures may have an increased potential for future seismicity.

In the response to RAI 2.5.1-4, the applicant cited multiple references to document that data constraining the down-dip geometry of Mesozoic-age basin-bounding faults are equivocal. The applicant also indicated that quantifying the large uncertainties in subsurface fault geometry is avoided in the EPRI seismic source models (EPRI, 1986) by defining areal seismic source zones for seismically active areas, rather than by characterizing individual fault sources within those zones.

Based on review of the applicant’s response to RAI 2.5.1-4, the staff concurs with the approach of modeling areal seismic source zones, rather than individual faults, for seismically active areas of the CEUS. The staff concurs because this approach avoids the need to quantify the large uncertainties related to subsurface fault geometry and fault location for seismically active areas of the CEUS where surface expression of tectonic features is rare. RG 1.208 recommends using areal source zones in seismically active areas of the CEUS, rather than attempting to characterize the highly uncertain subsurface geometry of individual faults which have no surface expression. Consequently, the staff considers RAI 2.5.1-4 to be resolved.

Based on the review of VCSNS COL FSAR Section 2.5.1.1.2.1 and the applicant’s response to RAI 2.5.1-4, the staff concludes that the applicant provided a thorough and accurate description of the regional geologic setting, including Paleozoic evolution of the Appalachian orogenic belt and post-Paleozoic extension of the eastern continental margin, in support of the VCSNS COL application.

Tectonic Stress in the Midcontinent Region

In VCSNS COL FSAR Section 2.5.1.1.2.2, the applicant discussed information related to tectonic stress in the midcontinent region. The applicant presented information that documented a northeast-southwest direction for maximum horizontal compressive stress, and stated that there is no significant change in the understanding of the regional stress field in the CEUS since publication of the original EPRI seismic source models (EPRI, 1986 and 1989). The applicant concluded that no significant new implications existed in regard to the regional stress field for potential activity of tectonic structures in the site region.

The NRC staff focused the review of VCSNS COL FSAR Section 2.5.1.1.2.2 on the data used by the applicant to support the conclusion that no new concerns exist regarding potential activity of tectonic structures in the site region due to changes in the regional tectonic stress field. Based on the review of VCSNS COL FSAR Section 2.5.1.1.2.2 and an independent assessment of the current references cited by the applicant, the staff concludes that the data presented by the applicant demonstrate that maximum horizontal compressive stress continues to be oriented northeast-southwest in the site region, and there are no implications for potential activity along any tectonic features due to changes in the regional stress field.

Based on the review of VCSNS COL FSAR Section 2.5.1.1.2.2, the staff concludes that the applicant provided a thorough and accurate description of tectonic stress in the midcontinent region in support of the VCSNS COL application.

Gravity and Magnetic Data

In VCSNS COL FSAR Section 2.5.1.1.2.3, the applicant discussed gravity and magnetic data for the site region and site vicinity. The applicant concluded that no gravity or magnetic data indicated any Cenozoic (65.5 Ma to present) tectonic activity or tectonic structures in the site region or site vicinity.

The NRC staff focused the review of VCSNS COL FSAR Section 2.5.1.1.2.3 on adequacy of the geologic interpretations provided in the FSAR based on site vicinity gravity and magnetic data. In RAI 2.5.1-6, the staff asked the applicant to discuss the criteria applied for determining that regional gravity and magnetic data show no evidence for Cenozoic tectonic structures in the site region.

In the response to RAI 2.5.1-6, the applicant stated that discussions in VCSNS COL FSAR Sections 2.5.1.1.2.3.1 and 2.5.1.1.2.3.2 were not intended to suggest that geologic structures could be dated using only regional gravity or magnetic data, and indicated that potentially misleading text in these FSAR sections would be deleted.

Based on review of the applicant's response to RAI 2.5.1-6 and changes provided by the applicant in Revision 2 of VCSNS COL FSAR Sections 2.5.1.1.2.3.1 and 2.5.1.1.2.3.2, the staff concludes that the applicant corrected the misconception that regional gravity and magnetic data were used to determine that no geologic features of Cenozoic age occur in the site region or site vicinity. Consequently, the staff considers RAI 2.5.1-6 to be resolved.

In RAI 2.5.1-10, the staff asked the applicant to discuss prominent regional aeromagnetic lows within the VCSNS site vicinity, shown in VCSNS COL FSAR Figures 2.5.1-206, 2.5.1-207, and 2.5.1-209 but not explained in FSAR Section 2.5.1.1.2.3.2, in regard to how they relate to geologic structure or lithologies in the site vicinity.

In the response to RAI 2.5.1-10, the applicant stated that, while magnetic lows which occur in the site region can be partly explained by geologic structure and rock type, regional magnetic data alone provide limited information on region-specific geology and should only be used to interpret geologic structures and rock types in combination with other geophysical and geologic data. The applicant proposed revisions to VCSNS COL FSAR Sections 2.5.1.1.2.3.1 and 2.5.1.1.2.3.2 to clarify the discussion of regional gravity and magnetic data, respectively.

Based on review of the applicant's response to RAI 2.5.1-10 and changes provided by the applicant in Revision 2 of VCSNS COL FSAR Sections 2.5.1.1.2.3.1 and 2.5.1.1.2.3.2, the staff agrees that regional magnetic data should be used to interpret geologic structures and rock types in the site vicinity in combination with other geophysical and geologic data. The staff draws this conclusion because regional magnetic data generally need to be supplemented by site-specific information to enable any definitive correlation between geologic structures and rock types. Consequently, the staff considers RAI 2.5.1-10 to be resolved.

In RAIs 2.5.1-11 and 2.5.1-51, the staff asked the applicant to clarify whether Mesozoic (251-66.5 Ma) structures can be identified using geophysical data, including regional magnetic data, since the VCSNS COL FSAR includes seemingly contradictory statements. FSAR Section 2.5.1.1.2.3.2 indicates that regional magnetic data do not have sufficient resolution to identify border faults along Triassic basins, while Section 2.5.1.1.2.4 states that most Mesozoic structures are recognizable using both geophysical and geologic data.

In the responses to RAIs 2.5.1-11 and 2.5.1-51, the applicant discussed how Mesozoic structures can be identified using geophysical data, including use of regional magnetic information. The applicant stated that the usefulness of magnetic data for identifying faults and other geologic structures is scale-dependent, but that both regional and more-detailed local magnetic surveys can locate features if the contrast in magnetic susceptibility is high enough. The applicant explained that, although regional magnetic data are not of sufficient resolution to identify border faults along Mesozoic rift basins, the rift basins can generally be identified by the presence of low magnetic susceptibility centered over the basin due to magnetic character of the basin-fill sediments. The applicant indicated that other geologic and geophysical data (e.g., borings and seismic data) have been used to identify border faults, however. The applicant also proposed changes to VCSNS COL FSAR Sections 2.5.1.1.2.3.2 and 2.5.1.1.2.4 to clarify how Mesozoic structures can be identified using geologic and geophysical data.

Based on review of the applicant's responses to RAIs 2.5.1-11 and 2.5.1-51 and changes provided by the applicant in Revision 2 of VCSNS COL FSAR Sections 2.5.1.1.2.3.2 and 2.5.1.1.2.4, the staff agrees that regional magnetic data are generally best used in combination with other geologic and geophysical techniques for defining specific faults, such as those which bound Mesozoic basins in the site region. The staff makes this conclusion because the approach described by the applicant, involving a combination of geologic and geophysical data and including magnetic data when the contrast in magnetic susceptibility is high enough, is a standard one for investigating geologic structures. Consequently, the staff considers RAIs 2.5.1-11 and 2.5.1-51 to be resolved.

Based on review of VCSNS COL FSAR Section 2.5.1.1.2.3 and the applicant's responses to RAIs 2.5.1-6, 2.5.1-10, 2.5.1-11, and 2.5.1-51, including revisions to FSAR Sections 2.5.1.1.2.3.1, 2.5.1.1.2.3.2, and 2.5.1.1.2.4, the staff concludes that the applicant provided a thorough and accurate description of gravity and magnetic data of the site region and site vicinity in support of the VCSNS COL application.

<u>Principal Regional Tectonic Structures</u>

In VCSNS COL FSAR Section 2.5.1.1.2.4, the applicant discussed principal regional tectonic structures located within a 320-km (200-mi) radius of the VCSNS site, including structures of Paleozoic (> 251 Ma), Mesozoic (251-65.5 Ma), and Cenozoic (65.5 Ma to present) age with a focus on potential Quaternary (i.e., Late Cenozoic, 2.6 Ma to present) features. The applicant also discussed regional geophysical anomalies and lineaments and their possible association with geologic structures and features.

The NRC staff focused the review of VCSNS COL FSAR Section 2.5.1.1.2.4 primarily on potential Quaternary (2.6 Ma to present) features in the site region since they represent potentially capable tectonic features. However, the staff also focused on understanding age constraints for certain of the regional structures interpreted to be pre-Quaternary in age. This secondary focus is important for quantifying the timing of last displacement on these structures and ensuring that they are not capable tectonic features.

Regional Paleozoic Tectonic Structures. In VCSNS COL FSAR Section 2.5.1.1.2.4.1, the applicant discussed regional tectonic structures in the site region which are interpreted to be Paleozoic (> 251 Ma) in age. This FSAR section specifically addresses the following Paleozoic faults and shear zones in regard to their potential for reactivation as capable tectonic structures:

Chappells Shear Zone – 3 km (2 mi) south of the site
Beaver Creek Shear Zone – 16 km (10 mi) north of the site
Gold Hill Fault Extension – 32 km (20 mi) north of the site
Central Piedmont Shear Zone (CPSZ) – northwest boundary of the Charlotte Terrane
Unnamed fault near Parr, South Carolina – 5 km (3 mi) south-southwest of the site
Cross Anchor fault – 16 km (10 mi) north of the site
Modoc Shear Zone – 32.2 km (20 mi) south of the site
Eastern Piedmont Fault Zone (EPFZ) – includes the Modoc Shear Zone, Augusta fault, and other fault zones
Augusta fault – 80 km (50 mi) southwest of the site
Other Paleozoic faults – located in the site region

In VCSNS COL FSAR Section 2.5.1.1.2.4.1, the applicant provided detailed discussions of the faults and shear zones listed above, including age constraint data that document a Paleozoic age for these structures and descriptions of associated ductile deformation fabrics, which clearly indicate the structures developed in a deep-seated crustal environment such as that known to be characteristic of Paleozoic deformation in the site region. In RAIs 2.5.1-12 through 2.5.1-18, the staff asked the applicant to document the information used to constrain ages of these faults and shear zones to ensure that none of these features were younger than Paleozoic in age and possible capable tectonic structures.

In the responses to RAIs 2.5.1-12 through 2.5.1-18, the applicant provided additional information and references to clearly document a Paleozoic (>251 Ma) age for last movement on these faults and shear zones. The applicant modified VCSNS COL FSAR Figure 2.5.1-202 to accurately distinguish certain of the structures and proposed revisions to FSAR Section 2.5.1.1.2.4.1 to present the additional information. The applicant concluded that none of these structures were capable tectonic features which pose a potential hazard to the VCSNS site.

Based on review of the applicant's responses to RAIs 2.5.1-12 through 2.5.1-18 and changes provided by the applicant in Revision 2 of VCSNS COL FSAR Section 2.5.1.1.2.4.1, including FSAR Figure 2.5.1-202, and 2.5.1.1.2.4, the staff concludes that there is strong evidence for a Paleozoic age for these faults and shear zones, and that none are capable tectonic features. The staff draws this conclusion because constraining ages are presented for these regional tectonic structures, and the structures commonly exhibit fabrics indicative of deformation in a deep-seated, high-temperature metamorphic environment, a setting characteristic of Paleozoic (>251 Ma) deformation in the site region. In addition, the areas encompassing the Paleozoic features are included in the zones defined for the original EPRI seismic source models (EPRI, 1986 and 1989) to capture the diffuse, small-magnitude seismic events that occur in those areas. Consequently, the staff considers RAIs 2.5.1-12 through 2.5.1-18 to be resolved.

Based on review of VCSNS COL FSAR Section 2.5.1.1.2.4.1 and the applicant's responses to RAIs 2.5.1-12 through 2.5.1-18, including the revisions to FSAR Sections 2.5.1.1.2.4.1 and FSAR Figure 2.5.1-202, the staff concludes that the applicant provided a thorough and accurate description of regional Paleozoic tectonic structures, including adequate documentation of a Paleozoic age (> 251 Ma) for these structures, in support of the VCSNS COL application.

Regional Mesozoic Tectonic Structures. In VCSNS COL FSAR Section 2.5.1.1.2.4.2, the applicant discussed regional Mesozoic (251-65.5 Ma) tectonic structures which occur in the site region, including both faults and fault-bounded extensional rift basins. This FSAR section specifically addresses the following faults and rift basins in regard to their potential for reactivation as capable tectonic structures:

Wateree Creek fault – 3 km (2 mi) south of the site
Summers Branch fault – 8 km (5 mi) southwest of the site
Ridgeway fault – 32 km (20 mi) east of the site
Longtown fault – 40 km (25 mi) east-northeast of the site
Unnamed fault near Ridgeway, South Carolina – located south of the Longtown fault
Mulberry Creek fault – 72 km (45 mi) northwest of the VCSNS site
Mesozoic Rift Basins – located in the site region

Wateree Creek, Summers Branch, and Ridgeway Faults

In VCSNS COL FSAR Section 2.5.1.1.2.4.2, the applicant stated that the minimum age of displacement on the unsilicified Wateree Creek fault is constrained as Mesozoic (specifically Triassic, 251-201.6 Ma) based on crosscutting dikes which are not offset by the fault. The applicant indicated that the unsilicified Summers Branch fault and the Ridgeway fault are also Triassic in age based on their association with the Wateree Creek fault. In RAI 2.5.1-19, the staff asked the applicant to summarize the information on the relationship of the Summers Branch and Ridgeway faults with the Wateree Creek fault, which was used to conclude that all three faults are Triassic in age.

In the response to RAI 2.5.1-19, the applicant stated that Secor and others (1982) reported strong similarities between the unsilicified Wateree Creek and Ridgeway faults, including length and strike. In addition, the applicant pointed out that Secor and others (1998) presented information showing the Ridgeway fault does not cut an overlying Mesozoic (specifically Upper Cretaceous, 99.6-65.5 Ma) stratigraphic unit, indicating last movement on this fault occurred prior to Late Cretaceous time (i.e., > 99.6 Ma). The applicant also stated that evidence for the unsilicified Summers Branch fault is speculative. Suggested strike and length of this fault are similar to that of the Wateree Creek and Ridgeway faults (Secor and others, 1982). However, a more recent geologic map prepared by Maher and others (1994), including Secor, omitted the Summers Branch fault. Based on the suggested similarities between the Summers Branch, Wateree Creek, and Ridgeway faults, the applicant concluded that the Summers Branch fault, if it exists, is most likely no younger than Mesozoic (i.e., not < 65.5 Ma).

Based on review of the applicant's response to RAI 2.5.1-19 and direct examination of the Wateree Creek fault in the field with the USGS during a March 2009 site visit, the staff concludes that these three faults are most likely no younger than Mesozoic. The staff draws this conclusion because of the Mesozoic age constraint on the Wateree Creek fault; the similarities between the three faults described by the applicant; and the characteristics of the Wateree Creek fault observed by the staff during the site visit, which indicate that this fault offsets only older Paleozoic rock units and does not exhibit a deformation fabric clearly related to late-stage brittle failure. Consequently, the staff considers RAI 2.5.1-19 to be resolved.

Longtown Fault

In VCSNS COL FSAR Section 2.5.1.1.2.4.2, the applicant stated that Jurassic (201.6-145.5 Ma) age diabase dikes crosscut, and are not offset by, the Longtown fault. However, this FSAR section then states that post-Mesozoic slip along the fault cannot be precluded by the available data. In RAI 2.5.1-20, the staff asked the applicant to explain why the crosscutting dikes of Jurassic age do not preclude post-Mesozoic displacement along the fault.

In the response to RAI 2.5.1-20, the applicant noted that a typographical error existed in the VCSNS COL FSAR, and the FSAR should have indicated post-Mesozoic slip could, rather than could not, be precluded on the Longtown fault because Jurassic age diabase dikes crosscut the fault without any offset. The applicant provided a revision to FSAR Section 2.5.1.1.2.4.2 to correct this error.

Based on review of the applicant's response to RAI 2.5.1-20 and changes provided by the applicant in Revision 2 of VCSNS COL FSAR Section 2.5.1.1.2.4.2, the staff concludes that the statement made in error has been corrected by the applicant. Consequently, the staff considers RAI 2.5.1-20 to be resolved.

Unnamed Fault near Ridgeway, South Carolina

In VCSNS COL FSAR Section 2.5.1.1.2.4.2, the applicant documented a minimum age of Mesozoic, specifically Triassic (251-201.6 Ma) for the unnamed fault near Ridgeway, South Carolina, based on the fact that Secor and others (1998) and Barker and Secor (2005) mapped six Triassic (251-201.6 Ma) or Jurassic (201.6-145.5 Ma) dikes that crosscut this fault without any displacement. The staff concludes that there is definitive field evidence for a Mesozoic age for this unnamed fault because of the age constraint imposed by the undeformed dikes that crosscut the fault.

Mulberry Creek Fault

In VCSNS COL FSAR Section 2.5.1.1.2.4.2, the applicant stated that the Mulberry Creek fault is Mesozoic (251-65.5 Ma) in age based on an association with other similar silicified breccias described by West (1998), although the legend symbol shown in FSAR Figure 2.5.1-212 indicates it is Paleozoic (> 251 Ma) in age. However, Nystrom (2006) discussed silicified breccias in the site region and suggested these breccias may occur along faults exhibiting Late Cenozoic (< 33.9 Ma) movement in the EPFZ. In FSAR Figure 2.5.1-212 illustrating tectonic features within 80.5 km (50 mi) of the VCSNS site, the applicant did not include in the figure legend the "diagonal line" symbol which appears to designate shear zones in some cases. In RAIs 2.5.1-21 and 2.5.1-52, the staff asked the applicant to document the age of the Mulberry Creek fault and summarize the logic presented by West (1998) that silicified breccias are indicative of Mesozoic age fault displacements in light of the interpretation by Nystrom (2006) that late Cenozoic movement may have occurred along some silicified faults in the site region. The staff also asked the applicant to explain the "diagonal line" symbol in Figure 2.5.1-212 and include the symbol in the legend for FSAR Figure 2.5.1-212.

In the responses to RAIs 2.5.1-21 and 2.5.1-52, the applicant stated that age dates on silicified breccias similar to those found along the Mulberry Creek fault (Fullagar and Butler, 1980; Hatcher, 2006) indicate these breccias formed 170-190 Ma during Mesozoic (i.e., specifically Jurassic) time. The applicant indicated the Mulberry Creek fault would be shown as a Mesozoic structure in revised VCSNS COL FSAR Figure 2.5.1-212 and proposed revisions to FSAR

Section 2.5.1.1.2.4.2 to document a Mesozoic age for this fault. The applicant also indicated that the diagonal line symbol would be added to VCSNS COL FSAR Figure 2.5.1-212 to distinguish fault zones that were mapped with a width greater than the narrower faults illustrated by a single line in that figure. The applicant stated further that Nystrom (2006) did not propose late Cenozoic movement on faults related to the EPFZ based on the existence of silicified breccias, but rather on map patterns and inferred offset of Eocene (55.8-33.9 Ma) and Miocene (23-5.3 Ma) stratigraphic units. The applicant pointed out that the Mulberry Creek fault is not a part of the EPFZ, and researchers in the region noted that silicified breccias are characteristic of Mesozoic (251-65.5 Ma) faults in the Piedmont (Secor and others, 1998).

Based on review of the applicant's responses to RAIs 2.5.1-21 and 2.5.1-52 and changes provided by the applicant in Revision 2 of VCSNS COL FSAR Section 2.5.1.1.2.4.2, including modified FSAR Figure 2.5.1-212, the staff concludes that the applicant properly documented a Mesozoic (251-65.5 Ma) age for the Mulberry Creek fault. The staff draws this conclusion because reliable age constraint data indicate silicified fault breccias in the Piedmont are commonly Mesozoic in age, and no field relationships suggest a different timing for the Mulberry Creek fault. The staff also concludes that the applicant qualified that Nystrom (2006) did not use the presence of silicification to suggest late Cenozoic (< 33.9 Ma) displacement along the EPFZ or other faults in the Piedmont, but rather based his age of displacement interpretation on map patterns and inferred offset of Eocene and Miocene stratigraphic units. Consequently, the staff considers RAIs 2.5.1-21 and 2.5.1-52 to be resolved.

Mesozoic Rift Basins

In VCSNS COL FSAR Section 2.5.1.1.2.4.2, the applicant stated that Mesozoic (251-65.5 Ma) rift basins are areas of extended continental crust with the potential for hosting the largest earthquakes, but no definitive correlation of seismicity with Mesozoic normal faults exists. However, VCSNS COL FSAR Section 2.5.3.1.5 indicates that two small-magnitude (i.e., 3.5 and 3.7) earthquakes, which occurred in September 2006 about 145 km (90 mi) east-northeast of the VCSNS site, are spatially associated with a small buried Mesozoic extensional basin mapped by Benson (1992) beneath Coastal Plain sediments. If these two earthquakes occurred on a fault bounding a buried Mesozoic basin, the presence of such basins in the site region may have implications for the existence of potentially capable tectonic structures. In addition, Chapman and Beale (2008) proposed Cenozoic (65.5 Ma to present, including Quaternary from 2.6 Ma to present) compressional reactivation of a Mesozoic extensional fault within the seismically-active meizoseismal area of the 1886 Charleston earthquake (i.e., specifically within the Middleton Place-Summerville Seismic Zone). In RAI 2.5.1-22, the staff asked the applicant to include earthquake epicenters on an appropriate figure to show their locations relative to areas of Mesozoic (251-65.5 Ma) extended crust. In light of information presented in FSAR Section 2.5.3.1.5 regarding possible spatial association of two earthquakes with a small buried Mesozoic basin and the data from Chapman and Beale (2008), the staff also asked the applicant to discuss whether Mesozoic structures in the site region are potentially capable tectonic sources.

In the response to RAI 2.5.1-22, the applicant referred to VCSNS COL FSAR Figure 2.5.1-212 and provided Figure 02-05-01-22.1 to document the general lack of correlation between Mesozoic (251-65.5 Ma) basins and seismicity in the site region and within 80.5 km (50 mi) of the VCSNS site. The applicant indicated that no investigations have demonstrated Quaternary (2.6 Ma to present) reactivation of Mesozoic basin-bounding faults in the site region, and proposed revisions to VCSNS COL FSAR Section 2.5.1.1.2.4.2 to clarify that no spatial correlation is clearly defined between Mesozoic basins and earthquake activity in the site region. Regarding the two small-magnitude earthquakes which appear to be spatially associated with a buried Mesozoic basin about 145 km (90 mi) east-northeast of the VCSNS site, the applicant stated that a lack of calculated focal mechanisms and large uncertainties in locations of these earthquakes made any correlation with a specific feature untenable, and no data indicate the buried basin is a potentially capable tectonic source.

In the response to RAI 2.5.1-22, the applicant also addressed the data used by Chapman and Beale (2008) to propose Cenozoic (65.5 Ma to present) reactivation of a Mesozoic structure within the Middleton Place-Summerville Seismic Zone, which they proposed as the potential causative structure for the 1886 Charleston earthquake. The applicant pointed out that the fault, which Chapman and Beale (2008) interpreted to show about 10 m (33 ft) of up-to-the-east reverse displacement of Coastal Plain sediments, is imaged in a single reprocessed seismic reflection profile in which the shallowest observed deformation appears to be about 100 m (328 ft) below the ground surface. This information suggests that the fault may not cut stratigraphic units younger than Eocene (55.8-33.9 Ma). Therefore, the applicant concluded that post-Eocene (i.e., possibly Quaternary) deformation is not demonstrated by the available data and additional information is needed to determine if this structure represents the Quaternary age causative fault for the 1886 Charleston earthquake. The applicant further concluded that all available data support the assessment that bounding faults of Mesozoic (251-66.5) basins in the site region are not capable tectonic sources.

Based on review of the applicant's response to RAI 2.5.1-22 and changes provided by the applicant in Revision 2 of VCSNS COL FSAR Section 2.5.1.1.2.4.2, the staff concludes that the available data support the applicant's assessment that bounding faults of Mesozoic basins in the site region are not capable tectonic sources, and do not exhibit any evidence for Quaternary deformation associated with these basin-bounding faults. The staff makes this conclusion based on the lack of spatial correlation between seismicity and Mesozoic (251-65.5 Ma) basin-bounding faults, and the fact that none of the Mesozoic structures investigated to date show reactivation during the Quaternary (2.6 Ma to present). Consequently, the staff considers RAI 2.5.1-22 to be resolved.

Based on review of VCSNS COL FSAR Section 2.5.1.1.2.4.2 and the applicant's responses to RAIs 2.5.1-19 through 2.5.1-22 and 2.5.1-52, including revisions to FSAR Section 2.5.1.1.2.4.2, and field observations made by the staff during a March 2009 site visit, the staff concludes that the applicant provided a thorough and accurate description of regional Mesozoic (251-65.5 Ma) tectonic structures, including adequate documentation of a Mesozoic age for these structures, in support of the VCSNS COL application.

Regional Cenozoic Tectonic Structures. In VCSNS COL FSAR Section 2.5.1.1.2.4.3, the applicant discussed regional tectonic structures interpreted to be Cenozoic (65.5 Ma to present) in age, which occur in the site region, including the Camden fault and prominent arches with adjacent embayments, in regard to their potential for reactivation as capable tectonic structures. Information related to these structures provided by the applicant, including evidence for age constraints, the applicant's responses to RAIs, and the appraisal of the RAI responses by the staff, is presented in the paragraphs below.

Camden Fault

In VCSNS COL FSAR Section 2.5.1.1.2.4.3, the applicant discussed the Camden fault, located about 64 km (40 mi) east of the VCSNS site, stating in one sentence that the age of most recent slip is uncertain and, in another, that age of displacement along the Camden fault is constrained because overlying Tertiary deposits are not offset. The VCSNS COL FSAR does not indicate which interpretation is preferred. In addition, pertinent information from the original cited source (Knapp and others, 2001) related to the constrained age interpretation is not summarized to document a pre-Quaternary (< 2.6 Ma) age for this fault. In RAI 2.5.1-23, the staff asked the applicant to clarify whether the age of the Camden fault is constrained or uncertain, and to summarize information used by Knapp and others (2001) to suggest the fault is pre-Quaternary in age.

In the response to RAI 2.5.1-23, based on geologic mapping (Balinsky, 1994; Secor and others, 1998; Barker and Secor, 2005) and geophysical data (Knapp and others, 2001), the applicant stated that the Camden fault is a Late Paleozoic ductile structure, reactivated during the Cenozoic, which is overlain by undeformed sedimentary units of Oligocene age (33.9-23 Ma). The applicant indicated that Knapp and others (2001) used both shallow seismic reflection and gravity data to provide evidence for undeformed Oligocene-age deposits overlying the southwestern projection of the Camden fault. Therefore, the applicant concluded that last movement on the Camden fault is older than Oligocene (i.e., > 23 Ma) and, consequently, is pre-Quaternary in age. The applicant proposed revisions to VCSNS COL FSAR Section 2.5.1.1.2.4.3 to summarize the information supporting this conclusion.

Based on review of the applicant's response to RAI 2.5.1-23 and changes provided by the applicant in Revision 2 of VCSNS COL FSAR Section 2.5.1.1.2.4.3, the staff concludes that the Camden fault is not younger than Oligocene and does not represent a capable tectonic structure. The staff draws this conclusion because undeformed sedimentary deposits of Oligocene age overlie the southwestern projection of the fault. Consequently, the staff considers RAI 2.5.1-23 to be resolved.

Arches and Embayments

In VCSNS COL FSAR Section 2.5.1.1.2.4.3, the applicant also discussed arches and embayments in the site region. FSAR Section 2.5.1.1.2.4.3 addresses the Cape Fear Arch and locates the arch on Figure 2.5.1-211 east of the VCSNS site, but does not discuss or show the location of the Yamacraw Arch, which also occurs in the site region south-southwest of the site. This FSAR section states that the arches and embayments developed in response to differential tectonic movement from Late Cretaceous (99.6-65.5 Ma) through Pleistocene (1.8 Ma to 10,000 years) time, so possibly as young as Quaternary (2.6 Ma to present). Crone and Wheeler (2000) label these structures as Class C features (i.e., features exhibiting insufficient evidence for documenting the existence of a tectonic fault or Quaternary deformation). In RAI 2.5.1-24, the staff asked the applicant to locate the Yamacraw Arch on Figure 2.5.1-211 and include a discussion of this arch in VCSNS COL FSAR Section 2.5.1.1.2.4.4, as was done for the Cape Fear Arch. The staff also asked the applicant to refer to primary sources of data, which render the conclusions about these features plausible, rather than relying only on the compiled information presented by Crone and Wheeler (2000).

In the response to RAI 2.5.1-24, the applicant indicated that detailed evidence constraining the timing of most recent movement on the Cape Fear and Yamacraw Arches is limited. The applicant cited Gohn (1988) and Prowell and Obermeier (1991) who suggested that the Cape Fear Arch has affected thickness and distribution of late Tertiary (23-2.6 Ma) sedimentary units, possibly into the Pleistocene (1.8 Ma to 10,000 years). The applicant interpreted the timing of the Yamacraw to likely be similar since the structures exhibit parallel orientations and similar structural styles, and proposed revisions to VCSNS COL FSAR Section 2.5.1.1.2.4.3 to present this information. The applicant reported that no evidence exists to indicate these two arches are potentially capable tectonic features.

Based on review of the applicant's response to RAI 2.5.1-24 and changes provided by the applicant in Revision 2 of VCSNS COL FSAR Section 2.5.1.1.2.4.3, including modified FSAR Figure 2.5.1-211, the staff concludes that the Cape Fear and Yamacraw Arches are most likely similar structures which exhibit no evidence to indicate they are potentially capable tectonic features. The staff draws this conclusion based on the similar orientation and structural styles for both arches, as well as the fact that researchers do not currently interpret these structures as capable tectonic features. Consequently, the staff considers RAI 2.5.1-24 to be resolved.

Based on review of VCSNS COL FSAR Section 2.5.1.1.2.4.3 and the applicant's responses to RAIs 2.5.1-23 and 2.5.1-24, including revisions to FSAR Section 2.5.1.1.2.4.3, the staff concludes that the applicant provided a thorough and accurate description of regional Cenozoic tectonic structures, giving credence to the interpretation that they are not potentially capable tectonic features, in support of the VCSNS COL application.

<u>Regional Quaternary Tectonic Structures</u>. In VCSNS COL FSAR Section 2.5.1.1.2.4.4, the applicant listed 14 potential Quaternary (2.6 Ma to present) tectonic features which occur in the site region. Locations of the features are shown in SER Figure 2.5.1-2 (reproduced from FSAR Figure 2.5.1-215). Quaternary tectonic structures warrant the most detailed evaluation because the structures represent potentially capable tectonic features.

The applicant defined the 14 potential Quaternary structures using a data compilation and classification system prepared by Crone and Wheeler (2000) and Wheeler (2005), which included faults, paleoliquefaction features, and possible tectonic features in the CEUS. Crone and Wheeler (2000) and Wheeler (2005) classified the features included in their data compilation as Class A, B, C, or D based on the strength of evidence for Quaternary deformation as derived from information presented in published literature. Only their Class A features clearly demonstrate the existence of a Quaternary fault of tectonic origin, whether exposed or inferred from liquefaction or other deformation features.

The 14 potential Quaternary tectonic features addressed by the applicant in the VCSNS COL FSAR, and the classifications for these features proposed by Crone and Wheeler (2000) and Wheeler (2005), are as follows:

Cape Fear Arch – Class C
Cooke Fault – Class C (Charleston area feature)
East Coast Fault System (ECFS) – Class C (Charleston area feature)
Helena Banks Fault Zone – Class C (Charleston area feature)
Charleston, Bluffton, and Georgetown Liquefaction Features – Class A (Charleston area features)
Eastern Tennessee Seismic Zone (ETSZ) – Class C
Fall Lines of Weems (1998) – Class C
Belair Fault – Class C
Pen Branch Fault – Class C
Hares Crossroads Fault – Class C
Stanleytown-Villa Heights Faults – Class C
Pembroke Faults – Class B

The applicant discussed the Cape Fear Arch in VCSNS COL FSAR Section 2.5.1.1.2.4.3 ("Regional Cenozoic Tectonic Structures"). Information related to this arch provided by the applicant, including the applicant's responses to RAIs and appraisals of those RAI responses by the staff, is presented in the above paragraphs of this SER which address that specific FSAR section.

The applicant discussed Charleston area features (i.e., the Cooke fault, ECFS, and Helena Banks fault zone as potential source faults; and the Charleston, Bluffton, and Georgetown liquefaction features as seismically-induced liquefaction features) in VCSNS COL FSAR Section 2.5.1.1.3.2.1 ("Charleston Seismic Zone"), and the ETSZ in FSAR Section 2.5.1.1.3.2.2 ("Eastern Tennessee Seismic Zone"). Information related to the Charleston area features and the ETSZ provided by the applicant, including the applicant's responses to RAIs and the staff's appraisal of the RAI responses, is presented in the SER paragraphs addressing those specific FSAR sections below.

The applicant discussed the remaining six potential Quaternary (2.6 Ma to present) tectonic features (i.e., the Fall Lines of Weems and the Belair, Pen Branch, Hares Crossroads, Stanleytown-Villa Heights, and Pembroke faults) in VCSNS COL FSAR Section 2.5.1.1.2.4.4. Information related to these six potential Quaternary faults, including the staff's appraisals of the RAI responses provided by the applicant, is presented in the paragraphs immediately below.

Fall Lines of Weems

In VCSNS COL FSAR Section 2.5.1.1.2.4.4, the applicant discussed the Fall Lines of Weems (Weems, 1998) and stated that Crone and Wheeler (2000) and Wheeler (2005) classified this feature as Class C because identification of the fall lines is subjective; criteria for recognition are not clearly defined; and a tectonic origin has not been demonstrated for the fall lines. These features are located as close as about 80 km (50 mi) north of the VCSNS site as shown in SER Figure 2.5.1-2. The applicant concluded, based on review of published literature, field reconnaissance, and work performed for the North Anna ESP application as summarized in NUREG-1835 (U.S. NRC, 2005), that the Fall Lines of Weems (Weems, 1998) are related to contrasts in resistance to erosion of adjacent rock types and are not tectonic in origin. The staff concurs with the applicant's conclusion based on the previous detailed assessment of these features for the North Anna ESP application as discussed in NUREG-1835 (U.S. NRC, 2005).

Belair Fault

In VCSNS COL FSAR Section 2.5.1.1.2.4.4, the applicant discussed the Belair fault and indicated that this structure may be a tear fault or lateral ramp in the hanging wall of the Augusta fault zone. The Belair fault is located about 113 km (70 mi) southwest of the VCSNS site (SER Figure 2.5.1-2) in the vicinity of the Augusta fault. If the Belair fault has this type of association with the Augusta fault zone, then movement on the Belair fault may be related to movement on the larger, regional-scale Augusta fault. Furthermore, VCSNS COL FSAR Section 2.5.1.1.2.4.4 states that Prowell and O'Connor (1978) constrained the age of last movement on the Belair fault to sometime between post-Late Eocene (< 33.9 Ma) and pre-26,000 years ago based on age of undeformed stratigraphic units overlying the fault, rendering this fault a structure which possibly shows evidence of Quaternary (2.6 Ma to present) displacement. The applicant stated that Quaternary displacement on the Belair fault is possible, but not demonstrated, by the available data. In RAI 2.5.1-27, the staff asked the applicant to discuss how the inference of possible Quaternary displacement on the Belair fault, coupled with a potential relationship to the regional-scale Augusta fault zone, could affect seismic hazard at the VCSNS site.

In the response to RAI 2.5.1-27, the applicant stated that different slip histories and opposite senses of slip for the Belair and Augusta faults indicate these structures have not been reactivated as a single tectonic element. The Augusta fault last moved in the Paleozoic (> 248 Ma) with a normal sense of displacement (Maher and others, 1994), while the Belair fault last moved in the Cenozoic (65 Ma to present) and exhibits reverse displacement (Prowell and O'Connor, 1978). Although the Belair fault demonstrates reverse slip during the Cenozoic (Prowell and O'Connor, 1978), the applicant noted that no compelling evidence for Quaternary (2.6 Ma to present) displacement exits for either the Belair fault or any other Cenozoic structures in the site region. The applicant cited work done on the Pen Branch fault, described in the VEGP ESP application and the VEGP FSER, as evidence that Cenozoic faulting in the site region generally does not extend into the Quaternary. The applicant concluded that the Belair fault does not represent a capable tectonic structure.

Based on review of the applicant's response to RAI 2.5.1-27, the staff concludes that the Belair fault is not structurally linked with the Augusta fault. The staff draws this conclusion because of the different timing and type of displacement for the two faults. The staff also concludes that the Belair fault does not represent a capable tectonic structure in the site region because no field evidence exists for Quaternary (2.6 Ma to present) displacement along the Belair fault, or any other Cenozoic structures in the site region. Consequently, the staff considers RAI 2.5.1-27 to be resolved.

Pen Branch Fault

In VCSNS COL FSAR Section 2.5.1.1.2.4.4, the applicant discussed the Pen Branch fault and concluded that it is not a capable tectonic structure, citing field evidence that last displacement on this structure was not younger than Eocene (55.8-33.9 Ma). This fault, located about 113 km (70 mi) south-southwest of the VCSNS site (SER Figure 2.5.1-2), is the northwestern border fault of the Dunbarton Triassic Basin. The applicant referred to studies performed for the Savannah River site (Cumbest and others, 2000), as well as the VEGP ESP application, (U.S. NRC, 2009) as the basis for this conclusion. The staff concurs with the applicant's conclusion, since information presented in the VEGP ESP application and reviewed by staff, as well as the staff's independent assessment of field data collected for the VEGP ESP application to characterize last movement on the Pen Branch fault, presented in NUREG-1923 (U.S. NRC, 2009), documents that the fault does not disrupt Quaternary (2.6 Ma to present) river terraces and is not younger than Eocene in age.

Hares Crossroads and Stanleytown-Villa Heights Faults

In VCSNS COL FSAR Section 2.5.1.1.2.4.4, the applicant discussed the postulated Hares Crossroads and Stanleytown-Villa Heights faults, interpreting them to be the result of land sliding and, therefore, of nontectonic origin. These faults are located at the edge of the site region about 320 km (200 mi) east-northeast and north-northeast of the VCSNS site, respectively (SER Figure 2.5.1-2). This FSAR section cites the data compilation by Crone and Wheeler (2000), who classified these faults as Class C features, but does not summarize information from original data sources to document the conclusion that these faults are nontectonic in origin. In RAI 2.5.1-29, the staff asked the applicant to summarize the evidence from primary data sources used to conclude that the faults formed in response to a nontectonic landslide mechanism, rather than referring only to the compiled data presented by Crone and Wheeler (2000).

In the response to RAI 2.5.1-29, the applicant summarized the logic for interpreting the Hares Crossroads and Stanleytown-Villa Heights faults as the result of landslides rather than tectonic processes. The applicant stated that Conley and Toewe (1968) initially proposed the existence of the Stanleytown-Villa Heights faults based on geologic mapping, but did not report any shear fabrics or shear sense indicators for these faults. In addition, the applicant indicated that Conley and Toewe (1968) did not did not show the faults extending into bedrock or offsetting bedrock contacts; that the features have limited lateral extent, no geomorphic expression, and are spatially associated with landslide-prone saprolitic bedrock on hillsides; and that an illustration of the proposed Stanleytown fault provided by Conley and Toewe (1968) could readily be interpreted as a depositional contact between alluvium and bedrock.

For the Hares Crossroads fault, the applicant indicated that Daniels and others (1972) showed this localized feature to be related to saprolitic Paleozoic crystalline rocks overlain by unconsolidated Coastal Plain sediments of Pliocene to Pleistocene age (i.e., 5.3 Ma to 10,000 years) along an irregular and undulatory contact without any evidence of shear fabrics. The applicant commented that neither the Hares Crossroads nor the Stanleytown-Villa Heights faults have received much attention from current researchers, indicating that these proposed faults are not currently interpreted as Quaternary tectonic features. Therefore, the applicant concluded that these structures most likely have a nontectonic origin.

Based on review of the applicant's response to RAI 2.5.1-29, the staff concludes that the preponderance of field evidence supports the interpretation that the Hares Crossroads and Stanleytown-Villa Heights structures are nontectonic in nature. The staff draws this conclusion because these features have not been shown to offset bedrock; are of limited lateral extent; have no associated shear fabrics or sense of shear indicators; and are spatially associated with landslide-prone saprolitic bedrock on hillsides. Consequently, the staff considers RAI 2.5.1-29 to be resolved.

Pembroke Faults

In VCSNS COL FSAR Section 2.5.1.1.2.4.4, the applicant discussed the postulated Pembroke faults, which are classified as Class B structures by Crone and Wheeler (2000). The Pembroke faults are located at the edge of the site region about 320 km (200 mi) north of the VCSNS site (SER Figure 2.5.1-2). The applicant did not provide information on fault geometry or fault length, and this FSAR section states that it is unclear whether they are of tectonic origin or the result of dissolution collapse. In RAI 2.5.1-30, the staff asked the applicant to summarize information on fault geometry and fault length and current lines of evidence related to whether these features are tectonic or nontectonic in origin as derived from primary data sources, rather than relying only on the compiled information presented by Crone and Wheeler (2000).

In the response to RAI 2.5.1-30, the applicant indicated that the postulated Pembroke faults occur in Pliocene (5.3-2.6 Ma) to early Quaternary (2.6 Ma to 10,000 years) alluvial terrace deposits (Law and others, 1997). The applicant stated that Law and others (1992) observed both normal (i.e., extensional) and reverse faults striking northeast to east-northeast, and Law and others (1997) indicated that maximum total oblique slip was about 11 m (36 ft) on the largest extensional features. Based on geophysical data (Callis and Williams, 1997; Law and others, 1997; Peavy and Sayer, 1998), the applicant noted that minimum length of the postulated faults was about 100 m (328 ft). The applicant further reported that the alluvial terrace deposits overlie faulted and folded Ordovician (488-444 Ma) carbonate rocks, which are susceptible to dissolution. Peavy and Sayer (1998) and Law and others (1998) described sinkholes in the terrace deposits, which they attributed to upward migration of collapse structures into the overlying terrace deposits from dissolution of the underlying carbonate bedrock. The applicant indicated that it has not been unequivocally determined whether tectonic deformation or dissolution-related collapse generated the Pembroke features. However, the applicant documented that the same researchers who initially concluded that these features were tectonic structures (e.g., Law and others, 1992) more recently favored dissolution-related collapse (Law and others, 1998) as the origin in light of the susceptibility of the underlying carbonate to dissolution. Consequently, the applicant did not interpret the postulated Pembroke faults as capable tectonic structures.

Based on review of the applicant's response to RAI 2.5.1-30, the staff concludes that evidence exists to suggest the postulated Pembroke faults are likely related to collapse of terrace deposits in response to dissolution of underlying carbonate bedrock. The staff draws this conclusion because carbonate rocks underlie the terrace deposits and researchers who initially interpreted the postulated faults as tectonic in origin have more recently suggested dissolution collapse as the formation mechanism. Consequently, the staff considers RAI 2.5.1-30 to be resolved.

Based on review of VCSNS COL FSAR Section 2.5.1.1.2.4.4 and the applicant's responses to RAIs 2.5.1-27, 2.5.1-29, and 2.5.1-30, the staff concludes that the applicant provided a thorough and accurate description of the six potential Quaternary features which occur in the site region and exhibit distinct linear traces in support of the VCSNS COL application.

<u>Regional Geophysical Anomalies and Lineaments</u>

In VCSNS COL FSAR Section 2.5.1.1.2.4.5, the applicant discussed regional geophysical anomalies and lineaments, including the East Coast Magnetic Anomaly (ECMA); the Appalachian gravity gradient; the zone of Iapetan (> 542 Ma) normal faulting as defined by its southeastern and northwestern boundaries; the New York-Alabama (NYAL), Clingman, and Ocoee lineaments; the Appalachian thrust front; and the Grenville front. The applicant documented that these regional anomalies and lineaments are not capable tectonic structures based on interpreted ages (i.e., all are > 65.5 Ma) and observed characteristics of the features. In addition, these regional anomalies and lineaments were all accounted for in the original EPRI seismic source models (EPRI, 1986 and 1989), and no new information has been acquired since development of those source models which indicates a need to treat any of them differently. The applicant separately addressed the potential for vibratory ground motion resulting from seismicity proximal to the NYAL and the Clingman-Ocoee lineaments in the ETSZ in FSAR Section 2.5.2.2.2.5.

Based on information presented in VCSNS COL FSAR Section 2.5.1.1.2.4.5 regarding interpreted ages (i.e., > 65.5 Ma) and observed characteristics of the regional geophysical anomalies and lineaments, as well as independent review of the existing data, the staff concludes that none of these features which occur in the site region represent capable tectonic features. The staff also acknowledges that the original EPRI seismic source models (EPRI, 1986 and 1989) accounted for these anomalies and lineaments, and that no new information has been acquired since the development of these source models to warrant changes in the models.

Based on review of VCSNS COL FSAR Section 2.5.1.1.2.4.5, the staff concludes that the applicant provided a thorough and accurate description of regional geophysical anomalies and lineaments in support of the VCSNS COL application.

Regional Seismicity and Paleoseismology

In VCSNS COL FSAR Section 2.5.1.1.3, the applicant discussed regional seismicity and paleoseismology. The applicant generally addressed seismicity in the CEUS (Section 2.5.1.1.3.1). The applicant discussed seismic sources defined by regional seismicity (Section 2.5.1.1.3.2) in detail, concentrating on the Charleston Seismic Zone (Section 2.5.1.1.3.2.1), the ETSZ (Section 2.5.1.1.3.2.2), and selected seismogenic and capable tectonic sources beyond the site region (Section 2.5.1.1.3.2.3), namely the New Madrid, Central Virginia, and Giles County seismic zones. For the Charleston Seismic Zone, the applicant specifically addressed potential Charleston source faults, Charleston area seismic zones, and Charleston area seismically-induced liquefaction features. Based on information presented in FSAR Sections 2.5.1.1.3.1 through 2.5.1.1.3.2.3, the applicant concluded that the Charleston area dominates ground motion hazard for the VCSNS site, although no specific causative fault has been identified. The staff's technical evaluation of FSAR Section 2.5.1.1.3 is presented below.

Charleston Seismic Zone

In VCSNS COL FSAR Section 2.5.1.1.3.2.1, the applicant discussed the Charleston Seismic Zone to specifically include potential Charleston source faults, Charleston area seismic zones, and Charleston area seismically-induced liquefaction features.

Potential Charleston Source Faults and Charleston Area Seismic Zones. In VCSNS COL FSAR Section 2.5.1.1.3.2.1, the applicant stated that no specific tectonic structure has been identified as the source for the 1886 Charleston earthquake, although 11 potential source faults have been proposed by researchers, including the ECFS, the Helena Banks fault zone, and the Adams Run, Ashley River, Charleston, Cooke, Drayton, Gants, Sawmill Branch, Summerville, and Woodstock faults as shown in SER Figure 2.5.1-3 (reproduced from FSAR Figure 2.5.1-218). The applicant also indicated that significant new information on source geometry and earthquake recurrence interval for a Charleston seismic source rendered an update of the original EPRI (EPRI, 1986 and 1989) Charleston seismic source model necessary. The applicant presented the UCSS model in FSAR Section 2.5.2.2.2.4. This model uses source areas represented by four different geometries, rather than a specific tectonic structure, to analyze seismic hazard at the site resulting from a Charleston source. Therefore, the potential source faults proposed for the 1886 Charleston earthquake, including the Dorchester fault in the vicinity of the Sawmill Branch fault proposed by Bartholomew and Rich (2007) based on the interpretation that conjugate normal faults related to fault rupture occurred in the walls of Colonial Fort Dorchester at that location, are captured in the UCSS model. Talwani and others (2008) proposed displacement along the Sawmill Branch fault as the cause of the conjugate faults in the walls of Fort Dorchester. The applicant related the displacements observed in the walls of Fort Dorchester to seismic shaking, rather than fault rupture.

The staff concludes that the relationships between individual faults in the Charleston area cannot currently be resolved due to a lack of data adequate for defining specific faults. The staff also concludes that the Charleston seismic source is best modeled as a source zone in the manner presented in VCSNS COL FSAR Section 2.5.2.2.2.4.1, which captures the Charleston seismic source in four different areal geometries. The staff makes these conclusions because exact fault locations are unknown and the source zones set up in the UCSS model for analyzing seismic hazard related to a Charleston area earthquake were established to capture the locations of all postulated tectonic sources in the Charleston area. The UCSS model for

Charleston is the same as that applied for the VEGP ESP site, and it has been reviewed and approved by the staff (U.S. NRC, 2009).

Also in VCSNS COL FSAR Section 2.5.1.1.3.2.1, the applicant discussed Charleston area seismic source zones, including the Middleton Place-Summerville, Bowman, and Adams Run Seismic Zones. The applicant indicated that these three zones, located in SER Figure 2.5.1-3, are generally defined based on areas of concentrated microseismicity in the greater Charleston area. The staff acknowledges that these three seismic zones are fully encompassed by the UCSS model, including the more recent interpretations by Dura-Gomez and Talwani (2008) and Chapman and Beale (2008) related to specific faults in the Middleton Place-Summerville Seismic Zone.

Based on review of VCSNS COL FSAR Section 2.5.1.1.3.2.1, the staff concludes that the applicant provided a thorough and accurate description of the level of knowledge regarding potential Charleston source faults and Charleston area seismic zones in support of the VCSNS COL application.

Charleston Area Seismically-Induced Liquefaction Features. In VCSNS COL FSAR Section 2.5.1.1.3.2.1, the applicant discussed seismically-induced liquefaction features in the Charleston area, including 1886 Charleston earthquake liquefaction features and paleoliquefaction features in coastal South Carolina which pre-date the 1886 Charleston earthquake. The applicant stated that 1886 Charleston earthquake liquefaction features are most heavily concentrated in the meizoseismal area, but are also reported elsewhere (e.g., near Bluffton and Georgetown, South Carolina southwest and northeast of the meizoseismal area, respectively).

In the discussion of paleoliquefaction features in VCSNS COL FSAR Section 2.5.1.1.3.2.1, the applicant did not address a newly-reported paleoliquefaction feature interpreted by Talwani and others (2008) to be associated with the Sawmill Branch fault. In RAIs 2.5.1-37 and 2.5.1-54, the staff asked the applicant to discuss this paleoliquefaction feature in regard to any bearing it may have on magnitude and recurrence interval for earthquakes in the VCSNS site region.

In the response to RAIs 2.5.1-37 and RAI 2.5.1-54, the applicant stated that the newly-discovered paleoliquefaction feature described by Talwani and others (2008) and interpreted to be associated with the Sawmill Branch fault is a sandblow with a width of about 1 m (3.3 ft) which occurs at a depth of 0.5 m (1.6 ft) below the ground surface in the Charleston miezoseismal area. Based on unspecified back-calculation techniques, Talwani and others (2008) estimated a magnitude of about 6.9, with the magnitude scale not indicated, for the causative earthquake. The applicant reported that Talwani and others (2008) believed the causative earthquake was pre-1886, presumably based on burial depth and observed degree of soil formation. The applicant pointed out that such a magnitude falls within the range of M_{max} captured in the UCSS model, and that the feature lies within one of the source area geometries defined for the UCSS model. The applicant concluded that no modifications to the UCSS model are required due to the discovery of this paleoliquefaction feature because none of the information presented by Talwani and others (2008) provided additional constraints on timing, magnitude, or location of an associated paleoearthquake. The applicant proposed modifications to VCSNS COL FSAR Section 2.5.1.1.3.2.1 to include a discussion of the feature as the basis for the conclusion.

Based on review of the applicant's response to RAIs 2.5.1-37 and 2.5.1-54 and changes provided by the applicant in Revision 2 of VCSNS COL FSAR Section 2.5.1.1.3.2.1, the staff concludes that no modification of the UCSS model is required as a result of the discovery of this paleoliquefaction feature. The staff draws this conclusion because the suggested characteristics of the feature are fully captured in the UCSS, and Talwani and others (2008) did not provide information to reliably constrain the timing, magnitude, or location of an associated paleoearthquake. Consequently, the staff considers RAIs 2.5.1-37 and 2.5.1-54 to be resolved.

Based on review of VCSNS COL FSAR Section 2.5.1.1.3.2.1, the applicant's responses to RAIs 2.5.1-37 and 2.5.1-54, and the revisions to FSAR Section 2.5.1.1.3.2.1, the staff concludes that the applicant provided a thorough and accurate description of Charleston area seismically-induced liquefaction features in support of the VCSNS COL application.

Eastern Tennessee Seismic Zone

In VCSNS COL FSAR Section 2.5.1.1.3.2.2, the applicant discussed the ETSZ, located approximately 282 km (175 mi) northwest of the VCSNS site as shown in SER Figure 2.5.1-4. Based on information provided by Chapman and others (2002), the applicant stated that the largest known earthquake in this zone was a magnitude 4.6, with magnitude scale unspecified. The applicant indicated that structures responsible for seismicity in the ETSZ are likely deep-seated Cambrian (542-488 Ma) or Precambrian (>542 Ma) normal faults reactivated in the present-day regional stress field, although seismicity in the zone cannot be attributed to any known fault.

In VCSNS COL FSAR Section 2.5.1.1.3.2.2, the applicant addressed the 6 EPRI/Seismicity Owners Group (EPRI/SOG) team source zones and the corresponding M_{max} values originally assigned for the ETSZ (EPRI, 1986). The FSAR specifies the upper-bound maximum range of the original EPRI/SOG teams M_{max} values as **M** 6.3 to 7.5. Although the FSAR states that more recent estimates of M_{max} are captured in the range of M_{max} values used by the original EPRI/SOG teams, the FSAR cites post-EPRI/SOG M_{max} estimates of **M** 6.3 (Bollinger, 1992) and **M** 7.5 (Frankel and others, 2002), but not the alternate higher estimate of **M** 7.8 by Bollinger (1992) which is presented in FSAR Section 2.5.2.2.2.5. The applicant concluded that no new information has been developed since the original EPRI study (EPRI, 1986 and 1989) that require any revision to the magnitude distribution used for the ETSZ in the EPRI source zone models. The applicant also concluded that the EPRI (EPRI, 1986 and 1989) representations of geometry, recurrence, and M_{max} values for the ETSZ encompass the range of values used for more recent characterizations of this seismic zone. Further discussion of the EPRI source models for the ETSZ is provided in SER Section 2.5.2.2.2.5.

The NRC staff focused the review of VCSNS COL FSAR Section 2.5.1.1.3.2.2 on M_{max} values assigned to the ETSZ. In RAI 2.5.1-38, the staff asked the applicant to clarify why FSAR Section 2.5.1.1.3.2.2 does not discuss the Bollinger (1992) M_{max} estimate of **M** 7.8 for the ETSZ.

In the response to RAI 2.5.1-38, the applicant agreed to modify VCSNS COL FSAR Section 2.5.1.1.3.2.2 to clarify the discussion of the **M** 7.8 value for the ETSZ (Bollinger, 1992) in FSAR Sections 2.5.1.1.3.2.2 and 2.5.2.2.2.5. The applicant cross-referenced FSAR Section 2.5.2.2.2.5, Revision 2, which indicates that the Bollinger (1992) ETSZ model included the **M** 7.8 value with only a low probability of 5 percent in the M_{max} distribution, with **M** 6.3 assigned a 95 percent weight. The applicant pointed out that the smaller value of **M** 6.3 is much closer to the mean magnitude (i.e., approximately **M** 6.2) defined in the original EPRI study (EPRI, 1986 and 1989). The applicant stated further that, because M 7.5 is interpreted to be the largest magnitude earthquake possible for that seismic zone and this magnitude is captured by the M_{max} distribution used for the EPRI study (EPRI, 1986 and 1989), no new information developed since 1986, including the assessment of Bollinger (1992), requires a significant revision to the original EPRI source model for the ETSZ.

Based on review of the applicant's response to RAI 2.5.1-38 and changes provided by the applicant in Revision 2 of VCSNS COL FSAR Section 2.5.1.1.3.2.2, which includes the cross-reference to FSAR Section 2.5.2.2.2.5, the staff concludes that the applicant clarified how Bollinger (1992) used the M_{max} value of 7.8 for assessment of seismic hazard in the ETSZ. The staff made this conclusion because the RAI response and the changes provided by the applicant in FSAR Revision 2 qualified the low weight which Bollinger (1992) assigned to the **M** 7.8 value (i.e., 5 percent) for the ETSZ, and documented that M 7.5 is interpreted to be the largest magnitude earthquake possible for the ETSZ. Consequently, the staff considers RAI 2.5.1-38 to be resolved.

Based on review of VCSNS COL FSAR Section 2.5.1.1.3.2.2, the applicant's response to RAIs 2.5.1-38, and revisions to FSAR Section 2.5.1.1.3.2.2, the staff concludes that the applicant provided a thorough and accurate description of the ETSZ in support of the VCSNS COL application.

Selected Seismotectonic Sources Beyond the Site Region

In VCSNS COL FSAR Section 2.5.1.1.3.2.3, the applicant discussed three areas of concentrated seismicity outside the VCSNS site region, namely, the New Madrid, Central Virginia, and Giles County Seismic Zones. These three seismic zones are located in SER Figure 2.5.1-4.

For the NMSZ, the applicant used the same seismic source model for the VCSNS site as that applied for the Clinton ESP site in central Illinois. This model, discussed in detail in VCSNS COL FSAR Section 2.5.2, reflects the updated New Madrid model that incorporates new paleoliquefaction data suggesting a mean recurrence interval of 500 years for earthquakes in the NMSZ. The NMSZ seismic source model has been previously reviewed and approved by the staff, as addressed in NUREG-1844, "Safety Evaluation Report for an Early Site Permit (ESP) at the Exelon Generation Company, LLC (EGC) ESP Site," (U.S. NRC, 2006) for the Clinton ESP site.

For the Central Virginia and Giles County Seismic Zones, the applicant used the existing EPRI seismic source models (EPRI, 1986 and 1989), because no new data acquired since the EPRI study required changes in the models for these seismic zones. These two seismic source zone models have previously been reviewed and approved by the staff, as addressed in NUREG-1835 (U.S. NRC, 2005) for the North Anna ESP site.

Based on review of VCSNS COL FSAR Section 2.5.1.1.3.2.3, the staff concludes that the applicant provided a thorough and accurate description of selected seismotectonic sources beyond the site region, including the New Madrid, Central Virginia, and Giles County seismic zones, in support of the VCSNS COL application.

Staff Conclusions on Regional Tectonic Setting and Regional Seismicity and Paleoseismology

Based on review of VCSNS COL FSAR Sections 2.5.1.1.2, "Regional Tectonic Setting," and 2.5.1.1.3, "Regional Seismicity and Paleoseismology," the applicant's responses to RAIs on those FSAR sections, and the revisions to FSAR Sections 2.5.1.1.2 and 2.5.1.1.3, the staff concludes that the applicant provided thorough and accurate descriptions of the regional tectonic setting and regional seismicity and paleoseismology for the VCSNS site, including regional geologic setting (FSAR Section 2.5.1.1.2.1), tectonic stress in the midcontinent region (FSAR Section 2.5.1.1.2.2), gravity and magnetic data (FSAR Section 2.5.1.1.2.3), principal regional tectonic structures (FSAR Section 2.5.1.1.2.4), and seismic sources defined by regional seismicity in the CEUS both inside and outside the 320 km (200 mi) site region (FSAR Sections 2.5.1.1.3.1 and 2.5.1.1.3.2). The staff also concludes that the descriptions provided in FSAR Sections 2.5.1.1.2 and 2.5.1.1.3 reflect the current literature and state of knowledge and meet the requirements of 10 CFR 52.79 and 10 CFR 100.23.

2.5.1.4.2 Site Geology

The NRC staff focused the review of VCSNS COL FSAR Section 2.5.1.2, "Site Geology," on the descriptions provided by the applicant for physiography and geomorphology, geologic setting and history, stratigraphy, structural geology, engineering geology, seismicity and paleoseismology, and groundwater conditions of the site area, defined as the area within an 8-km (5-mi) radius of the VCSNS site, as well as the site vicinity in some cases, defined as the area within a 40-km (25-mi) radius of the VCSNS site.

Site Area Physiography and Geomorphology

In VCSNS COL FSAR Section 2.5.1.2.1, the applicant stated that the VCSNS site is located in the Piedmont physiographic province, bounded on the southeast and northwest by the Coastal Plain and Blue Ridge physiographic provinces, respectively. The applicant noted that the site area is mantled by residual soils and saprolite which overlie igneous and metamorphic bedrock, and concluded that this relationship indicated a long weathering history for the Piedmont and the site area.

Based on review of VCSNS COL FSAR Section 2.5.1.2.1, the staff concludes that the applicant provided a thorough and accurate description of site area physiography and geomorphology in support of the VCSNS COL application.

Site Area Geologic Setting and History

In VCSNS COL FSAR Section 2.5.1.2.2, the applicant discussed geologic setting and geologic history of the site area. The applicant stated that the VCSNS site lies within the Charlotte Terrane, the westernmost lithotectonic terrain of the Carolina Zone, about 24 km (15 mi) southeast of the Central Piedmont Shear Zone (CPSZ). The CPSZ is the western boundary of the Charlotte Terrane and the Carolina Zone. The CPSZ is interpreted to be a Late Paleozoic (> 251 Ma) ductile thrust fault and is not a capable tectonic feature.

The NRC staff focused the review of VCSNS COL FSAR Section 2.5.1.2.2 on the applicant's descriptions of the regional tectonic structures, including the CPSZ, and timing of geologic events which occurred in the site area, including complex faulting and folding of the Charlotte Terrane. In RAI 2.5.1-44, the staff asked the applicant to provide age estimates for the 10 geologic events, specified in VCSNS COL FSAR Section 2.5.1.2.2, which affected the site area, including a summary of the radiometric age dates used to constrain timing of faulting in the site area, and to present references documenting the sources of the age dates. The staff also asked the applicant to quantify the amount of displacement referred to as "minor" and "very minor" along northeast and northwest joint systems in the list of geologic events which affected the site area.

In response to RAI 2.5.1-44, the applicant indicated that, of the 10 geologic events listed in VCSNS COL FSAR Section 2.5.1.2.2, four have limiting ages derived from radiometric age dating and provide chronologic reference points that can be used to calibrate timing of the remaining events. Based on Dennis and Wright (1997) and Hibbard and others (2002) using crosscutting relationships with an undeformed dike, the applicant documented that timing of regional deformation and metamorphism of rock units in the Charlotte Terrane (Event 3 of the 10 listed in VCSNS COL FSAR Section 2.5.1.2.2) occurred prior to 535 Ma. Based on a rubidium-strontium (Rb-Sr) age date from McSween and others (1991), the applicant estimated the timing for intrusion and crystallization of the Winnsboro plutonic complex (Event 4 in FSAR Section 2.5.1.2.2) at 295 +/- 2 Ma. The applicant used this age constraint in FSAR Section 2.5.1.1.2.4.1 to determine that the postulated unnamed fault near Parr, South Carolina, if it exists, is Paleozoic (> 251 Ma) in age as discussed in SER Section 2.5.1.4.1. Based on Rb-Sr and potassium-argon (K-Ar) age dates from Dames and Moore (1974), the applicant documented that intrusion of aplite and pegmatite dikes into the Winnsboro plutonic complex (Event 6 in FSAR Section 2.5.1.2.2) occurred just after crystallization of the plutonic complex at about 292 Ma. Finally, based on K-Ar age dates from Dames and Moore (1974) on undeformed laumontite crystals collected from the minor shear zones mapped in the Unit 1 foundation excavation, the applicant cited a minimum age of 45 +/- 5 Ma for these shear zones (related to Events 7, 8, 9 in VCSNS COL FSAR Section 2.5.1.2.2) and suggested, consequently, that the shears are likely no younger than Late Mesozoic (145.5-65.5 Ma). Based on Dames and Moore (1974) in regard to measured displacements on the localized shear zones mapped in Unit 1 foundation rocks, the applicant explained that the displacements described as “minor” for the northeast-trending shears and “very minor” for the northwest-trending shears (Events 7 and 8 in VCSNS COL FSAR Section 2.5.1.2.2) were roughly 2 m (7 ft) and less than 0.6 m (2 ft), respectively.

Based on review of VCSNS COL FSAR Section 2.5.1.2.2 and the applicant’s response to RAI 2.5.1-44, the staff concludes that the applicant provided age estimates to bracket the 10 geologic events, including a summary of the age dating results used to constrain timing of faulting in the site area; presented references documenting the sources of the radiometric age dates; and quantified the displacements referred to as “minor” and “very minor” which occurred along the localized northeast and northwest shear zones. The staff draws these conclusions because the information provided by the applicant properly documents age constraints for geologic events and tectonic features in the site area, including the northeast and northwest shear zones mapped in the Unit 1 foundation, and the fact that displacements reflected by the localized northeast and northwest shear zones are small. Age date constraints indicate that none of the 10 geologic events listed in FSAR Section 2.5.1.2.2 represent a capable tectonic source in the site area. Consequently, the staff considers RAI 2.5.1-44 to be resolved.

Based on review of VCSNS COL FSAR Section 2.5.1.2.2, the staff concludes that the applicant provided a thorough and accurate description of the geologic setting and geologic history of the site area in support of the VCSNS COL application.

Site Area Stratigraphy

In VCSNS COL FSAR Section 2.5.1.2.3, the applicant discussed stratigraphy of the site area. The applicant stated that three major rock types occur within the site area, the most prevalent of which is the Winnsboro plutonic complex of Carboniferous age (359-299 Ma) as reported by Secor and others (1982). Metamorphic rocks of the Charlotte Terrane of the Carolina Zone, which the Winnsboro complex intruded, and migmatites (i.e., a composite rock composed of pervasively inhomogeneous igneous or metamorphic materials that are commonly found in areas of medium to high-grade metamorphism) associated with the contact margins of the Winnsboro plutonic complex, comprise the other two major rock types in the site area.

Based on review of VCSNS COL FSAR Section 2.5.1.2.3, the staff concludes that the applicant provided a thorough and accurate description of stratigraphy of the site area in support of the VCSNS COL application.

Site Area Structural Geology

In VCSNS COL FSAR Section 2.5.1.2.4, the applicant discussed structural geology of the site area, including three minor localized shear zones (i.e., zones exhibiting minor fault displacement) mapped in the Unit 1 foundation; the Wateree Creek and Summers Branch faults; the unnamed proposed fault near Parr, South Carolina; and the Chappells Shear Zone. Based on the results of investigations performed for Unit 1 by Dames and Moore (1974), the applicant described the three locally-developed shear zones mapped in the Unit 1 excavation as near-vertical, northeast and northwest-striking zones that reflect orientations of regional and local joints in the site area. The applicant indicated that such localized, minor structures are common in the Piedmont, but did not cite a reference to document this statement. The applicant also stated that the shear zones terminated within the excavation exposure and exhibited a maximum displacement of 2 m (7 ft) in an oblique-slip sense with a maximum width of individual shear zones of less than 0.3 m (1 ft). Based on radiometric age dating of undeformed hydrothermal zeolite crystals collected from the shear zones (Dames and Moore, 1974), the applicant concluded that the zones were older than 45 Ma and did not represent capable tectonic features. However, the applicant did not discuss sample controls for the undeformed minerals to document that they were collected in the part of the shear zones which experienced the latest movement. This FSAR section also states, based on investigations performed for Unit 1, that an evaluation of the potential for movement along the shear zones due to filling of the Monticello Reservoir indicated reservoir impoundment would not adversely affect the shear zones; that both northwest and northeast-striking shear zones existed although the dominant set trended northeast; and that the shears did not penetrate into the soil profile.

In regard to the minor localized shear zones mapped in the Unit 1 excavation, the applicant indicated that detailed geologic mapping of the foundation exposures would be performed in the excavations for Units 2 and 3 to document the presence or absence of these types of tectonic features. Because there is a potential for similar minor shear zones to occur in bedrock underlying Units 2 and 3 of the VCSNS site, the staff proposed that the applicant specifically commit not only to conducting the geologic mapping of excavations for safety-related structures based on guidance provided in RG 1.208, but also to evaluate any geologic features encountered and notifying the NRC once any excavations for safety-related structures were open for examination by staff. These actions comprised License Condition 2.5.1-1.

Basis for Removal of Geologic Mapping License Condition 2.5.1-1 for VCSNS Unit 2

Beginning in February 2010, SCE&G began excavation activities for the VCSNS Unit 2 nuclear island. Subsequent to the issuance of the VCSNS advanced safety evaluation for FSAR Section 2.5.1, the staff visited the VCSNS Unit 2 excavation twice (i.e., August 23-24, 2010, and April 18-19, 2011) to directly examine geologic features in the rock units exposed by the excavation activities and to review the results of the geologic mapping conducted in the VCSNS Unit 2 excavation. At the time of the August 23-24, 2010, site visit, the applicant had generally excavated most of the Unit 2 nuclear island to the top of sound rock. In some parts of the Unit 2 excavation, however, the top of sound rock was approximately 4.6 m (15 ft) above the projected foundation grade level for the VCSNS Unit 2 nuclear island; rendering controlled blasting necessary to reach the foundation grade. At the time of the April 18-19, 2011, site visit, the applicant had excavated into sound rock at or below the foundation grade level for the VCSNS Unit 2 nuclear island using controlled blasting techniques to limit potential blast damage of the foundation rock units.

Trip reports dated August 30, 2010, and May 9, 2011, document the results of the August 23 - 24, 2010, and the April 18-19, 2011, site visits, respectively. As summarized in the two trip reports, the purposes of these site visits were as follows:

- To directly examine the geologic features exposed in the walls and floor of the VCSNS Unit 2 excavation and determine whether those features were consistent with descriptions of geologic features at the site as provided in FSAR Section 2.5, "Geology, Seismology and Geotechnical Engineering," of the VCSNS COL application.

- To review geologic maps of the walls and floor of the Unit 2 excavation, and the associated supporting data, prepared by the applicant and ensure that the maps and the data were consistent with the commitments contained in VCSNS COL FSAR Section 2.5.

- Specifically during the April 18-19, 2011, site visit, to examine the sound rock comprising the foundation materials for the VCSNS Unit 2 nuclear island and verify that the foundation rock units were not damaged by the controlled blasting that was done to remove the rock units lying above the foundation grade level. An additional purpose for this site visit was to determine that the sound rock comprising the foundation materials will provide an adequate foundation for VCSNS Unit 2 consistent with descriptions in VCSNS COL FSAR Section 2.5.

As stated in the trip reports, the staff drew the following conclusions from the two site visits:

- After directly examining the walls and floor of the Unit 2 excavation, the staff concludes that the geologic features observed and mapped in the excavation by the applicant are consistent with geologic characteristics of the site as described in VCSNS COL FSAR Section 2.5. The staff draws this conclusion because strong field evidence indicates that no capable tectonic structures, or other potentially detrimental geologic features, occur in the Unit 2 excavation.

- After reviewing the geologic maps and the associated supporting data produced by the applicant, and comparing a sample of these maps with field observations in the excavation, the staff concludes that the geologic maps and associated supporting data produced by the applicant for the Unit 2 excavation are consistent with the commitments contained in VCSNS COL FSAR Section 2.5. The staff draws this conclusion because the geologic maps were prepared at a scale sufficient to document a lack of capable tectonic structures, or other potentially detrimental geologic features, in the Unit 2 excavation.

- After examining the floor of the Unit 2 excavation, the staff concludes that the sound rock comprising the foundation materials for the VCSNS Unit 2 nuclear island was not damaged by the controlled blasting performed to remove the rock units overlying the foundation grade level, and that the sound rock which occurs in the excavation will provide an adequate foundation consistent with descriptions in the VCSNS COL FSAR. The staff draws this conclusion because careful visual examination of the rock units in the Unit 2 excavation did not reveal any detrimental blast damage of the foundation rock units.

Based on the conclusions stated above, which resulted from direct observations made during the two site visits to examine geologic features in the walls and floor of the Unit 2 excavation and the geologic maps of the excavation produced by the applicant, the staff does not propose a license condition for geologic mapping of the VCSNS Unit 2 excavation. Because geologic mapping of the Unit 3 excavation has not progressed to the same point as that for the VCSNS Unit 2 excavation, the geologic mapping license condition for the Unit 3 excavation will remain as proposed in the July 6, 2010, Safety Evaluation Report for VCSNS Units 2 and 3.

The NRC staff focused the review of VCSNS COL FSAR Section 2.5.1.2.4 primarily on the three localized shear zones mapped in the Unit 1 excavation since the applicant indicated that similar features may be expected at Units 2 and 3, but also on the four larger-scale mapped or proposed faults located near the site (i.e., the Wateree Creek and Summers Branch faults; the unnamed postulated fault near Parr, South Carolina; and the Chappells Shear Zone). In RAIs 2.5.1-46 and 2.5.1-55, the staff asked the applicant to describe the sample controls applied for collecting the undeformed zeolite minerals from the shear zones encountered in the Unit 1 excavation; show sampling locations on the geologic map of FSAR Figure 2.5.1-230; document that such old structures are common in the Piedmont; and summarize the information used to conclude that impoundment of the Monticello Reservoir would not adversely affect the shear zones.

In the responses to RAIs 2.5.1-46 and 2.5.1-55, the applicant provided additional information related to the three localized faults mapped in the Unit 1 excavation. The applicant discussed the controls imposed for sampling undeformed hydrothermal zeolite minerals in the shear zones to document that samples collected and radiometrically dated revealed a minimum age of 45 Ma for last displacement along these shear zones. This radiometric age date, and the fact that there are no known occurrences of hydrothermal zeolite minerals in the Piedmont younger than Mesozoic (251-65.5 Ma), indicates that the shear zones are pre-Quaternary (> 2.6 Ma) structures and, therefore, not capable tectonic features. The applicant provided references documenting that shear zones of the type mapped in the Unit 1 excavation are pre-Mesozoic (> 251 Ma) or older structures which are commonly observed in the Piedmont (Garihan and others, 1993; Secor and others, 1982; Dames and Moore, 1974). The applicant stated that impoundment of the Monticello Reservoir did not induce movement along the shear zones, or along any single structure in the site area, based on the distribution of reservoir-induced earthquakes defined by Secor and others (1982). Secor and others (1982) reported that the scattered microearthquakes reached a peak in 1978 after impoundment of the reservoir in the late 1970s and decayed to background levels in the early 1990s. The applicant indicated that the northwest-striking shears in the Unit 1 excavation were less common than those shears striking northeast, and exhibited minor displacements of 10 cm (4 in) or less. The applicant also stated that the shear zones were observed to penetrate saprolitic bedrock, but not the soil profile overlying the saprolite horizon (Dames and Moore, 1974). The applicant proposed changes to VCSNS COL FSAR Section 2.5.1.2.4 to describe sampling controls and to FSAR Figure 2.5.1-230 to show sampling locations.

In RAI 2.5.1-47, the staff asked the applicant to locate all four larger-scale structures discussed in VCSNS COL FSAR Section 2.5.1.2.4 (i.e., the Wateree Creek and Summers Branch faults, the unnamed postulated fault near Parr, and the Chappells Shear Zone) on the site area geologic map of Figure 2.5.1-224; address timing of displacement for the silicified faults in the site area; and explain why the contact of the Winnsboro plutonic complex is different between the maps produced by different researchers.

In response to RAI 2.5.1-47, the applicant provided additional pertinent information related to the Wateree Creek and Summers Branch faults, the unnamed postulated fault near Parr, and the Chappells Shear Zone. Based on information from Secor (written communication, 2007), Hatcher (2006), Garihan and others (1993), and Secor and others (1998), the applicant stated that silicified faults likely reflect Mesozoic (i.e., >65 Ma) hydrothermal activity, which constrains the timing of last fault displacement to that time frame. The applicant explained that the difference in representation of the contact for the Winnsboro plutonic complex in VCSNS COL FSAR Figure 2.5.1-224 was related to the scale at which the contact was mapped by different workers. Specifically, since the mapping of Secor and others (1982) at 1:24,000 scale did not cover the entire site area, the easternmost edge of FSAR Figure 2.5.1-224 was supplemented by the larger scale (1:500,000) mapping of Horton and Dicken (2001). The applicant proposed modifications to FSAR Figures 2.5.1-224 and 2.5.1-225 for showing the Chappells Shear Zone and the 8-km (5-mi) radius circle defining the site area, respectively, and to FSAR Section 2.5.1.2.4 for clarifying the descriptions of these structures.

Based on review of VCSNS COL FSAR Section 2.5.1.2.4, the applicant’s responses to RAIs 2.5.1-46, 2.5.1-55, and 2.5.1-47, and changes provided by the applicant in Revision 2 of VCSNS COL FSAR Section 2.5.1.2.4, including modifications to FSAR Figures 2.5.1-224, 2.5.1-225, and 2.5.1-230, the staff concludes that the applicant provided sufficient additional information related to the three localized faults mapped in the Unit 1 excavation and the four larger-scale faults mapped or proposed in the site area. The staff draws this conclusion because the applicant discussed in detail the control for collection of samples used to determine that the shear zones are likely not younger than Mesozoic (i.e., >65.5 Ma) in age; located the four larger-scale faults in Figure 2.5.1-224; and qualified the difference in the representation of the contact of the Winnsboro plutonic complex used to constrain displacement on the postulated unnamed fault near Parr. Consequently, the staff considers RAIs 2.5.1-46, 2.5.1-55, and 2.5.1-47 to be resolved.

Based on review of VCSNS COL FSAR Section 2.5.1.2.4, the staff concludes that the applicant provided a thorough and accurate description of structural geology of the site area in support of the VCSNS COL application.

Site Area Engineering Geology

In VCSNS COL FSAR Section 2.5.1.2.5, the applicant discussed engineering geology of the site area.

The NRC staff focused the review of VCSNS COL FSAR Section 2.5.1.2.5 on the adequacy of the structural interpretation for the shear zones mapped in the Unit 1 excavation. In RAI 2.5.1-48, the staff asked the applicant to document the statement in FSAR Section 2.5.1.2.5 that the shear zones reflect regional orientations of joints along which no displacement has occurred. The requested information is important for assessing the potential hazard from the relatively minor shear zones that were mapped in the Unit 1 excavation since the applicant indicated such shear zones may be found in the excavations for VCSNS Units 2 and 3.

In response to RAI 2.5.1-48, based on a regional study of brittle faults and shear zones by Garihan and others (1993), the applicant stated that regional data showed brittle faulting and shearing commonly occurred along pre-existing regional joint sets which trended northeast and northwest. The applicant indicated that minor shear zones and joints in the VCSNS Unit 1 excavation occurred as nearly orthogonal sets of planar structures striking northeast and northwest as illustrated in VCSNS COL FSAR Figure 2.5.1-230 (Dames and Moore, 1974), and that the three most prominent shear zones mapped in the Unit 1 excavation were parallel to the northeast-striking joints. These observed relationships support the interpretation that the shear zones parallel regional, previously-existing joint sets and do not reflect different orientations for the shear zones either regionally or locally.

Based on review of VCSNS COL FSAR Section 2.5.1.2.5 and the applicant's response to RAI 2.5.1-48, the staff concludes that the applicant properly documented that the shear zones mapped in the Unit 1 excavation parallel regional, previously-existing joint sets and do not reflect different orientations for the shear zones either regionally or locally. The staff draws this conclusion because the orientations of the shear zones and existing joint sets are similar. Consequently, the staff considers RAIs 2.5.1-48 to be resolved.

Based on review of VCSNS COL FSAR Section 2.5.1.2.5, the staff concludes that the applicant provided a thorough and accurate description of site area engineering geology in support of the VCSNS COL application.

Site Area Seismicity and Paleoseismicity

In VCSNS COL FSAR Section 2.5.1.2.6, the applicant discussed seismicity and paleoseismicity of the site area.

The NRC staff focused the review of VCSNS COL FSAR Section 2.5.1.2.6 on information used by the applicant to conclude that there is no evidence for post-Miocene (i.e., < 5.3 Ma) earthquake activity in the site area. In RAI 2.5.1-49, the staff asked the applicant to clarify whether an assessment of the presence or absence of paleoliquefaction studies was conducted specifically for Units 2 and 3 and, if so, to indicate types of materials examined and where the investigations were performed for documenting the areas in which no paleoliquefaction features were discovered.

In response to RAI 2.5.1-49, the applicant indicated that searches for materials susceptible to liquefaction and liquefaction features were conducted as part of the geologic field reconnaissance investigations specifically performed for Units 2 and 3. The applicant stated that the investigations included examination of aerial photographs covering the site area; road cuts, outcrops, and creek banks in the site area; and banks of the Broad River. The applicant stated that these efforts indicated a lack of both liquefaction-susceptible materials and liquefaction features in the VCSNS site area, and proposed changes to VCSNS COL FSAR Section 2.5.1.2.6 to provide this information in support of the conclusion that no evidence exits for post-Miocene earthquake activity in the site area.

Based on review of VCSNS COL FSAR Section 2.5.1.2.6, the applicant's response to RAI 2.5.1-49, and the changes provided by the applicant in Revision 2 of VCSNS COL FSAR Section 2.5.1.2.6, the staff concludes that paleoliquefaction evidence is lacking for post-Miocene earthquake activity in the site area. The staff draws this conclusion because the applicant documented the investigations performed to support this statement. Consequently, the staff considers RAI 2.5.1-49 to be resolved.

Based on review of VCSNS COL FSAR Section 2.5.1.2.6, the staff concludes that the applicant provided a thorough and accurate description of seismicity and paleoseismicity of the site area in support of the VCSNS COL application.

Site Groundwater Conditions

In VCSNS COL FSAR Section 2.5.1.2.7, the applicant stated that FSAR Section 2.4.14 includes the detailed discussion of groundwater conditions in the site area.

2.5.1.5 *Post-Combined License Activities*

For the reasons discussed in FSER Section 2.5.1.4.2 ("Site Geology") above, the staff proposes to include the following license condition for geologic mapping of the Unit 3 excavation:

- License Condition 2.5.1-1: The licensee shall perform detailed geologic mapping of the excavation for the VCSNS Unit 3 nuclear island structures; examine and evaluate geologic features discovered in excavations for safety-related structures other than those for the Unit 3 nuclear island; and notify the Director of the Office of New Reactors, or the Director's designee, once excavations for VCSNS Unit 3 safety-related structures are open for examination by the NRC staff.

2.5.1.6 *Conclusion*

The NRC staff reviewed the application and checked the referenced DCD. The staff's review confirmed that the applicant addressed the required information relating to basic geologic and seismic information, and there is no outstanding information expected to be addressed in the VCSNS COL FSAR related to this section. The results of the NRC staff's technical evaluation of the information incorporated by reference in the VCSNS COL application are documented in NUREG-1793 (U.S. NRC, 2004) and its supplements.

As set forth above, the staff has reviewed the information in VCS COL 2.5-1 and finds that the applicant provided a thorough characterization of the geologic and seismic characteristics of the VCSNS site, as required by 10 CFR 100.23 and 10 CFR 52.79(a)(1)(iii). In addition, the staff concludes that the applicant has identified and appropriately characterized all seismic sources significant for determining the GMRS, or SSE, for the COL site, in accordance with NRC regulations provided in 10 CFR 100.23 and 10 CFR 52.79(a)(1)(iii) and the guidance provided in RG 1.208. Based on the applicant's geologic investigations of the site region and site area, the staff concludes that the applicant has properly characterized regional and site lithology, stratigraphy, geologic and tectonic history, and structural geology, as well as subsurface soil and rock units at the site. The staff also concludes that there is no potential for the effects of human activity (i.e., mining activity or ground water injection or withdrawal) to compromise the safety of the site. Therefore, the staff concludes that the proposed COL site is acceptable from a basic geologic and seismic standpoint and meets the requirements of 10 CFR 100.23.

2.5.2 Vibratory Ground Motion

2.5.2.1 *Introduction*

The vibratory ground motion is evaluated based on seismic, geologic, geophysical, and geotechnical investigations carried out to determine the site-specific GMRS, or the SSE ground motion for the site. RG 1.208, defines the GMRS as the site-specific SSE to distinguish it from the certified seismic design response spectra (CSDRS), used as the design ground motion for the various certified designs, as well as the foundation input response spectra (FIRS), which is the site-specific ground motion at the foundation level rather than at the surface. The development of the GMRS is based upon 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. These investigations describe the seismicity of the site region and the correlation of earthquake activity with seismic sources. The applicant identifies and characterizes seismic sources, including the rates of occurrence of earthquakes associated with each seismic source. Seismic sources that cover any portion of the 320 km (200 mi) site radius 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 in 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 VCSNS COL FSAR, Revision 5 incorporates by reference Section 2.5.2 of the AP1000 DCD, Revision 19.

In addition, in VCSNS COL FSAR Section 2.5.2, the applicant provided the following:

AP1000 COL Information Items

- VCS COL 2.5-2

The applicant provided additional information in VCS COL 2.5-2 to resolve COL Information Item 2.5-2 (COL Action Item 2.5.2-1), which addresses the provision for site-specific information related to the vibratory ground motion aspects of the site including: seismicity, geologic and tectonic characteristics, correlation of earthquake activity with seismic sources, PSHA, seismic wave transmission characteristics and the SSE ground motion.

- VCS COL 2.5-3

The applicant provided additional information in VCS COL 2.5-3 to resolve COL Information Item 2.5-3 (COL Action Item 2.6-2), which addresses the provision for performing site-specific evaluations; if the site-specific spectra at foundation level exceed the response spectra in AP1000 DCD Figures 3.7.1-1 and 3.7.1-2 at any frequency, or if soil conditions are outside the range evaluated for the AP1000 DC.

Supplemental Information

- VCS SUP 2.5-2

The applicant provided supplemental information in VCSNS COL FSAR Section 2.5.2 to address the vibratory ground motion assessment for the VCSNS Units 2 and 3 site.

2.5.2.2.1 Seismicity

Updated Seismicity Catalog

VCSNS COL FSAR Section 2.5.2.1 describes the development of a current earthquake catalog for the VCSNS site. The applicant started with the EPRI historical earthquake catalog (EPRI NP-4726-A 1988), which is complete through 1984. To update the EPRI catalog, the applicant used information from the Advanced National Seismic System (ANSS) and the South Eastern United States Seismic Network (SEUSSN).

The EPRI catalog covers the time period from 1627 to 1984 and includes earthquakes that occurred within the CEUS. All earthquakes comprising the EPRI catalog are described in terms of body-wave magnitude (m_b). The applicant converted all earthquakes that were not originally characterized by m_b to best, or expected, estimates of m_b ($E[m_b]$) using conversion factors developed in EPRI NP-4726-A (1988).

The applicant updated the EPRI historical seismicity catalog to incorporate earthquakes that have occurred within the site region since 1984. To update the EPRI catalog, the applicant used a latitude-longitude window of 30° to 38°North (N), 77° to 89°West (W), which incorporated at least the 320-km (200-mi) site radius and all seismic sources contributing significantly to the VCSNS Units 2 and 3 site seismic hazard. The applicant used information from the ANSS and the SEUSSN for the update. Of these two catalogs, the applicant primarily used the SEUSSN catalog for the period from 1985 to 2006. To be consistent with the m_b estimates provided in the EPRI catalog, the applicant converted the magnitudes given in both the SEUSSN and ANSS catalogs to $E[m_b]$. The applicant included a total of 207 events with $E[m_b]$ magnitude greater than 3.0 in the update of the EPRI NP-4726-A (1988) seismicity catalog.

As shown in Figure 2.5.2-1 of this SER, a comparison of the geographic distribution of earthquakes in the EPRI catalog (1627-1984) and the earthquakes in the updated catalog (1985-2006) reveals a very similar spatial distribution. The cluster of events along the coast of South Carolina is related to the Charleston Seismic Zone, while the cluster of events in eastern Tennessee is associated with the ETSZ. The ETSZ extends from southwest Virginia to northeast Alabama. The NMSZ, although located well beyond the 320-km (200-mi) site radius, corresponds to the cluster of events stretching to the southwest from New Madrid, Missouri, to the western part of Tennessee and northeastern Arkansas.

Reservoir-Induced Seismicity

VCSNS COL FSAR Section 2.5.2.1 states that a concentration of seismicity in the VCSNS site area is attributed to the filling of the Monticello Reservoir, which began on December 3, 1977. The reservoir level reached a maximum pond elevation on February 8, 1978. In anticipation of reservoir-induced seismicity, the applicant stated that it installed a microseismic monitoring network in 1977 (three months before the impoundment of the reservoir) to record seismic activity in the area of the VCSNS site and the Monticello Reservoir.

The applicant stated that earthquake activity began in and around the reservoir area on December 25, 1977, about three weeks after filling of the reservoir began. Since the impoundment of the Monticello Reservoir, nearly 10,000 small earthquakes have been recorded. Most of these events occurred in 1978 and 1979. According to the applicant, the largest recorded event had a magnitude M_L 2.8, and none of the recorded events are large enough to include in the applicant's regional seismicity catalog (which is comprised of earthquakes with m_b 3 or larger).

Nearly 20 years after impoundment of the reservoir, the applicant noted that a subsequent increase in seismicity began in December 1996, which resulted in over 700 recorded earthquakes (up to M_L 2.5) by the end of 1999. The applicant also noted that after 1999, the earthquake activity again dropped to background levels. The applicant concluded that this renewed seismicity, which is likely to continue periodically, is still within the level considered acceptable by the earlier studies.

According to the applicant, the reservoir-induced seismicity events extend to a depth of 5 km (3.1 mi) and most events occurred within 3 km (1.9 mi) of the surface. The applicant further stated that the apparent scatter in the locations of the reservoir-induced seismicity events demonstrates that the earthquakes are not located on a single major fault, but instead are located along numerous small fractures that pervade the rock.

In summary, the applicant concluded that reservoir-induced seismicity does not pose any risk or safety issue for VCSNS Units 2 and 3. The applicant also concluded that the impact of the maximum size reservoir-induced seismicity events and their high frequency content on the Unit 1 site have already been considered with the implementation of the Seismic Confirmatory Program in 1983. The applicant further concluded that reservoir-induced seismicity events have occurred at a diminished rate since 1977.

2.5.2.2.2 Geologic and Tectonic Characteristics of the Site and Region

VCSNS COL FSAR Section 2.5.2.2 describes the seismic sources and seismicity parameters that the applicant used to calculate the seismic ground motion hazard for the VCSNS site. Specifically, the applicant described the seismic source interpretations from the 1986 EPRI Project (EPRI NP-4726 1986), relevant post-EPRI seismic source characterization studies, and an updated EPRI seismic source zone for the Charleston area based on more recent data. In addition, an updated seismic source model for the NMSZ is described by the applicant in VCSNS COL FSAR Section 2.5.2.4, which is summarized below.

Summary of EPRI Seismic Sources

The applicant used the 1986 EPRI seismic source model for the CEUS as a starting point for its seismic ground motion calculations. The 1986 EPRI seismic source model is comprised of input from six independent ESTs, which included the Bechtel Group, Dames and Moore, Law Engineering, Rondout Associates, Weston Geophysical Corporation, and Woodward-Clyde Consultants. Each team evaluated geological, geophysical, and seismological data to develop a model of seismic sources in the CEUS. The 1989 EPRI PSHA study (EPRI NP-6395-D 1989) subsequently incorporated each of the EST models. VCSNS COL FSAR Sections 2.5.2.2.1.1 through 2.5.2.2.1.6 provide a summary of the primary seismic sources developed by each of the six ESTs. As stated in FSAR Section 2.5.2.2.1, the 1989 EPRI seismic hazard calculations implemented screening criteria to include only those sources with a combined hazard that exceeded 99 percent of the total hazard from all sources (EPRI NP-6395-D 1989).

Each EST's representation of seismic source zones affecting the ESP site region differs significantly in terms of total number of source zones and source characterization parameters such as geometry and maximum magnitudes (and associated weights). For example, the total number of primary source zones identified by each EST ranged from 2 (Rondout Associates team) to 16 (Law Engineering team). However, all teams identified and characterized one or more seismic source zones or background sources that accounted for seismicity in the vicinity of the VCSNS site. In addition, all of the ESTs identified and characterized one or more seismic source zones to account for the occurrence of Charleston-type earthquakes.

Post-EPRI Seismic Source Characterization Studies

In VCSNS COL FSAR Section 2.5.2.2.2, the applicant described several post 1989 EPRI PSHA studies, which covered many of the seismic sources within the VCSNS site region. The applicant's discussion included the USGS National Seismic Hazard Mapping Project (Frankel et al. 1996, 2002), the South Carolina Department of Transportation (SCDOT) seismic hazard mapping project (Chapman and Talwani 2002), and the NRC's Trial Implementation Project (TIP) Study (Savy et al. 2002). RG 1.208 states that EPRI may be used as a starting point for the PSHA, but it specifies that more recent PSHA studies should be used to determined if updates to the 1989 EPRI PSHA are necessary. These more recent PSHA studies developed models of the Charleston seismic source that differed from those used in the 1989 EPRI PSHA study because they incorporated recent paleoliquefaction data. In addition to describing these more recent PSHAs, in FSAR Section 2.5.2.2.2, the applicant also provided its justification for not updating the EPRI seismic source parameters for the ETSZ, which is located within the 320-km (200-mi) site region radius.

With respect to the ETSZ, the applicant concluded that no new information regarding the ETSZ has been developed since 1986 that would require a significant revision to the original EPRI seismic source model. The applicant noted that despite being one of the most active seismic zones in Eastern North America, no evidence for larger prehistoric earthquakes, such as paleoliquefaction features, has been discovered. The largest earthquake recorded in the ETSZ was a magnitude 4.6 and occurred in 1973. The applicant also noted that a much higher degree of uncertainty is associated with the assignment of M_{max} for the ETSZ than for other CEUS seismic source zones where values of M_{max} are constrained by paleoliquefaction data.

In VCSNS COL FSAR Section 2.5.1.1.3.2.2, the applicant indicated that structures responsible for seismicity in the ETSZ are likely deep-seated Cambrian (543-490 Ma) or Precambrian (>543 Ma) normal faults reactivated in the present-day regional stress field, although seismicity in the zone cannot be attributed to any known fault.

The 1986 EPRI seismic source model (EPRI NP-4726 1986) included various source geometries and parameters to represent the seismicity of the ETSZ. All of the EPRI ESTs, except for the Law Engineering team, represented this area of seismicity with one or more local source zones. The Law Engineering team's Eastern Basement source zone included the ETSZ seismic source zone. With the exception of the Law Engineering team's Eastern Basement source, none of the other ETSZ sources contributed more than 1 percent to the site hazard, and thus were excluded from the final 1989 EPRI PSHA hazard calculations (EPRI NP-6452-D 1989). Upper-bound maximum values of M_{max} developed by the EPRI teams for the ETSZ ranged from **M** 4.8 to 7.5. The applicant found that M_{max} estimates for the ETSZ in more recent studies fall within the range of magnitudes captured by the EPRI model. Bollinger (1992) estimated an M_{max} range of **M** 6.3 to **M** 7.8, while the USGS hazard model (Frankel et al. 2002) assigned a single M_{max} value of **M** 7.5 for the ETSZ. In addition, the NRC's TIP study (Savy et al. 2002) assigned a M_{max} range of **M** 4.5 to **M** 7.5. According to the applicant the **M** 7.8 estimated by Bollinger (1992) slightly exceeds the EPRI range. However, the applicant noted that Bollinger (1992) only assigned a weight of 5 percent to **M** 7.8 and gave most of the weight (i.e., 95 percent) to the **M** 6.3 value.

Updated Seismic Sources

Charleston Seismic Source Zone

Based on the results of several post-EPRI PSHA studies (Frankel et al. 2002; Chapman and Talwani 2002) and the availability of paleoliquefaction data (Talwani and Schaeffer 2001), the applicant updated the EPRI characterization of the Charleston seismic source zone as part of the COL application. The applicant stated that it used the UCSS model to update the Charleston seismic source. The Site Safety Analysis Report (SSAR) for the VEGP ESP site (SNC, 2008) provides the details of the UCSS model and the SER for the VEGP ESP (NUREG-1923) describes the staff's review of the UCSS. The applicant stated that the UCSS model development followed the guidelines provided in RGs 1.165 and 1.208 and used a Senior Seismic Hazard Analysis Committee (SSHAC) Level 2 (SSHAC, 1997) expert elicitation method to incorporate current literature and data and the understanding of experts into an update of the Charleston seismic source model.

The applicant stated that the UCSS model includes four mutually exclusive source zone geometries and associated weights, referred to as A (0.7), B (0.1), B' (0.1), and C (0.1). These geometries, which are depicted in SER Figure 2.5.2-2, are based on: current understanding of geologic and tectonic features in the 1886 Charleston earthquake epicentral region; the 1886 Charleston earthquake shaking intensity; distribution of seismicity; and the geographic distribution, age, and density of liquefaction features associated with both the 1886 and prehistoric earthquakes. The applicant noted that Geometry A coincides with: the 1886 earthquake MMI X (severe damage) isoseismal (Bollinger 1977); the majority of identified Charleston-area tectonic features and inferred fault intersections; the area of ongoing concentrated seismicity; and the area of greatest density for the 1886 and prehistoric liquefaction features. Source zone B encompasses Geometry A and also extends beyond the Northeastern and Southeastern boundaries include paleoliquefaction features mapped by Amick (1990), Amick et al. (1990a, 1990b), and Talwani and Schaeffer (2001) and also extends offshore to include the Helena Banks fault zone. Geometry B' is identical to Geometry B, however it does not include the offshore Helena Banks fault zone. Geometry C envelops the southern segment of the ECFS as depicted by Marple and Talwani (2000).

In order to define the largest earthquake that could be produced by the Charleston seismic source, SNC (2008) developed a distribution for M_{max} based on several post-EPRI (1989) magnitude estimates for the 1886 Charleston earthquake, which are shown in SER Table 2.5.2-1. The SNC (2008) treated M_{max} events within the UCSS according to a characteristic earthquake model, which means that this source repeatedly generates earthquakes, known as characteristic earthquakes, similar in size to M_{max}.

To estimate recurrence for earthquakes with **M** < 6.7, the UCSS model used an exponential magnitude distribution. The SNC (2008) estimated the parameters of this exponential distribution from the earthquake catalog. The SNC (2008) estimated the recurrence of the characteristic earthquakes (i.e., **M** ≥ 6.7) from paleoliquefaction data. The SNC (2008) re-evaluated the data presented by Talwani and Schaeffer (2001) and provided an updated estimate of earthquake recurrence.

Based on its re-evaluation of Talwani and Schaeffer (2001), Southern Nuclear Company (2008) identified six individual paleoearthquakes, including the 1886 Charleston event. Southern Nuclear Company (2008) interpreted the six large paleoearthquakes (1886, A, B, C', E, and F') to represent Charleston-type events that occurred within the past ~5000 years. Furthermore, SNC (2008) determined that the results of its evaluation suggest there have been four large earthquakes in the most recent ~2000-year portion of the earthquake record (1886, A, B, and C').

The SNC (2008) calculated two different average recurrence intervals. The first average recurrence interval is based on the four events (1886, A, B, and C') that SNC (2008)) interpreted to have occurred within the past ~2000 years. According to the applicant, SNC (2008) concluded that this time period represents a complete portion of the paleoseismic record. The average recurrence interval for the ~2000-year record, based on the three most recent inter-event times (1886–A, A–B, B–C'), has a best estimate mean value of 548 years. The SNC (2008) assigned a weight of 0.8 to the logic tree branch representing the recurrence interval calculated for the 2000-year record. The second average recurrence interval is based on events that SNC (2008) interpreted to have occurred within the past ~5000 years and includes events 1886, A B, C', E, and F'. This time period represents the entire paleoseismic record based on available liquefaction data (Talwani and Schaeffer 2001). The average recurrence interval for the ~5000-year record, based on five inter-event times (1886–A, A–B, B–C', C'–E, E–F'), has a best estimate mean value of 958 years. The applicant indicated that the 0.80 and 0.20 weighting of the ~2000-year and 5000-year paleoliquefaction records, respectively, reflect the incomplete knowledge of both the short- and long-term recurrence behavior of the Charleston source.

The applicant stated that the UCSS modeled earthquakes in the exponential part of the distribution as point sources uniformly distributed within the source area, with a constant depth fixed at 10 km. For the characteristic model, SNC (2008) represented source zone Geometries A, B, B', and C by a series of closely spaced, vertical, northeast-trending faults parallel to the long axis of each source zone.

<u>New Madrid Seismic Source Zone</u>

The applicant stated that it also used an updated NMSZ source model. The applicant noted that the NMSZ extends from southeastern Missouri to southwestern Tennessee and is located more than 700 km (435 mi) west of the VCSNS site. The NMSZ produced a series of historical, large-magnitude earthquakes between December 1811 and February 1812; however, the applicant stated that an analysis based on the updated New Madrid source model indicates a minimal contribution to the low frequency hazard at the VCSNS site due to the minimal distance of the NMSZ to the site.

The applicant stated that the updated NMSZ source model described in the SSAR for the Clinton ESP site (Exelon, 2006) formed the basis for determining the potential contribution from the NMSZ to determine the hazard at the VCSNS site. The applicant stated that this model accounts for new information on recurrence intervals for large earthquakes in the New Madrid area, for recent estimates of possible earthquake sizes on each of the active faults, and for the possibility of multiple earthquake occurrences within a short period of time (earthquake clusters).

SER Figure 2.5.2-3 shows the New Madrid faults from the Clinton ESP source model. The applicant stated that the following three sources are identified in the NMSZ, each with two alternative fault geometries, which are provided in parentheses: Southern New Madrid (Blytheville arch/Bootheel Lineament, Blytheville arch/Blytheville Fault Zone); Northern New Madrid (New Madrid North, New Madrid North Plus Extension); and Reelfoot fault (Reelfoot Central Section, Reelfoot Full Length). The applicant stated that earthquakes in the NMSZ are treated as characteristic events in terms of magnitudes (similar to the UCSS model). The applicant stated that the magnitudes and weights for the New Madrid source faults (from the Clinton ESP model [Exelon, 2006]) are provided in VCSNS COL FSAR Table 2.5.2-221. The applicant noted that the characteristic magnitude ranges extend ±0.25 magnitude units above and below the indicated magnitudes in FSAR Table 2.5.2-221.

The applicant stated that seismic hazard is calculated considering the possibility of clustered earthquake occurrences. The applicant computed the hazard using a simplified model in which all three sources rupture during each "event," which results in slightly higher ground motion hazard than if the possibility of two source ruptures is considered, or if a smaller-magnitude earthquake is considered for one of the three ruptures. The applicant stated that the occurrence rate of earthquake clusters is developed using a Poisson model and a lognormal renewal model with a range of coefficients of variation (Exelon, 2006). Consistent with Exelon (2006), the applicant stated that all faults are assumed to be vertical and to extend from the surface to a depth of 20 km and extended rupture on all sources is represented by a finite rupture model.

2.5.2.2.3 Correlation of Earthquake Activity with Seismic Sources

VCSNS COL FSAR Section 2.5.2.3 describes the correlation of updated seismicity with the EPRI seismic source model. The applicant compared the distribution of earthquake epicenters from both the original EPRI historical catalog (1627-1984) and the updated seismicity catalog (1985-August 2006) with the seismic sources characterized by each of the EPRI ESTs. Based on this comparison, the applicant concluded that there are no new earthquakes within the site region that can be associated with a known geologic structure. In addition, it concluded that there are no clusters of seismicity that would suggest a new seismic source not captured by the EPRI seismic source models. The applicant also concluded that the updated catalog does not show a pattern of seismicity that would require significant revision to the geometry of any of the EPRI seismic sources. The applicant further stated that the updated catalog does not show or suggest an increase in M_{max} or a significant change in seismicity parameters (activity rate, b-value) for any of the EPRI seismic sources.

2.5.2.2.4 Probabilistic Seismic Hazard Analysis and Controlling Earthquakes

VCSNS COL FSAR Section 2.5.2.4 presents the results of the applicant's PSHA for the VCSNS site. PSHA is an acceptable method to estimate the likelihood of earthquake ground motions occurring at a site (RG 1.208). The hazard curves generated by the applicant's PSHA represent generic hard-rock conditions (characterized by a shear wave velocity (V_S) of 9200 fps). In FSAR Section 2.5.2.4, the applicant also described the earthquake potential for the site in terms of the most likely earthquake magnitudes and source-site distances, which are referred to as controlling earthquakes. The applicant determined the low-and high-frequency controlling earthquakes by deaggregating the PSHA at selected probability levels. Before determining the controlling earthquakes, the applicant updated the original 1989 EPRI PSHA

(EPRI NP-6395 1989) using the seismic source zone adjustments described in SER Section 2.5.2.1.2, and the new ground motion models described below.

PSHA Inputs

Before performing the PSHA, the applicant updated the original 1989 EPRI PSHA inputs using seismic source zone adjustments to the Charleston and New Madrid seismic source zones as described in VCSNS COL FSAR Section 2.5.2.2. The applicant also performed a sensitivity study to determine whether seismicity rates used in the original 1989 EPRI PSHA (EPRI NP-6395-D 1989) are appropriate for the assessment of the seismic hazard at the VCSNS site. In addition, the applicant used the updated 2004 EPRI (EPRI 1009684) ground motion models instead of the EPRI NP-6395-D (1989) ground motion models used in the original 1989 EPRI PSHA. The applicant also used a revised set of aleatory uncertainties and weights published by Abrahamson and Bommer (2006) to replace the original aleatory uncertainties associated with the 2004 EPRI (EPRI 1009684) ground motion models.

<u>Seismicity Rates</u>

To determine whether the seismicity rates used in the 1989 EPRI PSHA (EPRI NP-6395-D 1989) are appropriate for the assessment of the seismic hazard at the VCSNS site, the applicant assessed seismicity rates for three test areas shown in VCSNS COL FSAR Figure 2.5.2-219: (1) a rectangular area encompassing seismicity in the vicinity of the site; (2) a polygon encompassing seismicity in the region of eastern Tennessee; and (3) a square area encompassing seismicity in the Charleston, South Carolina region. The applicant calculated and compared earthquake recurrence rates for the original EPRI catalog and for the catalog extended through August 2006. These comparisons are shown in FSAR Figures 2.5.2-220 through 2.5.2-222. The applicant concluded that for all three test areas, the resulting earthquake recurrence rates for the extended catalog results in lower estimated earthquake recurrence rates. The applicant further concluded that the earthquake recurrence rates, developed in the EPRI evaluation, adequately and conservatively represent seismicity rates in the vicinity of the VCSNS site.

<u>Seismic Source Model</u>

To update the original EPRI model, the applicant removed the EPRI team Charleston sources from the seismic hazard analysis and replaced them with the UCSS described in the SSAR for the VEGP ESP site (Southern Nuclear Company, 2008). The applicant incorporated the four UCSS alternative source geometries, M_{max}, and recurrence distributions into each of the six EST models. The applicant used an exponential magnitude distribution to model smaller earthquakes (**M** less than 6.7) within the UCSS. To calculate the activity rate and b-value for this distribution, the applicant used the same methodology that was used in the 1989 EPRI study. Specifically, the applicant calculated these seismicity parameters with the EPRI EQPARAM software using the EPRI earthquake catalog through 1984. In addition, the applicant stated that it also modified other EPRI team sources surrounding the Charleston area so that they fully surround the UCSS geometries in order to ensure that no areas in the seismic hazard model are aseismic.

The applicant also included an updated NMSZ source model in the PSHA. The updated New Madrid seismic source model is based on the updated New Madrid seismic source model described in Exelon (2006). The applicant's updated model is summarized in VCSNS COL FSAR Section 2.5.2.2.2.

Ground Motion Models

The applicant stated that it used the ground motion models developed by the 2004 EPRI-sponsored study (EPRI 1009684 2004) for the updated PSHA. The applicant stated that these updated equations estimate median spectral acceleration and its uncertainty as a function of earthquake magnitude and distance. Epistemic uncertainty is modeled using multiple ground motion equations with weights, and using multiple estimates of aleatory uncertainty, also with weights. However, the applicant replaced the original aleatory uncertainties with a revised set of aleatory uncertainties and weights published by Abrahamson and Bommer (2006).

To model the damageability of small magnitude earthquakes to engineered facilities, the applicant implemented the cumulative absolute velocity (CAV) of Hardy et al. (2006). The applicant stated that the CAV model filters out the fraction of small magnitude earthquakes that do not cause damage to engineered structures, and includes in the hazard calculations only those ground motions with a CAV value greater than 0.16g-sec. The applicant stated that the filter that is used is based on empirical ground motion records and depends on ground motion amplitude, duration of the motion (which depends on earthquake magnitude), and a V_S in the top 30 m at the site.

PSHA Methodology and Calculation

For the PSHA calculation, the applicant used the Risk Engineering, Inc. FRISK88 seismic hazard code. This software is different than the one used in the original 1989 EPRI PSHA calculation. For this reason, the applicant first performed a PSHA using the original 1989 EPRI primary seismic sources and ground-motion models in order to validate FRISK88 against the EPRI software EQHAZARD. In VCSNS COL FSAR Table 2.5.2-216, the applicant compared the results from FRISK88 with the original EPRI hard-rock results. The applicant determined that for the mean hazard curves, the current calculation indicates slightly higher hazard, with up to a +6.1 percent difference at 1 g. The applicant further noted that for ground motions associated with typical seismic design levels (i.e., peak ground acceleration [PGA] <0.5 g), the differences are 3.5 percent or less. The applicant stated, however, that differences in hazard are also small for the median hazard, except at large ground motions (PGA ≥0.7 g) where differences of +20 percent and +30 percent are seen. In summary, the applicant concluded that the two sets of values shown in FSAR Table 2.5.2-16 are similar.

Using the updated EPRI seismic source characteristics and new ground-motion models along with the updated aleatory uncertainties as inputs, the applicant performed PSHA calculations for PGA and spectral acceleration at frequencies of 25, 10, 5, 2.5, 1, and 0.5 Hertz (Hz). Following the guidance provided in RG 1.165, the applicant performed PSHA calculations assuming generic hard-rock site conditions (i.e., an V_S of 9200 fps). The applicant determined that this V_S is representative of the VCSNS site geology, and thus used the hard-rock PSHA results directly into its calculation of the GMRS.

PSHA Results

VCSNS COL FSAR Figures 2.5.2-228 through 2.5.2-234 show mean and fractile (i.e., 15^{th}, median, and 85^{th} percentile) seismic hazard curves resulting from the applicant's PSHA calculation for the seven spectral frequencies that are available from the EPRI (2004) ground motion model. SER Figure 2.5.2-4 shows the mean and median uniform hazard response spectra (UHRS) for the 10^{-4} and 10^{-5} annual frequencies of exceedance, which the applicant generated from its seismic hazard curves shown in FSAR Figures 2.5.2-228 through 2.5.2-234. The mean UHRS values for annual frequencies of exceedance of 10^{-4}, 10^{-5}, and 10^{-6} are also provided in FSAR Table 2.5.2-217.

To determine the low- and high-frequency controlling earthquakes for the VCSNS site, the applicant followed the procedure outlined in Appendix C to RG 1.165. This procedure involves the deaggregation of the PSHA results at a target probability level to determine the controlling earthquake in terms of a magnitude and source-to-site distance. The applicant chose to perform the deaggregation of the mean 10^{-4}, 10^{-5}, and 10^{-6} PSHA hazard results. SER Figure 2.5.2-5 shows the results of the applicant's high-frequency (5 to 10 Hz) 10^{-4} hazard deaggregation, while SER Figure 2.5.2-6 shows the results of the low-frequency (1 to 2.5 Hz) 10^{-4} hazard deaggregation. SER Figures 2.5.2-7 and 2.5.2-8 show the results of the 10^{-5} high- and low-frequency hazard deaggregation, respectively.

SER Table 2.5.2-2 provides the mean magnitudes and distances resulting from the applicant's hazard deaggregation. Following the guidance of RG 1.165, the applicant selected the controlling earthquake for the low-frequency ground motions from the R>100-km calculation, and the controlling earthquake for the high-frequency ground motions from the overall calculation. Based on the deaggregation plots shown in VCSNS COL FSAR Figures 2.5.2-236 through 2.5.2-241 and the information provided in FSAR Table 2.5.2-218 the applicant concluded that for the 10^{-4} annual frequency of exceedance, the Charleston seismic source is the largest contributor to the seismic hazard for both 5 and 10 Hz and 1 and 2.5 Hz. The applicant stated that for the 10^{-5} annual frequency of exceedance, the contribution is smaller particularly for high frequencies (where the hazard mainly comes from local sources). The applicant also noted that for an annual frequency of exceedance of 10^{-6}, virtually all of the hazard at high frequency comes from local sources, while low frequencies have about equal contributions from the Charleston seismic source and from local sources.

For the high-frequency mean 10^{-4} hazard, the controlling earthquake is an **M** 6.8 event occurring at a distance of 160 km (99.4 mi) corresponding to an event in the Charleston Seismic Zone. For the high-frequency mean 10^{-5} hazard, the controlling earthquake is an **M** 6.2 event occurring at a distance of 30 km (43.5 mi) corresponding to an earthquake from a local seismic source zone. For the low-frequency mean 10^{-4}, 10^{-5}, and 10^{-6} hazard, the controlling earthquake is an **M** 7.2 event and occurs at a distance of 130 km (80.8 mi). This earthquake corresponds to an event in the Charleston Seismic Zone.

The applicant stated that it developed the smooth 10^{-4} and 10^{-5} UHRS, provided in VCSNS COL FSAR Table 2.5.2-219, from the UHRS amplitudes shown in FSAR Table 2.5.2-217 (also shown in SER Figures 2.5.2-9 and 10), using controlling earthquake magnitude and distance values shown in FSAR Table 2.5.2-218 and the hard-rock spectral shapes for CEUS earthquake ground motions recommended in NUREG/CR-6728, "Technical Basis for Revision of Regulatory Guidance on Design Ground Motions: Hazard- and Risk-Consistent Ground Motion Spectra Guidelines."

The applicant stated that it developed separate hard-rock spectral shapes for high frequencies and low frequencies. The applicant anchored the high-frequency spectral shape to the 10^{-4} UHRS values (i.e., from VCSNS COL FSAR Table 2.5.2-217) at 100 Hz, 25 Hz, 10 Hz, and 5 Hz and in between these frequencies, interpolated the spectrum using a weighting of the spectral shapes anchored to the next higher and lower frequency. For the interpolation, the applicant stated that it used a weighting of the two shapes equal to the inverse logarithmic difference between the intermediate frequency and the next higher or lower frequency. Below

5 Hz, the applicant extrapolated the high-frequency spectral shape from 5 Hz. The applicant stated that it used a similar procedure for the low-frequency spectral shape with the exception that it anchored the low frequency spectral shape to the UHRS values at 2.5 Hz, 1 Hz, and 0.5 Hz. Also, below 0.5 Hz and above 2.5 Hz, the applicant extrapolated the low-frequency spectral shape from these respective frequencies. The resulting 10^{-4} and 10^{-5} high- and low-frequency spectra are shown in SER Figures 2.5.2-9 and 2.5.2-10, respectively. The applicant developed the smooth 10^{-4} UHRS from the envelope of the high- and low-frequency spectra shown in SER Figure 2.5.2-9.

To develop the smooth 10^{-5} UHRS, the applicant repeated the above process using the 10^{-5} UHRS values from VCSNS COL FSAR Table 2.5.2-217, the controlling earthquake magnitude and distance values shown in FSAR Table 2.5.2-218, and the hard-rock spectral shapes for CEUS earthquake ground motions recommended in NUREG/CR-6728. The resulting 10^{-5} high- and low-frequency spectra are shown in SER Figure 2.5.2-10. The applicant then developed the smooth 10^{-5} UHRS from the envelope of the high- and low-frequency spectra shown in SER Figure 2.5.2-10.

2.5.2.2.5 Seismic Wave Transmission Characteristics of the Site

VCSNS COL FSAR Section 2.5.2.4 describes the method used by the applicant to develop the site free-field soil UHRS. The hazard curves generated by the PSHA are defined for generic hard-rock conditions (i.e., characterized by an V_S of 9200 fps based on the EPRI 2004 ground motion model). According to the applicant, the VCSNS Units 2 and 3 site is underlain by weathered and unweathered bedrock, which is characterized by an V_S greater than 8500 fps (refer to SER Figure 2.5.2-11). The applicant stated that the VCSNS Units 2 and 3 site V_S profile is consistent with the hard-rock site classification used for the EPRI 2004 ground motion model (i.e., defined by an V_S of 9200 fps) because there is an uncertainty of several hundred fps in the best estimate of 9200 fps. Thus, the applicant concluded that the smooth 10^{-4} and 10^{-5} rock UHRS, shown in SER Figures 2.5.2-9 and 2.5.2-10 do not need to be modified to account for the effects of local soft rock or soil on seismic wave propagation. The applicant used the smooth 10^{-4} and 10^{-5} rock UHRS directly into its calculation of the GMRS, which is summarized below in SER Section 2.5.2.2.6.

2.5.2.2.6 Ground Motion Response Spectra

SSAR Section 2.5.2.6 describes the method used by the applicant 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, Systems, and Components in Nuclear Facilities and Commentary." The applicant developed the vertical GMRS from the vertical-to-horizontal (V/H) response spectral ratios and resulting 10^{-4} and 10^{-5} vertical UHRS described in VCSNS COL FSAR Section 2.5.2.4.7.

Horizontal Ground Motion Response Spectrum

The applicant developed a horizontal, site-specific, performance-based GMRS using the method described in ASCE/SEI Standard 43-05 and RG 1.208. The performance-based method achieves the annual target performance goal (P_F) of 10^{-5} per year for frequency of onset of significant inelastic deformation. This damage state represents a minimum structural damage state, or essentially elastic behavior, and falls well short of the damage state that would interfere with functionality. The horizontal GMRS (for each spectral frequency), which meets the P_F, is obtained by scaling the smooth rock 10^{-4} UHRS by the design factor (SER Equation 2.5.2-1), or by scaling the smooth rock 10^{-5} UHRS by a factor of 0.45, whichever value is larger.

$$DF = \max\left\{1.0, 0.6\left(A_R\right)^{0.8}\right\} \qquad \text{Equation (2.5.2-1)}$$

In SER Equation 2.5.2-11, the amplitude ratio, AR, is given by the ratio of the smooth rock 10^{-5} UHRS and the smooth rock 10^{-4} UHRS spectral accelerations for each spectral frequency. The resulting horizontal GMRS is shown in SER Figure 2.5.2-11.

Vertical GMRS

The applicant calculated the vertical GMRS using the 10^{-4} and 10^{-5} vertical UHRS. In VCSNS COL FSAR Section 2.5.2.4.7, the applicant stated that it obtained the vertical UHRS by multiplying the horizontal UHRS using scaling factors for hard-rock published in NUREG/CR-6728. The applicant stated that these scaling factors (i.e., V/H response spectral ratios) depend on the PGA of the horizontal motion and are different for the 10^{-4} UHRS and the 10^{-5} UHRS. The applicant noted that categories of V/H ratios in NUREG/CR-6728 are for PGA less than 0.2 g, between 0.2 g and 0.5 g, and greater than 0.5 g. To obtain the vertical GMRS for each spectral frequency, the applicant either scaled the 10^{-4} vertical UHRS by the design factor in SER Equation 2.5.2-1 or scaled the vertical 10^{-5} UHRS by a factor of 0.45, depending on which value is larger. The resulting vertical GMRS is shown in SER Figure 2.5.2-11.

2.5.2.3 *Regulatory Basis*

The regulatory basis of the information incorporated by reference is addressed in NUREG-1793 and its supplements.

In addition, the acceptance criteria associated with the relevant requirements of the Commission regulations for the vibratory ground motion are given in Section 2.5.2 of NUREG-0800.

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. One way to comply with this regulation is by meeting the guidance in RG 1.132, Revision 2 and RG 1.208.

The related acceptance criteria from Section 2.5.2 of NUREG-0800 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 Lawrence Livermore National Laboratory (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 data bases, 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 data base.

- 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.

In addition, the seismic characteristics, including the GMRS, should be consistent with appropriate sections from: RG 1.132, Revision 2; RG 1.206; and RG 1.208.

2.5.2.4 *Technical Evaluation*

The NRC staff reviewed Section 2.5.2 of the VCSNS COL FSAR and checked the referenced DCD to ensure that the combination of the DCD and the COL application represents the complete scope of information relating to this review topic.[1] The NRC staff's review confirmed that the information in the application and incorporated by reference addresses the required information relating to the vibratory ground motion. The results of the NRC staff's evaluation of the information incorporated by reference in the VCSNS COL application are documented in NUREG-1793 and its supplements.

The staff reviewed the information in the VCSNS COL FSAR:

AP1000 COL Information Items

- VCS COL 2.5-2

The NRC staff reviewed VCS COL 2.5-2 related to COL Information Item 2.5-2 (COL Action Item 2.5.2-1), which addresses the provision for site-specific information related to the vibratory ground motion aspects of the site including: seismicity, geologic and tectonic characteristics, correlation of earthquake activity with seismic sources, PSHA, seismic wave transmission characteristics and the SSE ground motion. The COL information item in AP1000 DCD Section 2.5.2.1 states:

> Combined License applicants referencing the AP1000 certified design will address the following site-specific information related to the vibratory ground motion aspects of the site and region: (1) seismicity, (2) geologic and tectonic characteristics of site and region, (3) correlation of earthquake activity with seismic sources, (4) probabilistic seismic hazard analysis and controlling earthquakes, (5) seismic wave transmission characteristics of the site; and (6) SSE ground motion.

- VCS COL 2.5-3

The NRC staff reviewed VCS COL 2.5-3 related to COL Information Item 2.5-3 (COL Action Item 2.6-2), which addresses the provision for performing site-specific evaluations; if the site-specific spectra at foundation level exceed the response spectra in AP1000 DCD Figures 3.7.1-1 and 3.7.1-2 at any frequency, or if soil conditions are outside the range evaluated for AP1000 DC. The COL information item in AP1000 DCD Section 2.5.2.3 states:

> The Combined License applicant may identify site-specific features and parameters that are not clearly within the guidance provided in subsection 2.5.2.1. These features and parameters may be demonstrated to be acceptable by performing site-specific seismic analyses. If the site-specific spectra at foundation level at a hard rock site or at grade for other sites exceed the certified seismic design response spectra in Figures 3.7.1-1 and 3.7.1-2 at any frequency, or if soil conditions are outside the range evaluated for AP1000 design certification, a site-specific evaluation can be performed. These analyses may be either 2D or 3D. Results will be compared to the corresponding 2D or 3D generic analyses.

Supplemental Information

- VCS SUP 2.5-2

The applicant provided supplemental information in VCSNS COL FSAR Section 2.5.2 to address the vibratory ground motion assessment for the VCSNS Units 2 and 3 site.

SER Section 2.5.2.4 provides the NRC staff's evaluation of the seismic, geologic, geophysical, and geotechnical investigations carried out by the applicant to determine the site-specific GMRS or the SSE ground motion for the site. The development of the GMRS is based upon 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.

During the early site investigation stage, the staff visited the site and interacted with the applicant regarding the geologic, seismic and geotechnical investigations conducted for the VCSNS COL application. To thoroughly evaluate the geologic, seismic, and geophysical information presented by the applicant, the staff obtained additional assistance from experts at the USGS. The staff, with its USGS advisors, made an additional visit to the VCSNS site in April 2009, to confirm interpretations, assumptions, and conclusions presented by the applicant related to potential geologic and seismic hazards. The staff's evaluation of information presented by the applicant in VCSNS COL FSAR Section 2.5.2 and of the applicant's responses to RAIs is presented below.

2.5.2.4.1 Seismicity

VCSNS COL FSAR Section 2.5.2.1 describes the development of a current earthquake catalog for the VCSNS site. The applicant started with the EPRI historical earthquake catalog (EPRI NP-4726-A 1988), which is complete though 1984. To update the earthquake catalog, the applicant used information from the ANSS and SEUSS. FSAR Section 2.5.2.1 also describes the seismicity associated with the impoundment of the nearby Monticello reservoir.

Update of EPRI Earthquake Catalog

The staff focused its review of VCSNS COL FSAR Section 2.5.2.1 on the adequacy of the applicant's description of the historical record of earthquakes in the site region. In RAI 2.5.2-4, the staff asked the applicant to provide electronic versions of the EPRI seismicity catalog (EPRI NP-4726-A 1988) for the region of interest (30° to 38°N, 77° to 89°W), as well as its updated seismicity catalog. In response to RAI 2.5.2-4, the applicant provided the staff with electronic copies of the EPRI-SOG seismicity catalog as well as the updated seismicity.

In its review, that staff evaluated the applicant's updated earthquake catalog (provided in response to RAI 2.5.2-4) by comparing the applicant's earthquake catalog to a compilation catalog derived from the USGS seismicity catalogs. The catalog from March 1985 to August 2006 is shown in SER Figure 2.5.2-12 as the red circles. The applicant's updated seismicity catalog is illustrated by the blue circles, which covers March 1985 to August 2006. The comparison of these datasets illustrates that the applicant's updated earthquake catalog adequately characterizes the seismicity within and around the VCSNS Unit 3 site region. The yellow circles in SER Figure 2.5.2-12 illustrate the seismicity from the USGS catalog covering August 2006 to April 2010. This recent seismicity does not show any significant deviations from the applicant's seismicity catalogs. Therefore, the staff concludes that the VCSNS Unit 3 earthquake catalog adequately characterizes the regional and local seismicity through April 2010.

In RAI 2.5.2-5, the staff asked the applicant why it used the SEUSSN catalog as the preferred catalog to update the EPRI earthquake catalog (1988) instead of the ANSS catalog since the ANSS catalog covers the site region. In its response, the applicant stated that it used both the SEUSSN and the ANSS catalogs for the temporal update (1985 to present) of the EPRI (1988) seismicity catalog. The applicant noted that the SEUSSN catalog, which has coverage over the entire project region (30°N to 38°N, 77°W to 89°W) is, according to the ANSS web page (http://www.ncedc.org/anss/cnss-detail.html), the "authoritative" source used to compile the national ANSS seismicity catalog in this region and was preferred. Specifically, the applicant incorporated earthquakes from the ANSS catalog that were not already included in the SEUSSN in its updated seismicity catalog.

The staff concludes that the applicant's response to RAI 2.5.2-5 is adequate because according to the ANSS website: "Each seismic network that contributes catalog data to the ANSS composite catalog is assigned a geographic region where that network's solution (location and magnitude) for earthquakes is considered "*authoritative."* This means that if that network locates an earthquake in its authoritative region, the network's solution is considered to be the "best" solution, and its solution is guaranteed to be in the catalog." The ANSS website lists the SEUSSN catalog as the authoritative catalog for the region that encompasses the latitude-longitude window of 30° to 38°N, 77° to 89°W that the applicant used for its update. Furthermore, based on its review of the applicant's response to RAI 2.5.2-4, which included a comparison with the USGS seismicity catalog, the staff concludes that the applicant's updated seismicity catalog is complete and provides a conservative estimate of earthquake magnitudes and locations for the VCSNS site region.

Earthquake Magnitude Conversion

All earthquakes comprising the EPRI catalog are described in terms of m_b. The applicant converted all earthquakes that were not originally characterized by m_b to best, or expected, estimates of m_b ($E[m_b]$) using conversion factors developed in EPRI NP-4726-A (1988). In

RAI 2.5.2-6, the staff asked the applicant to justify the use of FSAR Equations 2.5.2-1 and 2.5.2-2, which the applicant used to convert magnitudes in its updated catalog to EPRI best-estimate values of m_b. The staff asked for this justification because these equations are based on magnitude data acquired more than 20 years ago. In addition, the staff asked the applicant whether or not the value of b=1.0, used in FSAR Equation 2.5.2-3, is supported by regional seismicity data.

In response to RAI 2.5.2-6, the applicant stated that there are relatively few data occurring after 1984 with which to supplement the rigorous statistical analysis done by EPRI (EPRI NP-4726-A, 1988) for the original EPRI seismicity catalog. The applicant noted that in VCSNS COL FSAR Table 2.5.2-202, which lists the earthquakes in the region occurring since 1984, there are only about 10 events with both E_{mb} values determined from M_d using FSAR Equation 2.5.2-1 and an alternate and independent m_b value. The applicant further noted that the trend of these values, although too small in number to confidently determine an alternate conversion relation, suggests a slightly lower E_{mb} value than assigned using FSAR Equation 2.5.2-1. The applicant stated that the E_{mb} values adopted for the update of the EPRI catalog are reasonable for their purpose: to investigate whether the recurrence parameters or maximum magnitudes used in the original EPRI study need to be modified on the basis of more recent seismicity. With respect to the b-value, the applicant stated that in EPRI (EPRI NP-4726-A, 1988) a b-value of 1.0 was used to determine uniform magnitude, m_b*, in the EPRI seismicity catalog. The applicant stated that it used b=1 in the FSAR updated seismicity catalog when using FSAR Equation 2.5.2-3 for consistency in the methodology. The applicant referred to FSAR Figures 2.5.2-220, 2.5.2-221, and 2.5.2-222, and stated that these figures show that b=1.0 is a reasonable global b-value for the purposes of evaluating m_b* and is consistent with b-values of about 0.95 to 1.1 found for regional seismicity for both the EPRI and updated EPRI catalogs as measured from these figures. In addition, the applicant stated that although E_{mb} values for earthquakes in the updated portion of the catalog are derived from several directly reported magnitude scales, all have been assumed to have uncertainties represented by standard deviations between 0.1 and 0.41. For σ values in this range, and for b-values between 0.95 and 1.1, the correction to E_{mb} from Equation 2.5.2-3 of the FSAR is 0.02 or less indicating that the use of a b-value of 1.0 is not critical.

After review of the applicant's response, the staff, in RAI 2.5.2-23 requested the applicant to clarify the statement: "For σ values in this range, and for b-values between 0.95 and 1.1, the correction to E_{mb} from Equation 2.5.2-3 of the FSAR is 0.02 or less indicating that the use of a b-value of 1.0 is not critical," since E_{mb} is derived from FSAR Equations 2.5.2-1 and 2.5.2-2, and not FSAR Equation 2.5.2-3. In addition, the staff asked the applicant to clarify what is meant by the statement "…E_{mb} values for earthquakes in the updated portion of the catalog are derived from several directly reported magnitude scales…"

In response, the applicant stated that it is the b-value of FSAR Equation 2.5.2-3 that is addressed in this part of the response to RAI 2.5.2-6, not the estimation of E_{mb} using FSAR Equations 2.5.2-1 and 2.5.2-2. The applicant stated that once the best estimate, or E_{mb}, values have been found, these values are adjusted through the use of FSAR Equation 2.5.2-3 to get R_{mb} which, according to the EPRI (NP-4726-A, 1988) methodology, is a more statistically appropriate magnitude to use in earthquake recurrence regression analysis. The applicant further stated that in FSAR Equation 2.5.2-3, the adjustment to E_{mb} depends, in part, on an estimate of uncertainty in the data used to calculate E_{mb}. In the EPRI methodology this estimate of uncertainty, σ, is made on the basis of what data were used to develop the E_{mb} estimate. According to the applicant, these data may be intensity, felt area, local magnitude (M_L), duration magnitude (M_d), m_b or some combination of these parameters. For the updated portion of the catalog all earthquakes had either a published M_d, M_L, or m_b value. Therefore, E_{mb} values were estimated from "directly reported" magnitudes.

The staff concludes that RAI 2.5.2-23 is resolved because the applicant provided adequate clarification of the referenced statements. With these clarifications, the staff was then able to review applicant's response to RAI 2.5.2-6, which is summarized above. The staff concludes that the applicant's use of a b-value of 1 is appropriate. VCSNS COL FSAR Figures 2.5.2-220, 2.5.2-221, and 2.5.2-222 show b-values in the range of 0.95 to 1.1 and thus that b=1.0 is a reasonable global b-value for the purposes of evaluating m_b*.

The staff concludes that the use of FSAR Equations 2.5.2-1 and 2.5.2-2 are appropriate because there are relatively few data occurring after 1984 with which to supplement the rigorous statistical analysis done by EPRI (EPRI NP-4726-A, 1988). The applicant noted that in VCSNS COL FSAR Table 2.5.2-202, there are only about 10 events with both E_{mb} values determined from M_d using FSAR Equation 2.5.2-1 and an alternate and independent m_b value. The applicant further noted that the trend of these values, although too small in number to confidently determine an alternate conversion relation, suggests a slightly lower E_{mb} value than assigned using FSAR Equation 2.5.2-1. All of the E_{mb} values determined from M_L and FSAR Equation 2.5.2-2 are obtained from the ANSS catalog, which presents only a single magnitude field, precluding investigation of an $E_{mb}(M_L)$ trend considering these data. Therefore, the staff concludes that RAI 2.5.2-6 is resolved.

In RAI 2.5.2-4, the staff asked the applicant to clarify the method it used to convert the various earthquake magnitudes scales (i.e., M_L and M_d) to body-wave magnitude (m_b) scale. Specifically, the staff asked the applicant to confirm whether or not it derived the values for the variability of earthquake body-wave magnitude, σ_{mb}, (in FSAR Equation 2.5.2-3) from the original EPRI seismicity catalog or the updated seismicity catalog. In response, the applicant stated that it used the values for σ_{mb} from the original 1988 EPRI catalog. However, because the staff concluded that the applicant's response did not include a discussion as to whether these σ_{mb} values are appropriate to use for the new seismicity data, in RAI 2.5.2-22, the staff asked the applicant to provide justification for the use of the σ_{mb} values from the original 1988 EPRI catalog for the updated seismicity in the region. The staff also requested that the applicant provide the updated seismicity catalog with the original magnitude values, as well as the converted magnitude values, in order for the staff to verify the conversions. In its response, the applicant stated that the parameter σ_{mb} is obtained from the regression equations for converted values when direct instrumental values for m_b are not available. The applicant noted that there are very few data occurring after 1984 with which to supplement the rigorous statistical analysis done by EPRI (VCSNS COL FSAR Section 2.5.2). In the updated catalog there are only 10 events with both the selected E_{mb} values determined from M_d using FSAR Equation 2.5.2-1 and an alternate and independent m_b value. All of the E_{mb} values determined from M_L and FSAR Equation 2.5.2-2 are obtained from the ANSS catalog, which presents only a single magnitude field, precluding investigation of an $E_{mb}(M_L)$ trend considering these data. An attempt to improve the EPRI E_{mb} equations and their associated σ_{mb} values for the recent period of the updated seismicity would not be meaningful with these few new data. The EPRI seismicity catalog and the magnitude conversion relations developed from that database are still considered to be an adequate characterization of seismicity in the CEUS through 1984. In response to RAI 2.5.2-22, the applicant also provided a table of the updated seismicity catalog, which included the original magnitude values as well as the converted magnitude values.

The staff reviewed the applicant's response to RAI 2.5.2-22 and concluded that the use of the original EPRI σ_{mb} values is appropriate because there is not enough data to develop new values. The staff also reviewed the catalog of the updated seismicity with the original magnitude values as well as the converted magnitude values and was able to verify these values. Thus, the staff concludes that RAI 2.5.2-4 and RAI 2.5.2-22 are resolved.

Reservoir-Induced Seismicity

The staff also focused its review of VCSNS COL FSAR Section 2.5.2.1 on the adequacy of the applicant's evaluation of reservoir-induced seismicity associated with the nearby Monticello reservoir. VCSNS COL FSAR Section 2.5.2.1.3 states an initial surge of reservoir-induced seismicity was associated with the initial filling of the reservoir in 1977 but subsequent intervals of increased seismicity have also occurred in succeeding years. In RAI 2.5.2-7, the staff asked the applicant to explain if the reservoir seismicity correlated with water level changes in the Monticello Reservoir. The staff also asked the applicant to explain whether the recent upsurge in seismicity starting in 1996 correlated with any change in the water level. In response to RAI 2.5.2-7, the applicant stated that beyond the initial occurrence of reservoir-induced seismicity, which was associated with the initial filling of Monticello Reservoir in 1977-1978, there has been no correlation between reservoir-induced seismicity activity and changes in water level within the impoundment, including the increase in activity in 1996. The applicant noted that Dr. Pradeep Talwani, at the University of South Carolina and a prominent researcher of reservoir-induced seismicity in the southeastern United States, has evaluated reservoir-induced seismicity activity at Monticello Reservoir since 1977, including pre-impoundment activity for the period 1974-77. SCE&G has interactively worked with Dr. Talwani since the mid-1970s and provided data on daily water fluctuations of Monticello Reservoir and Parr Reservoir, located within a few kilometers to the north and east, respectively, of the VCSNS site. After approximately 30 years of study, SCE&G is not aware that Dr. Talwani has ever been able to conclusively correlate water level changes in Monticello Reservoir, rainfall data, or flood conditions in Parr Reservoir to any specific increases in seismicity activity. Additionally, the applicant noted that the fluctuation of water level in Monticello Reservoir is limited to a maximum change of 4.5 ft (1.4 m) per day based on Federal Energy Regulatory Commission operating license controls that establish the upper water level at 425 ft (130 m) msl and the lower water level of 420.5 ft (128 m) msl. Therefore, based on over 30 years of observations, the applicant concluded that this relatively small change in water level in Monticello Reservoir has an insignificant affect on reservoir-induced seismicity activity.

The staff reviewed the applicant's response to RAI 2.5.2-7, and in RAI 2.5.2-24, requested the applicant to provide data or documentation to support Dr. Talwani's conclusion that water level changes in the Monticello Reservoir have not been correlated with any reservoir-induced seismicity. In response to RAI 2.5.2-24, the applicant stated that from 1981 through 1995, Dr. Talwani prepared quarterly reports, which provided the updated data and conclusions from his studies of reservoir-induced seismicity near the VCSNS site. The applicant noted that SCE&G transmitted these reports on a periodic basis. The applicant also noted that as the years progressed, the reports concluded that there was no observed systematic correlation between the reservoir level fluctuations and seismicity in the area. The staff concludes that RAI 2.5.2-24 and RAI 2.5.2-7 are resolved since the applicant referenced specific documentation to support Dr. Talwani's conclusions that that water level changes in the Monticello Reservoir have not been correlated with any reservoir-induced seismicity.

VCSNS COL FSAR Section 2.5.2.1.3 states that Unit 1 was required to have a margin of safety by design for a magnitude 5.0 event associated with reservoir-induced seismicity. In

RAI 2.5.2-8, the staff asked the applicant to confirm whether this is also the case for Units 2 and 3. In addition, the staff noted that the reservoir-induced seismicity events do not appear to be included in the updated seismicity catalog and expressed concern that ground motion from events of this size could be removed from the design process by the CAV filter. In response to RAI 2.5.2-8, the applicant stated the following:

1. The magnitude 5.0 event (as described in VCSNS COL FSAR Section 2.5.2.1.3) was suggested by expert opinion during the NRC's Advisory Committee on Reactor Safeguards (ACRS) hearings for Unit 1 to be an upper bound estimate of the largest earthquake that could potentially occur as a result of reservoir-induced seismicity activity due to the impoundment of Monticello Reservoir. In NUREG-0717, "Safety Evaluation Report Related to the Operation of the Virgil C. Summer Nuclear Station Unit No. 1, Docket No. 50-395," Section 2.5.3, "Maximum Earthquake Associated with Reservoir Impoundment at Monticello Reservoir," (February 1981), the NRC staff chose a magnitude 4.5 earthquake as the largest reservoir-induced event likely to occur. This postulated event was subsequently characterized by the applicant as a magnitude 4.5 earthquake of normal tectonic depth anchored to a zero period acceleration (ZPA) of 0.22 g. In NUREG-0717, Supplement 4 (August 1982), the NRC staff found the applicant's characterization of this earthquake to be conservative. Although this earthquake exceeded the Unit 1 SSE design response spectrum at frequencies generally above 10 Hz, it was subsequently shown to have an insignificant impact on plant components required for safe shutdown. These results were documented and submitted to NRC in the following reports, which satisfied the Unit 1 Operating License Condition 2.C(25): (1) Seismic Confirmatory Program, Virgil C. Summer Nuclear Station Unit 1, OL No. NPF-12, February 1983; and (2) Seismic Confirmatory Program Equipment Margin Study, Virgil C. Summer Nuclear Station Unit 1, OL No. NPF-12, November 1983. This postulated reservoir-induced seismicity earthquake was evaluated solely for Unit 1 and is not a design requirement for Units 2 and 3. Additionally, the applicant noted that the Westinghouse AP1000 CSDRS, anchored to a ZPA of 0.30 g, easily bounds this postulated reservoir-induced seismicity event.

2. The Monticello Reservoir reservoir-induced seismicity events, which have occurred since late 1977, have all been small, with the largest earthquakes of magnitude 2.8 occurring in 1978 and 1979. Since the updated seismicity catalog only considered earthquakes of magnitude 3.0 and larger, none of the reservoir-induced seismicity events would be included. The magnitude 5.0 event discussed in VCSNS COL FSAR Section 2.5.2.1.3 was only a postulated event for engineering design considerations as part of the ACRS evaluations for Unit 1.

The staff reviewed the applicant's response to RAI 2.5.2-8 as well as NUREG-0717 and concluded that the response is adequate since the Westinghouse AP1000 CSDRS, anchored to a ZPA of 0.30 g, bounds this postulated reservoir-induced seismicity event. Furthermore, since the impoundment of the Monticello Reservoir, in late 1977, the largest earthquake has been a magnitude 2.8 event.

Earthquake Recurrence Parameters

To determine whether the seismicity rates used in the EPRI study (EPRI NP-6395-D 1989) are appropriate for the assessment of the seismic hazard at the VCSNS site, the applicant used three test areas shown in VCSNS COL FSAR Figure 2.5.2-219: (1) a rectangular area encompassing seismicity in the vicinity of the site; (2) a polygon encompassing seismicity in the region of eastern Tennessee; and (3) a square area encompassing seismicity in the Charleston, South Carolina region. The applicant calculated and compared earthquake recurrence rates for the original EPRI catalog and for the catalog extended through 2006. These comparisons are shown in VCSNS COL FSAR Figures 2.5.2-220 through 2.5.2-222. The applicant concluded that for all three test areas, the earthquake recurrence rates for the extended earthquake catalog result in lower estimated earthquake recurrence rates compared to rates determined from the original EPRI catalog. Therefore, the applicant concluded that the earthquake recurrence rates, developed in the original EPRI evaluation, adequately and conservatively represent seismicity rates in the vicinity of the VCSNS site.

Based on the applicant's evaluation of multiple areas and its determination that seismicity rates in the region have not increased since 1985 for any of these selected areas, the staff concludes that the applicant's use of the EPRI seismicity rates is appropriate and that these rates are appropriate for the assessment of the seismic hazard at the VCSNS site.

Staff Conclusions Regarding Seismicity

Based upon its review of VCSNS COL FSAR Section 2.5.2.1, the staff concludes that the applicant developed a completed and accurate earthquake catalog for the region surrounding the VCSNS site. The staff concludes that the seismicity catalog as described by the applicant in FSAR Section 2.5.2.1 forms an adequate basis for the seismic hazard characterization of the site and meets the requirements of 10 CFR 52.79 and 10 CFR 100.23.

2.5.2.4.2 Geologic and Tectonic Characteristics of the Site and Region

VCSNS COL FSAR Section 2.5.2.2 describes the seismic sources and seismicity parameters used by the applicant to calculate the seismic ground motion hazard for the VCSNS site. Specifically, the applicant described the seismic source interpretations from the 1986 EPRI Project (EPRI NP-4726), relevant post-EPRI seismic source characterization studies, and its updated EPRI seismic source zone for the Charleston area (UCSS). The staff previously reviewed and approved the UCSS as part of its review of the VEGP ESP application (NUREG-1923, "Safety Evaluation Report for an Early Site Permit (ESP) at the Vogtle Electric Generating Plant (VEGP) ESP Site"). RG 1.208 specifies that applicants may use the 1986 EPRI seismic source model as a starting point for characterizing regional seismic sources. As such, the staff focused on the applicant's investigation of post-EPRI seismic source studies and its decision to either use the original EPRI source models or updated source models.

Summary of EPRI Seismic Sources

VCSNS COL FSAR Sections 2.5.2.2.1.1 through 2.5.2.2.1.6 provide a summary of the primary seismic sources developed in the 1980s by each of the six EPRI ESTs. Each EST described its set of seismic source zones for the CEUS in terms of source geometry, probability of activity, recurrence, and M_{max}. Each EPRI EST identified one or more seismic source zones that include the VCSNS site. In VCSNS COL FSAR Section 2.5.2.2.1.2 and Table 2.5.2-204, the Dames and Moore EST source characterization parameters derived for the EPRI/SOG assessment are presented for Zones 41 (the Southern Cratonic Margin) and 53 (the Southern Appalachian Mobile Belt). Relatively low probabilities were assigned to these two zones by the Dames and Moore EST. In RAI 2.5.2-3, the staff asked the applicant to justify the source characterization parameters used by the Dames and Moore EST for Zones 41 and 53 to assess seismic hazard of the region surrounding the VCSNS site. In response, the applicant stated that industry strongly believes that the integrity of the original EPRI/SOG ESTs should be maintained as part of the individual site seismic hazard evaluations in order to provide the diversity and range of interpretations of the scientific community. In addition, the applicant performed a sensitivity study to compare total mean seismic hazard at the VCSNS site to mean seismic hazard calculated by simply removing the Dames and Moore team's contribution and averaging the results from the remaining five ESTs. The applicant stated that the results of its sensitivity study show that deleting the Dames and Moore team's contribution increases the hazard at the original GMRS amplitudes by between 0.8 percent (at 0.5 Hz) and 8.4 percent (at 100 Hz). The applicant noted that discarding the Dames and Moore team's contribution incorporates not only any effects from alternative characterization of probability of activity for Dames and Moore source Zones 41 and 53, but also any relative differences between the Dames and Moore's model for the Charleston source and the Charleston source models of the remaining ESTs. The applicant further noted that for the VCSNS site, contributions to total hazard from Dames and Moore source Zones 41 and 53 are much less than from the Charleston sources; therefore, modifications to the probability of activity of these zones is relatively insignificant. That is, because the Dames and Moore total hazard for the VCSNS site is somewhat less than for the remaining ESTs, and because this team's relative contribution to total hazard at the VCSNS site has little to do with Dames and Moore source Zones 41 and 53, elimination of the Dames and Moore team's contribution exaggerates the effect of modifying the probability of Zones 41 and 53.

The staff reviewed the applicant's response to RAI 2.5.2-3 and identified a discrepancy between the applicant's RAI response and the VCSNS COL FSAR text. Specifically, the applicant, in its RAI response stated "It should be noted that discarding the Dames & Moore team's contribution incorporates not only any effects from alternative characterization of probability of activity for Dames & Moore source Zones 41 and 53, but also any relative differences between the Dames & Moore's model for the Charleston source and the Charleston source models of the remaining ESTs." However, VCSNS COL FSAR Section 2.5.2.4.4 states that "these EPRI team Charleston sources were removed from the seismic hazard analysis." The FSAR also states that the EPRI team Charleston sources were then replaced by the UCSS model. Thus, in RAI 2.5.2-21, the staff asked the applicant to address the discrepancy between the response to RAI 2.5.2-3 and the FSAR text. In response to RAI 2.5.2-21, the applicant stated that the implication in its response to RAI 2.5.2-3 that the original EPRI EST Charleston seismic source models were included in the seismic hazard analysis is incorrect. In its response, the applicant confirmed that the UCSS model was used instead of the original EPRI-SOG Charleston seismic source models for all ESTs so that the contribution to earthquake hazard at the VCSNS site from all EST's is the same. The applicant also stated that the fundamental conclusion drawn in response to RAI 2.5.2-3; "deleting the Dames & Moore team from the V. C. Summer seismic hazard analysis would not lead to a significant change in hazard at the GMRS amplitudes," under the proposed criterion for "significance" given, also remains correct.

As stated above in response to RAI 2.5.2-3, the results of the applicant's sensitivity study showed that deleting the Dames and Moore team's contribution only increases the hazard at the original GMRS amplitudes by between 0.8 percent (at 0.5 Hz) and 8.4 percent (at 100 Hz). Thus, in spite of the issues identified in RAI 2.5.2-3, that the Dames and Moore team did not adequately characterize the regional seismic hazard, the staff considers RAIs 2.5.2-3 and 2.5.2-21 resolved because the Dames and Moore team's contribution to the total mean hazard at the VCSNS site is not significant and the applicant confirmed that it used the UCSS model rather than the original EPRI EST Charleston seismic source models.

VCSNS COL FSAR Section 2.5.2.2.1.5 describes the source zones developed by the Weston Geophysical team for the EPRI PSHA. RAI 2.5.2-10 relates to a discrepancy between the text on FSAR page 2.5.2-16 and FSAR Table 2.5.2-207. Specifically, FSAR page 2.5.2-26 states "The largest M_{max} assigned by the Weston Geophysical team to these combination zones is m_b 6.6 (**M** 6.5)." However, in VCSNS COL FSAR Table 2.5.2-207 (page 2.5.2-69), the M_{max} for combination zone C33 is listed as m_b 7.2 at 10 percent weight. The staff thus asked the applicant to address this discrepancy. In response, the applicant stated that FSAR Table 2.5.2-207 correctly states the M_{max} distributions for Weston Geophysical's combination zones, while FSAR Section 2.5.2.2.1.5 incorrectly states the largest M_{max} value assigned by Weston Geophysical to their combination zones. In addition, the applicant stated that this error has no effect on downstream analyses performed for the VCSNS Units 2 and 3 site and that it intends to revise FSAR Section 2.5.2.2.1.5 to correctly state that the M_{max} upper-bound for Weston Geophysical combination zones is m_b 7.2 (**M** 7.5). The staff concludes that the applicant’s response to RAI 2.5.2-10 is adequate because the discrepancy is the result of a typographical error and has no effect on any of the applicant’s subsequent analyses. Furthermore, the applicant updated the FSAR accordingly.

Post-EPRI Seismic Source Characterization Studies

VCSNS COL FSAR Section 2.5.2.2.2 describes three PSHA studies that were completed after the 1989 EPRI PSHA and which involved the characterization of seismic sources within the VCSNS site region. These three studies include the USGS National Seismic Hazard Mapping Project (Frankel et al. 1996, 2002), the SCDOT seismic hazard mapping project (Chapman and Talwani 2002), and the NRC TIP study (NUREG/CR-6607, “Guidance for Performing Probabilistic Seismic Hazard Analysis for a Nuclear Plant Site: Example Application to the Southeastern United States”). The applicant provided a description of both the USGS and SCDOT models, as well as a comparison of these more recent studies with the EPRI source PSHA models.

U.S. Geological Survey

The USGS has developed a PSHA for areas of the CEUS that encompass the VCSNS site region. FSAR Section 2.5.2.2.2.1 provides a description of the USGS study and a comparison of its seismic source model parameters with the 1989 EPRI PSHA. The USGS produces seismic hazard maps on a six-year cycle based on its PSHA for the continental United States. These hazard maps are primarily intended for national building codes and standards and not for critical facilities such as nuclear power plants. The USGS hazard maps target 500 to 2500 year ground motion return periods. In contrast, RG 1.208 specifies that the GMRS developed for nuclear power plant siting have a minimum ground motion return period of 10,000 years.

USGS 2002 Hazard Map

The applicant described the 2002 USGS PSHA used to produce the seismic hazard maps and compared the source model parameters such as maximum magnitude, probability of activity, recurrence rate, as well as the source geometries with the EPRI PSHA. The primary difference between the USGS and EPRI PSHAs are the number of source zones used to characterize the seismic hazard for the CEUS. The USGS uses two regional source zones referred to as the extended margin and stable craton background zones. In addition to these large zones, the USGS also models the Charleston and New Madrid sources using paleoliquefaction data. For the extended margin background zone, the USGS defines a single maximum magnitude value of 7.5. In contrast, EPRI developed multiple source models for the eastern seaboard and

Appalachians with a range of maximum magnitudes, recurrences, and probabilities of activity. The staff reviewed the EPRI source model parameters and found that the overall mean maximum magnitude is about 6.2. Based on this comparison of seismic source model parameters outside of the major Charleston source, the staff concludes that an overall magnitude of 6.2 together with the multiple source zone geometries, maximum magnitudes, and recurrences better reflects the large uncertainty in the region. For the Charleston source, the USGS uses a similar maximum magnitude range and recurrence interval as the UCSS, which is described in this section below.

USGS 2008 Hazard Map

The applicant did not have access to the PSHA used by the USGS to develop the 2008 update of the seismic hazard map. This update is described in USGS Open-File Report 2008-1128, "Documentation for the 2008 Update of the United States National Seismic Hazard Maps." As part of its review of the applicant's PSHA using the updated EPRI source model, the staff reviewed the 2008 USGS updates. For its 2008 PSHA, the USGS uses a range of maximum magnitudes from 7.1 to 7.7 (7.1 (0.1), 7.3 (0.2), 7.5 (0.5), 7.7 (0.2)) for the large extended margin background zone rather than a single value of 7.5. In addition for the Charleston source, the USGS extended the southeastern edge of the larger source zone offshore to enclose the Helena Banks fault zone. In addition to updating its source models, the USGS also updated its ground motion prediction equations for the 2008 hazard maps. The net result of these changes is an overall 10 to 15% decrease in the hazard for 1-second spectral acceleration. Other areas of the CEUS, decreased by larger percentages compared to the 2002 maps.

Eastern Tennessee Seismic Zone

In addition to the three PSHA studies mentioned above, the applicant discussed the significance of the ETSZ on the VCSNS site seismic hazard. The ETSZ, which is located approximately 282 km (175 mi) northwest of the VCSNS site, is considered to be one of the most active seismic areas east of the Rocky Mountains. As shown in SER Figure 2.5.2-1, the ETSZ covers a cluster of earthquakes in eastern Tennessee. In VCSNS COL FSAR Section 2.5.2.2.2.5, the applicant stated that, despite being one of the most active seismic zones in Eastern North America, the largest recorded earthquake in the ETSZ is only a magnitude 4.6, and no evidence for larger prehistoric earthquakes, such as paleoliquefaction features, has been discovered. The applicant concluded that no new information regarding the ETSZ had been developed since 1986 that would require a significant revision to the original EPRI seismic source model, specifically with regards to the M_{max} values developed by the ESTs for the ETSZ.

Recent studies of the ETSZ have postulated that this seismic zone may possess the potential to produce large-magnitude earthquakes. The distribution of upper bound M_{max} values developed by the EPRI ESTs for the ETSZ ranges from 4.8 to 7.5. However, the M_{max} distributions of more recent post-EPRI seismic hazard studies (i.e., the USGS National Seismic Hazard Mapping Project (Frankel et al. 2002), the SCDOT (Chapman and Talwani 2002), and the NRC TIP study (NUREG/CR-6607), and the Tennessee Valley Authority (TVA) Dam Safety Study (Geomatrix, 2004)) are weighted more heavily towards the larger magnitudes (i.e., refer to SER Figure 2.5.2-13). Thus, in RAI 2.5.2-2, the staff asked the applicant to provide a discussion and basis for not including these newer source models in the overall final PSHA. In response to RAI 2.5.2-2, the applicant referenced a recent sensitivity study by the Nuclear Energy Institute (NEI) (White Paper on 'Seismic Hazard in the Eastern Tennessee Seismic Zone,' 2008) and concluded that based on the results of the NEI sensitivity study, potential changes resulting from the updating the EPRI-SOG ETSZ are not significant; therefore, the applicant chose not to update the original EPRI-SOG source models for the ETSZ for the VCSNS site. The applicant also noted that "although the conclusion of the NEI study applies directly to a test site lying near the center of historical seismicity in the ETSZ region, effects for a site at the edges of the ETSZ or farther away, such as the VCSNS site, will certainly have relatively less contribution to total seismic hazard and affect the total overall site specific hazard less, especially since the dominant contribution to hazard at the VCSNS site is from Charleston, South Carolina, seismic sources."

The NEI study, referred in the applicant response to RAI 2.5.2-2, provides the results of comparative analyses of hazard curves and GMRS values calculated using both the original EPRI-SOG source model parameters and updated ETSZ M_{max} values taken from the LLNL TIP study and the TVA Dam Safety Study. The NEI study selected a hypothetical site in the middle of the ETSZ for its assessment with the assumption that the impacts of the ETSZ M_{max} updates would be the highest there and it would represent the worst case scenario. The NEI sensitivity study maintained the original geometries of the EPRI-SOG seismic sources while updating the Mmax values of the four EPRI ESTs source models. The other two ESTs have incorporated the ETSZ in their background sources covering much larger areas; hence, the applicant did not update the M_{max} values for those sources. The results of this NEI sensitivity study are that the proposed higher M_{max} values increase the GMRS values by no more than 6 percent at this hypothetical site across the frequency range of interest. The NEI study further argues that the proposed changes in the EPRI-SOG M_{max} values are not warranted, since no new data is available to justify the need for higher M_{max} values in the ETSZ. Based on these calculations, the NEI study concludes that there is no need to revise the EPRI-SOG ETSZ M_{max} values in COLs' PSHA studies.

The staff reviewed the applicant's response to RAI 2.5.2-2 and notes that in its review of the NEI study as part of the Bellefonte Nuclear Plant (BLN) SER, the staff concluded that potential percentage increases in GMRS due to the ETSZ updates at the hypothetical site as well as at the BLN COL site were relatively minor given the very high hazard contributions of the NMSZ. However, in its review the staff concluded that the NEI ETSZ sensitivity study may not provide a generic answer to all potential COL PSHA studies in the region. Specifically, the staff concluded that the hypothetical site may not represent the worst case scenario for percentage increases of the GMRS due to changes in ETSZ models since the impacts of the ETSZ M_{max} updates on GMRS will vary from site to site depending on the contributions of other seismic sources surrounding a site. To verify that the updated M_{max} distribution used in the NEI sensitivity study does not significantly change the final GMRS for the VCSNS site, the staff performed its own sensitivity study, as described below.

In its assessment the staff used an ETSZ source geometry that encompasses the cluster of ETSZ seismicity, as shown in SER Figure 2.5.2-14. This single source zone geometry for ETSZ differs from the source zone geometries developed by EPRI-SOG for ETSZ, which tend to be broader for the most part and encompass a larger area. At the time of the original mid-1980's EPRI-SOG study, these was not much known about the ETSZ; therefore, as shown in SER Figure 2.5.2-14, some of the ETSZ geometries defined by the EPRI teams are not completely centered over the area of the largest concentration of seismicity in the ETSZ. For its sensitivity study the staff used the same higher M_{max} distribution and accompanying weights (6.3 [0.28], 6.6 [0.44], 6.9 [0.28]) that were used for the NEI sensitivity study. The resulting GMRS values for VCSNS increase only slightly at 1 Hz (0.094 g to 0.104 g) and 10 Hz (0.428 g to 0.468 g); therefore, the results support the applicant's overall conclusion that increasing the original EPRI-SOG M_{max} distributions for ETSZ does not significantly impact the hazard for the VCSNS site.

In SER Section 2.5.1.4.1, the staff also reviewed M_{max} values assigned to the ETSZ. The staff noted that although the VCSNS COL FSAR states that more recent estimates of M_{max} are captured in the range of M_{max} values used by the EPRI/SOG teams, the FSAR cites post-EPRI/SOG M_{max} estimates of **M** 6.3 (Bollinger, 1992) and **M** 7.5 (Frankel and others, 2002), but not the alternate higher estimate of **M** 7.8 by Bollinger (1992), which is presented in FSAR Section 2.5.2.2.2.5. Therefore, in RAI 2.5.1-38, the staff asked the applicant to clarify why FSAR Section 2.5.1.1.3.2.2 does not discuss the Bollinger (1992) M_{max} estimate of **M** 7.8. In response to RAI 2.5.1-38, the applicant agreed to modify FSAR Section 2.5.1.1.3.2.2 to clarify the discussions of the **M** 7.8 value for the ETSZ (Bollinger, 1992) in FSAR Sections 2.5.1.1.3.2.2 and 2.5.2.2.2.5. In its response, the applicant explained that the Bollinger (1992) ETSZ model included the **M** 7.8 value with a low probability of 5 percent in the M_{max} distribution, with **M** 6.3 assigned a 95 percent weight. The applicant also pointed out that the smaller magnitude value is much closer to the mean magnitude (i.e., approximately **M** 6.2) of the EPRI study (EPRI, 1986 and 1989). Based on review of the applicant's response to RAI 2.5.1-38 and the revision to FSAR Section 2.5.1.1.3.2.2, the staff concludes that the applicant adequately addressed the M_{max} values used by Bollinger (1992) for the ETSZ.

Based on review of VCSNS COL FSAR Sections 2.5.1.1.3.2.2 and 2.5.2.2.2.5, the applicant's responses to RAIs 2.5.1-38 and 2.5.2-2, and proposed revisions to FSAR Section 2.5.1.1.3.2.2, the staff concludes that the applicant provided a thorough and accurate description of the ETSZ in support of the VCSNS COL application.

Updated EPRI Seismic Sources

Based on the results of several post-EPRI PSHA studies (Frankel et al. 2002; Chapman and Talwani 2002) and the recent availability of paleoliquefaction data (Talwani and Schaeffer 2001) for the Charleston and New Madrid source zones, the applicant updated the EPRI characterization of the Charleston and New Madrid seismic source zones as part of the COL application.

<u>Update of the Charleston Seismic Source</u>

The applicant updated the original EPRI-SOG Charleston seismic source models with the UCSS model, which was originally presented in the SSAR for the VEGP ESP site (Southern Nuclear Company, 2008). The staff reviewed and approved the UCSS model as part of its review of the VEGP ESP application (NUREG-1923). However, in SER Section 2.5.1.4.1, in several RAIs, the staff asked the applicant to address a newly-reported Charleston-area paleoliquefaction feature that was interpreted by Talwani and others (2008) to be associated with the Sawmill Branch fault. Specifically, in RAIs 2.5.1-37 and 2.5.1-54, the staff asked the applicant to discuss this paleoliquefaction feature in regard to any bearing it may have on magnitude and recurrence interval for earthquakes in the VCSNS site region. In response, the applicant stated that Talwani and others (2000) believed the causative earthquake was pre-1886, presumably based on burial depth and observed degree of soil formation. Also in response, the applicant stated that Talwani and others (2008) estimated a magnitude of about 6.9, with the magnitude scale not indicated, for the causative earthquake. The applicant stated that this magnitude falls within the range of M_{max} captured in the UCSS model, and that the feature lies within one of the source area geometries defined for the UCSS model. The applicant concluded that no modifications to the UCSS model are required due to the discovery of this paleoliquefaction feature because none of the information presented by Talwani and others (2008) provided additional constraints on timing, magnitude, or location of an associated paleoearthquake. As discussed in SER

Section 2.5.1.4.1, the staff concurs with the applicant that no modification of the UCSS model is required as a result of the discovery of this paleoliquefaction feature. The staff agrees with the applicant because the suggested characteristics of the feature are fully captured in the UCSS.

Update of the New Madrid Seismic Source

In VCSNS COL FSAR Section 2.5.2.4.4, the applicant stated that the updated New Madrid seismic source model described in the SSAR for the Clinton ESP site (Exelon, 2006) formed the basis for determining the potential contribution from the NMSZ to determine the hazard at the VCSNS site. The applicant stated that this model accounts for new information on recurrence intervals for large earthquakes in the New Madrid area, for recent estimates of possible earthquake sizes on each of the active faults, and for the possibility of multiple earthquake occurrences within a short period of time (earthquake clusters). The staff previously reviewed and accepted the New Madrid seismic source model as part of the Clinton ESP application review.

Staff Conclusions of the Geologic and Tectonic Characteristics of the Site and Region

Based upon its review of VCSNS COL FSAR Sections 2.5.2.2 and 2.5.2.4, the staff concludes that the applicant adequately updated the original EPRI seismic source models as the input to its PSHA for the VCSNS site. The staff concludes that the applicant's use of EPRI seismic source models, in addition to the updates of the model, as described by the applicant in FSAR Sections 2.5.2.2 and 2.5.2.4, forms an adequate basis for the seismic hazard characterization of the site and meets the requirements of 10 CFR 52.79 and 10 CFR 100.23.

2.5.2.4.3 Correlation of Earthquake Activity with Seismic Sources

SSAR Section 2.5.2.3 describes the correlation of updated seismicity with the EPRI seismic source model. The applicant compared the distribution of earthquake epicenters from both the original EPRI historical catalog (1627–1984) and the updated seismicity catalog (1985–2006) with the seismic sources characterized by each of the EPRI ESTs. Based on this comparison, the applicant concluded that there are no new earthquakes within the site region that can be associated with a known geologic structure and that there are no clusters of seismicity suggesting a new seismic source not captured by the EPRI seismic source model. The applicant also concluded that the updated catalog does not show a pattern of seismicity that would require significant revision to the geometry of any of the EPRI seismic sources. The applicant further concluded that the updated catalog does not show or suggest an increase in M_{max} or a significant change in seismicity parameters (activity rate, b-value) for any of the EPRI seismic sources.

In RAI 2.5.2-4, the staff requested electronic versions of the EPRI seismicity catalog and the applicant's updated EPRI seismicity catalog for the region of interest. In addition, in Part 1 of RAI 2.5.2-1, the staff requested the geographic coordinates of the source zones developed by each of the six EPRI ESTs that are within the 320 km (200 mi) site region. The staff used the information provided in response to RAI 2.5.2-4 and Part 1 of RAI 2.5.2-1 to compare the applicant's update of the regional seismicity catalog with the USGS earthquake catalog (reference) for the equivalent time period. Based on this comparison, the staff concurs with the applicant's assertion that the rate of seismic activity has not increased in the ESP region since 1985. Using the information provided in response to RAI 2.5.2-4 and Part 1 of RAI 2.5.2-1, the staff also compared the updated earthquake catalog with each of the primary seismic sources developed by each EPRI EST. Based on the comparison of earthquakes in the updated catalog with each of the EPRI EST seismic sources, the staff concurs with the applicant's conclusion that revisions to the existing EPRI sources are not warranted.

2.5.2.4.4 Probabilistic Seismic Hazard Analysis and Controlling Earthquakes

VCSNS COL FSAR Section 2.5.2.4 presents the earthquake potential for the VCSNS site in terms of the controlling earthquakes. The applicant determined the high- and low-frequency controlling earthquakes by deaggregating the PSHA results at selected probability levels following the guidance provided in RG 1.208. Before determining the controlling earthquakes, the applicant updated the 1989 EPRI PSHA using the seismic source zone adjustments described in SER Section 2.5.2.1.2 and the new ground motion models described in SER Section 2.5.2.1.4. The staff focused its review of FSAR Section 2.5.2.4 on the applicant's updated PSHA and the VCSNS site controlling earthquakes determined by the applicant after completion of its PSHA. While the staff's review of the applicant's update of the EPRI seismic source model is described in SER Section 2.5.2.3.2, this SER section focuses on the review of the application of the updated seismic source model to the hazard calculation at the VCSNS site.

In VCSNS COL FSAR Table1.9-202 and Appendix1AA, the applicant took an exception to RGs 1.206 and 1.208, respectively, by providing the 0.15 and 0.85, instead of the 0.16 and 0.84 fractile hazard curves. The applicant also took an exception to RG 1.208 by not providing the 0.05 and 0.95 fractile hazard curves. Additionally, the applicant identified exceptions to RG 1.206 in that it did not provide the 0.05 and 0.95 fractile hazard curves and that the 100Hz amplitude frequencies for mean and fractile rock were not run. In RAI 01-6, the staff asked the applicant to explain the 0.05 and 0.95 fractile hazard curves and 100Hz amplitude frequencies exceptions to RG 1.206, as the 0.05 and 0.95 fractile hazard curves, are not included in RG 1.206 and the applicant had provided the equivalent 100Hz amplitude frequencies. In its response to RAI 01-6, the applicant stated that those two exceptions to RG 1.206 were added inappropriately and committed to updating FSAR Table 1.9-202 to delete the reference to the 0.05 and 0.95 fractile hazard curves and the 100Hz amplitude frequencies exceptions. The staff reviewed the FSAR as well as the changes proposed in the response to RAI 01-6 and concludes that these exceptions to RGs 1.206 and 1.208 are acceptable, because the 0.15 and 0.85 fractile hazard curves are very close to the 0.16 and 0.84 fractile levels. In addition, the specific ground motion response spectra are developed from the mean hazard curves rather than the fractile hazard curves. The commitment to update VCSNS COL FSAR Table 1.9-202 is being tracked as **Confirmatory Item 2.5.2-1**.

<u>Resolution of Confirmatory Item 2.5.2-1</u>

Confirmatory Item 2.5.2-1 is an applicant commitment to update FSAR Table 1.9-202. The staff verified that the VCSNS COL FSAR was appropriately updated. As a result, Confirmatory Item 2.5.2-1 is now closed.

PSHA Inputs

As input to its PSHA, the applicant used its updated version of the 1989 EPRI seismic source model. The staff's evaluation of the applicant's update is described in SER Section 2.5.2.3.2. The applicant also used the ground motion models developed by the 2004 EPRI-sponsored study (EPRI 1009684 2004) as input to its PSHA. The ESP applications for the Clinton (Illinois), Grand Gulf (Mississippi) and North Anna (Virginia) sites also used the updated EPRI ground motion models. The staff's final SERs for Clinton, Grand Gulf, and North Anna provide an extensive review of the EPRI 2004 ground motion models. Thus, the staff considers the applicant's use of the EPRI 2004 ground motion model to be appropriate. Furthermore, NUREG-0800 states that use of the EPRI ground motion models (2004) "is acceptable as long as an adequate investigation has been carried out to provide reasonable assurance that there are no significant updates or new models that may impact on the results of the PSHA." Section 2.5.2.4.5 of the FSAR does not discuss any new ground motion models. However, at least two new ground motion prediction models for the CEUS have been published in peer-reviewed literature since 2004: (1) "Empirical-stochastic ground-motion prediction for eastern North America" by Tavakoli and Pezeshk (Bulletin of the Seismological Society of America, 2005, v.95[6], 2,283-2,296); and (2) "Earthquake ground-motion prediction equations for eastern North America" by Atkinson and Boore (Bulletin of the Seismological Society of America, 2006, v.96[6], 2,181-2,205). In addition to these specific models, the latest version of the USGS National Seismic Hazard maps (Petersen et al., 2008) computes ground motions from a weighted combination of a number of ground-motion prediction equations. In RAI 2.5.2-14, the staff requested that the applicant provide a justification for not considering these new ground-motion prediction models. In response to RAI 2.5.2-14, the applicant provided a plot of ground motion amplitudes for 1 Hz spectral acceleration corresponding to an M=7 earthquake versus distance for the 12 equations used from EPRI (2004), and for the Tavakoli and Pezishk (2005) and Atkinson and Boore (2006) references (i.e., Figure RAI-14A). The applicant stated that at all distances, the range of the 12 EPRI (2004) models encompasses the ground motions predicted by Tavakoli and Pezishk (2005) and Atkinson and Boore (2006). The applicant also provided a plot of ground motion amplitudes for 10 Hz spectral acceleration for an M=5.7 earthquake (i.e., Figure RAI-14B). The applicant stated at all distances, the range of the 12 EPRI (2004) models encompasses the ground motions predicted by the other two references, except for distances between about 50 and 90 km, where the Atkinson and Boore (2006) equation falls below the range of the 12 EPRI (2004) models. With respect to the ground motions models used in the USGS National Seismic Hazard maps, the applicant stated that the USGS included the following nine ground motion models:

- Atkinson and Boore (1995)
- Atkinson and Boore (2006)
- Frankel et al. (1996)
- Toro et al. (1997)
- Toro (2002)
- Campbell (2003)
- Somerville (2001)
- Silva et al. (2002)
- Tavakoli and Pezeshk (2005)

The applicant stated that among these nine ground motion models, the Atkinson and Boore (1995), Toro et al. (1997), Campbell (2003), Frankel et al. (1996), Somerville (2001), and Silva et al. (2002) equations were considered in the EPRI (2004) study that was used in the seismic hazard calculations for the Summer site. The Toro (2002) reference is an update of the Toro et al. (1997) reference for close distances to large magnitude earthquakes. The Atkinson and Boore (2006) and Tavakoli and Pezeshk (2005) references are evaluated above and are encompassed by the range of EPRI (2004) ground motion equations. Thus, the weighting of the nine equations in the Peterson et al. (2008) study does not constitute an independent ground motion model, but involves a weighting of many of the same equations used in the EPRI (2004) study, and includes some models (e.g., Frankel, et al., 1996) that have not undergone peer review. The two more recent equations, published since the EPRI (2004) study, are consistent with the EPRI (2004) study. Thus, the EPRI (2004) ground motion equations are considered representative of those used by the Peterson et al. (2008) study.

The staff reviewed the applicant's response to RAI 2.5.2-14 and in RAI 2.5.2-27, asked the applicant to clarify whether the "weighted average" of Equations 1 through 12 in Figures RAI-14A and RAI-14B reflects the actual weights of these equations as represented in the EPRI 2004 ground motion model. In addition, the staff requested that the applicant provide additional plots to encompass the controlling earthquakes listed in SER Table 2.5.2-1. As shown in SER Table 2.5.2-1, the controlling earthquakes for the VCSNS site range from **M** 6.1 to 7.3. The staff also requested that the applicant provide further justification for not considering the Peterson et al. (2008) model as a separate and new ground motion model because even though the model uses many of the equations used in the EPRI (2004) model, the weights are different. Lastly, the staff asked the applicant to explain why the 5 and 10 Hz, 10^{-5} controlling earthquake is not **M** ~ 5.0 to 5.5 at a distance of approximately 0 to 20 km (i.e., based on VCSNS COL FSAR Figure 2.5.2-239), instead of 6.1 at 70 km, which is the value listed in FSAR Table 2.5.2-218 (and SER Table 2.5.2-2).

In response to RAI 2.5.2-27, the applicant replaced Figures RAI-14A and 14B with a new set of figures. Plots comparing 1 Hz and 10 Hz spectral accelerations for **M**=5.2, 6.1, and 7.3 are shown in Figures RAI 2.5.2-27.2 through RAI 2.5.2-27.7. The applicant clarified that in these figures, the "weighted average" curves uses the weights given in Figure 5-2 of EPRI (2004) for the 9 equations for "general area sources" or Figure 5-3 of EPRI (2004) for the 12 equations for "non-general area sources," not equal weights. In Figures RAI 2.5.2-27.2 through 2.5.2-27.7, the applicant compared the EPRI (2004) equations and the weighted average, with the Atkinson and Boore (2006) and the Tavakoli and Pezeshk (2005) equations. The applicant stated that the 10^{-4} and 10^{-5} high-frequency (i.e., 5 to 10 Hz) controlling earthquake magnitudes and distances range from **M**=6.2 to **M**=6.9 and R=31 to 120 km. The applicant stated that for the **M**=6.1 and **M**=7.3 (10 Hz) plots (i.e., Figures RAI 2.5.2-27.5 and RAI 2.5.2-27.7), which are close to the high-frequency controlling earthquakes, the weighted average EPRI curve lies above the middle range of the ground motions from the Atkinson and Boore (2006) and the Tavakoli and Pezeshk (2005) equations for distances between 30 and 120 km (19 and 75 mi). The applicant concluded that the inclusion of the Atkinson and Boore (2006) and the Tavakoli and Pezeshk (2005) equations into the hazard analysis likely would reduce the 10^{-4} and 10^{-5} high-frequency UHRS. The applicant stated that the low frequency (i.e., 1 to 2.5 Hz) 10^{-4} and 10^{-5} controlling earthquakes are **M**~7.3 and source-to-site distance (R)~210 km (130 mi). The applicant stated that in the 1 Hz **M**=7.3 plot (shown in SER Figure 2.5.2-15), the Atkinson and Boore (2006) equation lies near the weighted average of the EPRI Equations for a distance of 200 km (124 mi), while the Tavakoli and Pezeshk (2005) lies above the EPRI weighted average. The applicant stated that the inclusion of the Atkinson and Boore (2006) and the Tavakoli and Pezeshk (2005) equations would increase the 10^{-4} and 10^{-5} UHRS low frequency values. However, the applicant noted that the likely effect of including these two equations on the low-frequency UHRS would be small given that these equations would be weighted accordingly.

Also in response to RAI 2.5.2-27, the applicant provided further explanation to support its decision not to include Peterson et al. (2008) as a separate and new ground motion model. The applicant stated that Peterson et al. (2008) assigned weights to the equations making up their model according to category (i.e., single corner-finite fault, single corner-point source, dynamic corner frequency, full waveform simulation, or hybrid empirical). In comparison, the applicant stated that the EPRI (2004) ground model assigned weights to the individual equations based on consistency with CEUS data, strength of seismological principles, and consideration of epistemic uncertainty. The applicant stated that the EPRI (2004) model weighting is consistent with documentation for a SSHAC Level 3 study (SSHAC, 1997).

Additionally in response to RAI 2.5.2-27, the applicant stated that it made modifications to the 5 and 10 Hz hazard deaggregation. The applicant stated as a result of more accurate assumptions about magnitudes below 5.0 with the CAV filter, the 10^{-5} UHRS values changed slightly. The applicant also stated that the calculation of mean distance was made using the exponent of the average logarithmic distance, which is recommended in RG 1.208, rather than using the mean arithmetic distance. As a result of these modifications, the mean magnitude and distance for the 5 and 10 Hz hazard deaggregation are changed from **M**=6.1 and R=70 km (43 mi) to **M**=6.2 and R=31 km (19 mi). The applicant stated that it intends to update VCSNS COL FSAR Figure 2.5.2-239 and FSAR Table 2.5.2-218 to reflect the revised mean magnitudes and distance.

The staff reviewed the first part of the applicant's response to RAI 2.5.2-27 and concluded that the applicant's use of the EPRI (2004) ground motion models, without the consideration of the Atkinson and Boore (2006) and the Tavakoli and Pezeshk (2005) ground motion models is acceptable. The staff concurred with the applicant that the inclusion of these new ground motion models would likely reduce the 10^{-4} and 10^{-5} high-frequency UHRS. Even though the inclusion of these models would increase the 10^{-4} and 10^{-5} UHRS low frequency values, as shown in SER Figure 2.5.2-15 (and Figure RAI 2.5.2-27.6), the staff concludes that the increase would be small because these equations would be weighted amongst the individual EPRI (2004) equations. The staff also concurs with the applicant's decision not to include the Peterson et al. (2008) model because of the more rigorous weighting scheme used by EPRI (2004) than Peterson et al. (2008) to combine the individual equations. Lastly, the staff concluded that the applicant's modifications to the 5 and 10 Hz deaggregation (including the applicant's revisions to VCSNS COL FSAR Figure 2.5.2-239 and FSAR Table 2.5.2-218) are acceptable because the applicant recalculated the mean deaggregation distance using the method recommended by RG 1.208, which resulted in a more conservative distance. As a result of the above conclusions, RAI 2.5.2-27 is resolved.

In VCSNS COL FSAR Section 2.5.2.4.5, the applicant stated that it used the EPRI (2004) ground motion equations in its updated PSHA. However, the EPRI 2004 ground motion report includes many equations that are arranged in "clusters." The staff, in RAI 2.5.2-13, asked the applicant to provide more detail regarding how it used the various equations from the EPRI ground motion report to compute the site hazard, including the weights that the applicant applied for the specific equations, if multiple equations were used in the analysis. In response to RAI 2.5.2-13, the applicant stated that the (2004) ground motion equations consist of four clusters, each of which has a high, medium, and low estimate. The applicant stated that for general area sources, only the first three clusters are used in the analysis (i.e., a total of nine equations with weights). The applicant stated that for nongeneral sources, all four clusters are used in the analysis (i.e., a total of 12 equations with different weights). When both general area sources and nongeneral sources are used in a hazard analysis the nine equations for general sources and the 12 equations for nongeneral sources are used in a specific set of combinations. The applicant concluded that the seismic hazard analysis for the VCSNS site used the weights given in EPRI (2004) for all clusters and all equations within a cluster.

The staff reviewed the applicant's response to RAI 2.5.2-13 and in RAI 2.5.2-26 requested that the applicant specify which equations were used with which sources in the PSHA because different clusters are used depending upon whether the source is a general area source (i.e., sources capable of generating events 5.0<**M**≤6.0) or a nongeneral source (i.e., sources capable of generating event of **M**>6.0). In response, the applicant stated that the ground motion clusters, individual models, and weights recommended in EPRI (2004) for hazard calculations incorporating multiple source types were used in hazard calculations. The staff concluded that the responses to RAI 2.5.2-13 and RAI 2.5.2-26 are adequate because the applicant appropriately used the EPRI (2004) combination of ground motion equations for both general sources and nongeneral sources. The staff further notes that RG 1.208 approves the use of the EPRI 2004 ground motion models.

In VCSNS COL FSAR Section 2.5.2.4.5, the applicant stated that it used the CAV model of Hardy et al. (2006) to model the damageability of small-magnitude earthquakes to engineered facilities. In RAI 2.5.2-16, the staff asked the applicant to clarify the following statement regarding its description of the CAV model in FSAR Section 2.5.2.4.5: "The ground motions for frequencies other than 100 Hz are assumed to be correlated with the ground motions at 100 Hz, so that the filtering is consistent from frequency to frequency." Specifically, the staff asked the applicant to clarify whether the above statement is referring to structural frequencies rather than ground motion frequencies. In addition, the staff asked the applicant to provide a justification for the assumption included in the above statement. In response to RAI 2.5.2-16, the applicant stated that the quoted statement refers to frequencies in the GMRS used to determine the UHRS at the site. The applicant also noted that the statement is made in the context of the application of the CAV filter, wherein the deviation of ground motion amplitude at each spectral frequency (from its logarithmic mean value) is correlated to the deviation of ground motion amplitude at a different spectral frequency (from its logarithmic mean value). The correlation model is given in Equations 3-2 and 3-3 of Hardy et al. (2006). The correlation is specified between values of spectral acceleration and PGA, which is equivalent to spectral acceleration at a frequency of 100 Hz. The CAV model is an overall model of the damageability of earthquake ground motions that is consistent across all spectral frequencies. As a result, seismic hazard curves for different spectral frequencies have the same horizontal asymptote, because they reflect the same frequency of occurrence of damaging earthquakes in the region.

The staff concludes that the applicant's response to RAI 2.5.2-16 is acceptable because the applicant clarified that it was referring to response spectral frequencies (i.e., structural frequencies) in its statement: "ground motions for frequencies other than 100 Hz are assumed to be correlated with the ground motions at 100 Hz, so that the filtering is consistent from frequency to frequency." In addition, the staff concludes that the applicant provided adequate justification for its assumption for correlating ground motions at 100 Hz with ground motions at other response spectral frequencies. The basis for the applicant's assumption is the correlation model of Hardy et al. (2006). The staff notes that the dataset used to develop this correlation model for PGA and spectral acceleration is the PEER NGA data set, which is an extensive database of strong motion earthquake records from active tectonic regions. Furthermore, Hardy et al. (2006) is the reference recommended by RG 1.208, regarding the use of CAV.

PSHA Calculation

In VCSNS COL FSAR Section 2.5.2.4.1, the applicant stated that it used the 1989 EPRI study as the starting point for probabilistic seismic hazard calculations. Because the applicant used different software than what was used in the original 1989 EPRI PSHA calculation, it first performed a PSHA using the original 1989 EPRI primary seismic sources and ground-motion models in order to validate the new software. In FSAR Table 2.5.2-216, the applicant compared the results from FRISK88 with the original EPRI hard-rock results. The applicant determined that for the mean hazard curves, the current calculation indicates slightly higher hazard, with up to a +6.1 percent difference at 1 g. The applicant further noted that for ground motions associated with typical seismic design levels (i.e., PGA <0.5 g), the differences are 3.5 percent or less. The applicant stated, however, that differences in hazard are also small for the median hazard, except at large ground motions (PGA ≥0.7 g) where differences of +20 percent and +30 percent are seen. Thus, in RAI 2.5.2-11, the staff asked the applicant to provide an explanation for the relatively large difference in seismic hazard of +20 percent to +30 percent between the 1989 EPRI analysis and the recent one done using Risk Engineering, Inc.'s FRISK88 software for the median hazard at large ground motions.

In response to RAI 2.5.2-11, the applicant stated that the good agreement between the current hazard calculations and the 1989 EPRI study for mean and 85 percent hazard, for PGA amplitudes between 0.05 g and 1 g, indicates that the seismic sources from the 1989 EPRI study have been accurately modeled. The applicant also stated that the good agreement between median hazard for PGAs amplitudes between 0.05 g and 0.5 g also supports this conclusion. The larger difference between median hazards for PGA amplitudes of 0.7 g and 1 g indicates that the current estimates of median hazard exceed those from the 1989 EPRI study by 20 percent to 30 percent. This means that the current calculations are slightly more conservative than the 1989 EPRI study for these amplitudes and for median hazards. One possible explanation for the difference is that the 1989 EPRI study used an integration step size corresponding to approximately 5 km (3 mi), whereas the current hazard calculations use an integration step size corresponding to approximately 2.5 km (1.5 mi), which is more accurate. SCE&G believes that the assumptions made in the current calculations correctly reflect the interpretations of the EPRI teams regarding their seismic sources, and use calculational parameters (e.g., integration step size) that provide accurate hazard results. Thus, the current calculations accurately reflect the hazard, given the inputs, from the 1989 EPRI study.

The staff reviewed the response to RAI 2.5.2-11 and, in RAI 2.5.2-25, asked that the applicant provide any other possible reasons for this difference. In response, the applicant stated that the distribution of seismic hazard is calculated from a family of individual seismic hazard curves, each of which is assigned a weight. For the EPRI 1989 calculations, six teams provided alternative interpretations of seismic sources and parameters. Also, the EPRI 1989 calculations used three ground motion equations. The applicant stated that in order to replicate the original EPRI 1989 calculations, it used a post-processing algorithm to calculate overall fractiles that efficiently gives approximate, generally conservative estimates of hazard fractiles from the family of all hazard curves, but is less accurate at representing lower fractiles of highly skewed distributions of hazard. The applicant stated that rerunning this algorithm without the approximation indicates a better agreement of the median hazard curve with the EPRI 1989 hazard results. Thus, because the applicant has demonstrated that the reasons for differences between the current calculations and those reported in the EPRI 1989 study are well understood, the staff concludes that the EPRI 1989 seismic sources have been modeled appropriately and conservatively.

Controlling Earthquakes

VCSNS COL FSAR Section 2.5.2.4.4.5 describes the deaggregation of final PSHA hazard curves to determine the controlling earthquakes for the VCSNS site. To determine the low-and high-frequency controlling earthquakes, the applicant followed the procedure outlined in RG 1.165. This procedure specifies that the controlling earthquakes are determined from the deaggregation of the PSHA results corresponding to the annual frequencies of 10^{-4}, 10^{-5}, and 10^{-6} and are based on the magnitude and distance values that contribute most to the hazard at the average of 1 and 2.5 Hz and the average of 5 and 10 Hz. SER Table 2.5.2-2 (reproduced from FSAR Table 2.5.2-218) lists the low- and high-frequency 10^{-4} and 10^{-5}

controlling earthquakes for the site. For the high-frequency mean 10^{-4} and 10^{-5} hazard levels, the controlling earthquakes are a **M** 6.9 at 120 km (74.6 mi) and a **M** 6.2 at 31 km (19.3 mi), respectively, corresponding to an earthquake from a local seismic source zone. In contrast, for the low-frequency mean 10^{-4} and 10^{-5} hazard levels, the controlling earthquakes are an **M** 7.2 and **M** 7.3 at 210 km (130.5 mi), respectively. This controlling earthquake corresponds to an event in the Charleston Seismic Zone. After review of these four controlling earthquake magnitudes and distances, the staff concludes that they are representative of earthquakes in the site region and adequately characterize the seismic hazard for the site.

Staff Conclusions Regarding PSHA and Controlling Earthquakes

The staff concludes the applicant's PSHA adequately characterizes the seismic hazards for the region surrounding the VCSNS site and that the controlling earthquakes determined by the applicant are typical of earthquakes that would be expected to contribute the most to the hazard.

2.5.2.4.5 Seismic Wave Transmission Characteristics of the Site

VCSNS COL FSAR Section 2.5.2.5 states that the site is underlain by weathered and unweathered bedrock with a high shear velocity (greater than 8,500 fps); therefore, a site response analysis was not performed to develop the final hazard results because the V_S is consistent (i.e., within the uncertainty) with the ground motion model used in the PSHA (V_S greater than 9,200 fps). While FSAR Figure 2.5.4-226, "Shear Wave Velocity of Layer V with 5-Foot Vertical Distance Averaging" shows the mean V_S to be greater than 8,500 fps, the profile exhibits a large variability (~6000 fps to ~1150 fps) particularly below Unit 2 in the 310 to 355 ft elevation range. In RAI 2.5.2-18, the staff asked the applicant to provide additional justification for not performing a site response calculation as part of the development of the final hazard results, in light of the significant V_S variability beneath the site and the observed V_S values that are lower than 8,500 fps.

In response to RAI 2.5.2-18, the applicant performed a site response sensitivity analysis to confirm its decision that a site response analysis is not warranted for the VCSNS site. In order to capture the variability of the data and using the mean damping value of 1 percent for its sensitivity study, the applicant developed a set of 60 randomized velocity and damping profiles for each unit. In addition, the applicant used the high-frequency and low-frequency response spectra corresponding to 10^{-4} and 10^{-5} hazard levels as input motions to its site response analysis. The applicant's results (i.e., the mean and median of the spectral amplifications) are shown in SER Figure 2.5.2-15. The applicant stated that the amplification is very small and is limited to the high frequency range. In summary, the applicant concluded that due to the limited thickness and aerial extent of the weathered rock beneath Unit 2 and its generally higher V_S, the overall amplification is very small and its impact on the final hazard results is negligible.

The staff reviewed the applicant's response to RAI 2.5.2-19, including the results of its site response sensitivity analysis. The staff finds the sensitivity analysis acceptable and agrees with the applicant's conclusion because the amplification is small (i.e., less than a factor of 1.1 in the frequency range of 20 to 100 Hz). Therefore, the staff concludes that RAI 2.5.2-19 is resolved and that the applicant's assumption of the VCSNS site as a hard-rock site is acceptable and that the use of EPRI ground motion equations without a site-specific response analysis is adequate for the GMRS calculations.

2.5.2.4.6 Ground Motion Response Spectra

VCSNS COL FSAR Section 2.5.2.6 describes the method used by the applicant to develop the horizontal and vertical, site-specific, GRMS. To obtain the horizontal GMRS, the applicant used the performance-based approach described in RG 1.208, and ASCE/SEI Standard 43-05. In FSAR Section 2.5.2.4.7, the applicant stated that it multiplied the horizontal spectra by a frequency-dependent, but magnitude and distance-independent, scaling factor in order to obtain the vertical spectra before using the performance-based approach to develop the vertical GMRS. However, some studies (for example, Bozorgnia and Campbell, 2004) have found that the V/H ratio can depend strongly on distance (and to a lesser extent, magnitude). In RAI 2.5.2-17, the staff asked the applicant to explain how these different dependencies would impact the modeled ground motions at the VCSNS site. In response to RAI 2.5.2-17, the applicant stated that the V/H ratios used in FSAR Section 2.5.2.4.7 are those presented in Chapter 4 of NUREG/CR-6728 for rock sites in the CEUS. The applicant noted that this reference acknowledges the dependence of V/H on distance and magnitude: "With the dramatic increase in strong motion data since the development of these design specifications in the 1970's [i.e., the simple V/H implied from RG 1.60], the conclusion that the vertical and average horizontal ground motions vary in stable and predictable ways with magnitude, distance, and site condition has become increasingly compelling." The applicant stated that further extensive discussion on vertical motions is presented in Appendix J of NUREG/CR-6728. The applicant further stated that V/H ratios presented in NUREG/CR-6728 are a function of ranges of expected horizontal peak acceleration, which are a "reasonable accommodation of magnitude and distance dependency" (NUREG/CR-6728). The applicant concluded that the V/H ratios used in FSAR Section 2.5.2.4.7 effectively incorporate magnitude and distance dependency through their dependency on peak acceleration. The staff reviewed the response to RAI 2.5.5-17 and concluded that the response is acceptable since the V/H ratios do incorporate a magnitude and distance dependency through their dependency on peak acceleration. Furthermore, the staff notes that appropriate V/H ratios for CEUS rock sites provided in NUREG/CR-6728 may be used.

Since the applicant used the standard procedure outlined in RG 1.208, to calculate the final horizontal GMRS and NUREG/CR-6728 to calculate the vertical GMRS, the staff concludes that the applicant's GMRS adequately represent the site ground motion.

2.5.2.5 *Post Combined License Activities*

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

2.5.2.6 *Conclusion*

The NRC staff reviewed the application and checked the referenced DCD. The NRC staff's review confirmed that the applicant addressed the required information relating to vibratory ground motion, and there is no outstanding information expected to be addressed in the VCSNS COL FSAR related to this section. The results of the NRC staff's technical evaluation of the information incorporated by reference in the VCSNS COL application are documented in NUREG-1793 and its supplements.

As set forth above, the staff reviewed the seismological information submitted by the applicant in VCSNS COL FSAR Section 2.5.2. On the basis of its review of VCS COL 2.5-2, VCS COL 2.5-3 and VCS SUP 2.5-2, the staff finds that the applicant has provided a thorough characterization of the seismic sources surrounding the site, as required by 10 CFR 100.23. In addition, the staff finds that the applicant has adequately addressed the uncertainties inherent in the characterization of these seismic sources through a PSHA, and this PSHA follows the guidance provided in RGs 1.165 and 1.208. The staff concludes that the controlling earthquakes and associated ground motion derived from the applicant's PSHA are consistent with the seismogenic region surrounding the COL site. In addition, the staff finds that the applicant's GMRS, which was developed using the performance-based approach, adequately represents the regional and local seismic hazards and accurately includes the effects of the local COL subsurface properties. The staff concludes that the proposed COL site is acceptable from a geologic and seismologic standpoint and meets the requirements of 10 CFR 100.23.

2.5.3 Surface Faulting

2.5.3.1 *Introduction*

VCSNS COL FSAR Section 2.5.3 discusses the potential for surface deformation due to faulting. The information related to surface deformation due to faulting is collected by the applicant during site characterization investigations and addresses the following specific topics related to surface faulting: geologic, seismic, and geophysical investigations; geologic evidence, or absence of evidence, for tectonic surface deformation; correlation of earthquakes with capable tectonic sources; ages of most recent deformation; relationship of tectonic structures in the site area to regional tectonic structures; characterization of capable tectonic sources; designation of zones of Quaternary (i.e., 2.6 Ma to present) deformation requiring fault investigation; and potential for surface tectonic deformation at the site.

2.5.3.2 *Summary of Application*

Section 2.5.3 of the VCSNS COL FSAR, Revision 5, incorporates by reference Section 2.5.3 of the AP1000 DCD, Revision 19.

In addition, in VCSNS FSAR Section 2.5.3, the applicant provided the following information:

AP1000 COL Information Item

- VCS COL 2.5-4

The applicant provided additional information in VCS COL 2.5-4 to address COL Information Item 2.5-4 (COL Action Item 2.5.3-1), which addresses the evaluation of site-specific subsurface geologic, seismic, and geophysical information related to the potential for surface or near-surface faulting affecting the site.

The applicant developed FSAR Section 2.5.3 for the VCSNS site based on its review of existing geologic, seismic, and geophysical data and the published literature; discussions with experts in geology and seismotectonics of the site region; interpretation of aerial photography and satellite imagery employed for reconnaissance in the site vicinity; and geologic field investigations. The existing geologic data included geologic maps prepared by the USGS, the SCDNR, and other researchers. The existing seismic data included information on both historical and recorded seismicity. The geologic field investigations performed by the applicant included field reconnaissance and drilling of boreholes for VCSNS Units 2 and 3. In addition, the applicant cited documents which reported on pre-Quaternary faults (i.e., >2.6 Ma) mapped at the VCSNS Unit 1 site (Dames and Moore, 1972 and 1974; USAEC, 1974) to supplement the information acquired from the geologic and seismic investigations performed for VCSNS Units 2 and 3.

Through the aforementioned efforts, the applicant concluded that no deformation or geomorphic features indicative of potential Quaternary activity have been reported in the literature and none were identified during field investigations.

2.5.3.2.1 Geologic, Seismic, and Geophysical Investigations

VCSNS COL FSAR Section 2.5.3.1 describes geologic, seismic, and geophysical investigations performed by the applicant to assess the potential for surface and near-surface tectonic and nontectonic deformation within the VCSNS site. Based on the results of these investigations, the applicant concluded that no evidence exists to indicate the presence of capable tectonic sources within 40 km (25 mi) of the site (i.e., the site vicinity), and the potential for tectonic fault rupture within the site vicinity is negligible. The applicant further concluded that there is also negligible potential for nontectonic deformation within 8 km (5 mi) of the site (i.e., the site area).

The following sections summarize the geologic, seismic, and geophysical investigations performed by the applicant to investigate the potential for surface and near-surface faulting and nontectonic deformation within the VCSNS site vicinity and site area or at the site location.

Previous Investigations

VCSNS COL FSAR Section 2.5.3.1.1 discusses previous investigations conducted for the VCSNS Unit 1 site in connection with preparation of the FSAR for Unit 1. The applicant reported that geologic investigations, including detailed mapping of bedrock in the excavation for Unit 1, did not reveal any evidence for Quaternary (2.6 Ma to present) or currently active tectonic faulting in the site area. The applicant did identify features with postulated Mesozoic (251-65.5 Ma) displacement and older within the site area. The applicant described three minor shear zones mapped in bedrock of the Unit 1 excavation, and stated that radiometric age dating of undeformed zeolite minerals in the shear zones precluded displacements along these zones younger than 45 Ma in age. The applicant also stated that such pre-Quaternary (> 2.6 Ma) minor structures were common in rocks of the South Carolina Piedmont and could possibly be encountered within the foundation excavations for Units 2 and 3.

Published Geologic Mapping

VCSNS COL FSAR Section 2.5.3.1.2 addresses the results of published geologic mapping conducted by the USGS, the South Carolina Geological Survey, and other researchers in the site vicinity and site area. The applicant reported that these mapping efforts did not reveal any evidence for Quaternary (2.6 Ma to present) or currently active faulting in the site area.

Current Geologic Mapping

VCSNS COL FSAR Section 2.5.3.1.3 states that existing geologic maps discussed in FSAR Section 2.5.3.1.2 formed the basis for the geologic maps presented for VCSNS Units 2 and 3. The applicant conducted geologic field reconnaissance for Units 2 and 3 to check these existing maps and refined them as necessary. The applicant cross-referenced FSAR Section 2.5.1.2, which discusses geologic mapping in detail, and stated in FSAR Section 2.5.3.1.3 that surficial geology in the site area is predominately characterized by saprolite and residual soil with sparse outcrops of weathered igneous and metamorphic bedrock.

Previous Seismicity Data

VCSNS COL FSAR Section 2.5.3.1.4 discusses previous seismicity data. The applicant stated that the 1986 EPRI seismicity catalog (EPRI, 1986) does not include any earthquakes of body wave magnitude (m_b) ≥ 3.0 within 8 km (5 mi) of the site, but does show two earthquakes with m_b ≥ 3.0 within 40 km (25 mi) of the site. These two earthquakes occurred south-southeast of the site in 1853 (m_b = 4.3) and southwest of the site in 1968 (m_b = 3.68), with epicentral locations shown in SER Figure 2.5.3-1 (reproduced from FSAR Figure 2.5.1-212).

The applicant stated that the 1886 Charleston earthquake, with an epicenter located more than 201 km (125 mi) southeast of the VCSNS site, produced a shaking intensity of about MMI Level VII or VIII at the site. The applicant discussed an earthquake (m_b = 4.8) which occurred in January 1913 in Union County, South Carolina, with an epicenter located less than 80 km (50 mi) northwest of the VCSNS site as shown in SER Figure 2.5.3-1. The applicant indicated that the shaking intensity from the Union County earthquake was MMI Level IV at the site. Neither the 1886 Charleston earthquake nor the 1913 Union County seismic event can be associated with a known causative fault.

Current Seismicity Data

VCSNS COL FSAR Section 2.5.3.1.5 discusses current seismicity data within the VCSNS site vicinity and site area, using updated information to include earthquakes that occurred in the site region between 1985 and 2005. The applicant stated that, for this time frame, the updated earthquake catalog contained a single event within the site vicinity and no events within the site area. The event in the site vicinity occurred in 2005, with m_b = 3.17 and an epicentral location about 32 km (20 mi) southeast of the VCSNS site (SER Figure 2.5.3-1).

The applicant also noted that four earthquakes occurred in 2006. Two of these occurred in January 2006 with epicenters located near Jonesville, South Carolina, approximately 64 km (40 mi) northwest of the VCSNS site. These earthquakes exhibited m_b = 2.5 (24 January) and m_b = 1.5 (25 January) based on information from Talwani (2006). The applicant stated that the location of the epicenters of these two small earthquakes was highly inaccurate due to their small magnitudes and sparse station coverage.

The other two 2006 earthquakes occurred during the month of September at an epicentral location near Bennettsville, South Carolina, more than 145 km (90 mi) east-northeast of the VCSNS site, with m_b = 3.5 (September 22) and m_b = 3.7 (September 25). Benson (1992) reported that these September earthquakes show a possible spatial association with a small Mesozoic (251-65.5 Ma) extensional basin mapped beneath the Coastal Plain. Talwani (2006) suggested that these earthquakes may be spatially related to a regional fault system in the Eastern Piedmont. As defined by Hatcher and others (1977), the Eastern Piedmont fault system lies beneath the Coastal Plain at the estimated epicentral locations of the earthquakes. The applicant indicated that no definitive correlation exists between these two earthquakes and the Eastern Piedmont fault system.

Current Aerial and Field Reconnaissance

VCSNS COL FSAR Section 2.5.3.1.6 addresses current aerial and field reconnaissance studies performed using aerial photographs, satellite imagery, and topographic maps. The applicant indicated that no information acquired from these studies showed any evidence for surface fault rupture, surface warping, or offset of geomorphic features indicative of active faulting in the site area.

2.5.3.2.2 Geologic Evidence, or Absence of Evidence, for Surface Deformation

VCSNS COL FSAR Section 2.5.3.2 addresses the presence or absence of surface deformation in the VCSNS site vicinity. The applicant reviewed existing literature, performed aerial and field reconnaissance studies, and examined aerial photographs and satellite imagery for indications of Quaternary surface deformation along 12 bedrock faults mapped within the site vicinity. The applicant concluded that none of these 12 faults, interpreted to range in age from Paleozoic (542-251 Ma) to Cenozoic (65.5 Ma to present), exhibit any geomorphic features indicative of Quaternary (2.6 Ma to present) activity. In addition to these 12 bedrock faults, the applicant acknowledged that the VCSNS site is underlain at depth by low-angle Paleozoic age thrust faults that do not reach the surface in the site area or site vicinity.

The following sections discuss the 12 bedrock faults and the geologic evidence used by the applicant to conclude that there is no Quaternary activity associated with any of these bedrock structures. SER Figure 2.5.3-1 shows the locations of these structures.

Wateree Creek Fault

The applicant stated that the Wateree Creek fault is a northerly-trending structure, approximately 13 km (8 mi) in length, which lies about 3 km (2 mi) south of the site at its nearest point. The applicant indicated that, based on crosscutting relationships with unfaulted diabase dikes, Secor and others (1998) estimated a minimum age of Triassic (251-201.6 Ma) for the Wateree Creek fault.

Summers Branch Fault

The applicant described the postulated Summers Branch fault as a northerly-trending structure, approximately 13 km (8 mi) in length, which lies about 8 km (5 mi) southwest of the VCSNS site at its nearest point, if it exists. The applicant reported that, based on an association with the Wateree Creek fault, Secor and others (1998) estimated a minimum age of Triassic (248-206 Ma) for the Summers Branch fault. More recent interpretations of site area geology (Maher and others, 1991; Secor, 2007) do not include this fault zone.

Chappells Shear Zone

The applicant stated that the Chappells Shear Zone is a northeast-trending, 3.2-km (2-mi) wide zone of ductile deformation with a length of about 97 km (60 mi). This shear zone lies about 3 km (2 mi) south of the site at its nearest point. The applicant stated that post-Paleozoic (<251 Ma) displacement along the shear zone is precluded by crosscutting relationships with the unfaulted Winnsboro pluton, which has been dated radiometrically at about 309 Ma.

Cross Anchor Fault

The applicant described the Cross Anchor fault as a thrust fault of variable strike, with a length of more than about 97 km (60 mi). This fault lies about 16 km (10 mi) north of the VCSNS site at its nearest point. The applicant stated that field relationships indicate the Cross Anchor fault is about 325 Ma in age (i.e., Late Paleozoic), and possibly part of the CPSZ, which forms the western tectonic boundary of the Carolina Zone in which the site is located.

Beaver Creek Shear Zone

The applicant indicated that the northeast-trending Beaver Creek Shear Zone is a 3.2-km (2-mi) wide zone of ductile deformation having a length of more than 80 km (50 mi). This shear zone lies about 16 km (10 mi) north of the site and exhibits evidence for strike-slip displacement. The applicant stated that crosscutting relationships with the undeformed Newberry granite preclude displacement along the Beaver Creek Shear Zone that is younger than 415 Ma, indicating the structure is Paleozoic in age.

Modoc Shear Zone

The applicant described the northeast-trending Modoc Shear Zone as an extensive tectonic feature, traceable from central Georgia to central South Carolina and possibly into North Carolina. The zone is characterized by ductile and brittle deformation, and lies about 32 km (20 mi) south of the VCSNS site at its nearest point. The applicant stated that both ductile and brittle deformation fabrics in the shear zone developed during the Alleghanian orogeny approximately 315-290 Ma.

Gold Hill Fault Extension

The applicant indicated that the Gold Hill fault extension is the southwestern extension of the northeast-trending Gold Hill fault, which is characterized by right-lateral strike-slip displacement. The Gold Hill fault extension is located approximately 32 km (20 mi) north of the VCSNS site. The applicant stated that, based on correlations with the Deal Creek Shear Zone and crosscutting relationships with intrusive igneous bodies, West (1998) constrained displacement on the Gold Hill fault to between 400-325 Ma. Consequently, the applicant interpreted the Gold Hill fault extension to be Paleozoic in age.

Ridgeway Fault

The applicant described the Ridgeway fault as a northerly-trending fault zone, approximately 15 km (9 mi) in length, which lies about 32 km (20 mi) east of the site. The applicant stated that, based on an association with the Wateree Creek fault, Secor and others (1998) estimated a minimum age of Triassic (251-201.6 Ma) for the Ridgeway fault.

Longtown Fault

The applicant indicated that the west-northwest-trending Longtown fault is associated with fracturing and brecciation of crystalline rocks along its trace length, and reported that this fault lies about 40 km (25 mi) east-northeast of the VCSNS site. The applicant stated that Barker and Secor (2005) reported Jurassic (201.6-145.5 Ma) age diabase dikes which cross the Longtown fault without offset, and that there is no evidence for post-Mesozoic (i.e., < 65.5 Ma) displacement along this fault.

Fault #67 Near Irmo, South Carolina, Prowell (1983)

The applicant described postulated Fault #67 of Prowell (Prowell, 1983), which, if it exists, occurs southeast of the VCSNS site as a series of northeast-trending, near-vertical reverse faults exposed in a single construction excavation over 25 years ago. The applicant indicated that one strand of this series of faults was interpreted by Prowell (1983) to offset Eocene to

Pliocene (55.8-2.6 Ma) age sands and gravels about 1.5 m (5 ft), but that these postulated faults, now covered, were not mapped beyond the excavation and were not correlated with any fault of known tectonic origin. The applicant noted that this fault is not included on more recent geologic maps.

Unnamed Fault Near Ridgeway, South Carolina, Secor and Others (1998)

The applicant indicated that the unnamed fault of Secor and others (1998) occurs east of the VCSNS site, just south of the Longtown fault, and terminates against the Ridgeway fault. Based on mapping of six diabase dikes of Triassic (251-201.6 Ma) or Jurassic (201.6-145.5 Ma) age which cross this unnamed fault without offset (Secor and others, 1998; Barker and Secor, 2005), the applicant stated that this unnamed fault has a minimum age of Triassic.

Unnamed Fault Near Parr, South Carolina, Dames and Moore (1972)

The applicant described the postulated, northeast-trending, unnamed fault of Dames and Moore (1972) as occurring in a single exposure about 5 km (3 mi) south-southwest of the site. The applicant indicated that geologic field work performed for VCSNS Units 2 and 3 did not reveal any evidence for this fault. The applicant stated that, if it exists, this unnamed fault does not offset the contact of the Late Paleozoic (about 309 Ma) Winnsboro pluton, and assigned a Paleozoic age to this postulated structure.

2.5.3.2.3 Correlation of Earthquakes with Capable Tectonic Sources

VCSNS COL FSAR Section 2.5.3.3 discusses correlation of earthquakes with capable tectonic sources within 80 km (50 mi) of the VCSNS site. The applicant illustrated locations of earthquake epicenters and tectonic features within 80 km (50 mi) of the site location (SER Figure 2.5.3-1), including all earthquakes with a body wave magnitude (m_b) ≥ 3.0, which occurred from 1627 to 2006. SER Figure 2.5.3-1 shows only three historical earthquakes with m_b ≥ 3.0 within 40 km (25 mi) of the site location, including events in 1853 (m_b = 4.3), 1968 (m_b = 3.68), and 2005 (m_b = 3.17). The applicant stated that the largest earthquake within 80 km (50 mi) of the site was the January 1913 event in Union County, South Carolina, with m_b = 4.8. The applicant presented detailed information on these four earthquakes in FSAR Sections 2.5.3.1.4 and 2.5.3.1.5.

Based on SER Figure 2.5.3-1, which shows the locations of earthquake epicenters and tectonic features, the applicant concluded that no spatial correlation exists between earthquake epicenters and known or postulated faults, geomorphic features, or other tectonic elements within 80 km (50 mi) of the site. Based on review of published literature, the applicant further concluded that no historical earthquakes have been associated with bedrock faults within 80 km (50 mi) of the VCSNS site, and none of these bedrock faults are capable tectonic sources because all are older than Quaternary (i.e., >2.6 Ma).

2.5.3.2.4 Ages of Most Recent Deformations

VCSNS COL FSAR Section 2.5.3.4 discusses ages of most recent deformations within the VCSNS site vicinity. The applicant reported that, of the 12 faults identified within the site vicinity, five (the Beaver Creek, Chappells, and Modoc Shear Zones, Cross Anchor fault, and Gold Hill fault extension) are Paleozoic (>251 Ma) in age; five (the Wateree Creek, Summers Branch, Ridgeway, Longtown faults and the unnamed fault near Ridgeway, South Carolina) are

Mesozoic or pre-Mesozoic (> 65.5 Ma); and two (Fault #67 of Prowell and the unnamed fault near Parr, South Carolina) are likely nontectonic in origin.

The applicant discussed the Camden fault, a northeast-striking structure exhibiting Cenozoic (65 Ma to present) displacement, located about 64 km (40 mi) east of the site (SER Figure 2.5.3-1). Based on seismic reflection data from Knapp and others (2001), the applicant suggested a pre-Tertiary (>2.6 Ma) age for the Camden fault.

2.5.3.2.5 Relationships of Tectonic Structures in the Site Area to Regional Tectonic Structures

VCSNS COL FSAR Section 2.5.3.5 addresses the relationships of certain of the 12 faults defined in the site vicinity with regional tectonic structures. The applicant stated that West (1998) interpreted the Beaver Creek Shear Zone to be part of the more regional Lowdenville Shear Zone, and the Cross Anchor fault to be part of the CPSZ. The applicant also stated, based on Hatcher and others (1977) that the Modoc Shear Zone is part of the proposed regional Eastern Piedmont fault system. The applicant did not associate any of the other 12 bedrock faults with regional tectonic structures.

2.5.3.2.6 Characterization of Capable Tectonic Sources

VCSNS COL FSAR Section 2.5.3.6 discusses characterization of capable tectonic sources within the VCSNS site vicinity. Based on review of published geologic, seismic, and geophysical data, interviews with earth scientists knowledgeable about the site region and vicinity, and field investigations performed for the COL application, the applicant concluded that no capable tectonic sources exist within 40 km (25 mi) of the site.

2.5.3.2.7 Designation of Quaternary Deformation Zones Requiring Detailed Fault Investigation

VCSNS COL FSAR Section 2.5.3.7 addresses zones of Quaternary (2.6 Ma to present) deformation in the site area that may require detailed investigation. Based on review of published geologic, seismic, and geophysical data, interviews with earth scientists knowledgeable about the site region and vicinity, and field investigations performed for the COL application, the applicant concluded that no evidence exists for Quaternary deformation within the site area. Consequently, the applicant concluded that no further investigations for Quaternary deformation are necessary.

2.5.3.2.8 Potential for Surface Tectonic Deformation at the Site

VCSNS COL FSAR Section 2.5.3.8 discusses the potential for surface tectonic and nontectonic deformation at the site. The applicant stated that detailed geologic mapping of Unit 1 excavations revealed no evidence of Quaternary (2.6 Ma to present) or currently active faulting, and stated that no Quaternary faults or capable tectonic sources exist within 40 km (25 mi) of the site.

Based on the fact that the primary rock types occurring in the site area are igneous and metamorphic rock units, the applicant concluded that these rocks are not susceptible to dissolution collapse or subsidence due to fluid withdrawal. The applicant also stated that no information exists to suggest a potential for nontectonic surface deformation within 8 km (5 mi) of the site, and concluded that the potential for nontectonic surface deformation within the site area is negligible.

2.5.3.3 *Regulatory Basis*

The regulatory basis of the information incorporated by reference is addressed in NUREG-1793 and its supplements.

In addition, the acceptance criteria associated with the relevant requirements of the Commission regulations for surface faulting are given in Section 2.5.3 of NUREG-0800.

The applicable regulatory requirements for reviewing the applicant's discussion of surface faulting are as follows:

- 10 CFR 52.79(a)(1)(iii), as it 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, as it relates to determining the potential for surface tectonic and nontectonic deformations at and in the region surrounding the site.

The related acceptance criteria from Section 2.5.3 of NUREG-0800 are as follows:

- Geologic, Seismic, and Geophysical Investigations: Requirements of 10 CFR 100.23 are met and the guidance in RG 1.132, Revision 2; RG 1.198; RG 1.208; and RG 4.7, Revision 2, is followed for this area of review 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 well with studies conducted by others in the same area, and are supported by detailed investigations performed by the applicant.

- Geologic Evidence, or Absence of Evidence, for Surface Tectonic Deformation: Requirements of 10 CFR 100.23 are met and the guidance in RG 1.132, Revision 2; RG 1.198; RG 1.208; and RG 4.7, Revision 2 is followed for this area of review if sufficient surface and subsurface information is provided by the applicant for the site vicinity, site area, and site location to confirm presence or absence of surface tectonic deformation (i.e., faulting) and, if present, to demonstrate the age of the most recent fault displacement and ages of previous displacements.

- Correlation of Earthquakes with Capable Tectonic Sources: Requirements of 10 CFR 100.23 are met for this area of review if all reported historical earthquakes within the site vicinity are evaluated with respect to accuracy of hypocenter location and source of origin, and if all capable tectonic sources that could, based on fault orientation and length, extend into the site area or site location are evaluated with respect to potential for causing surface deformation.

- Ages of Most Recent Deformation: Requirements of 10 CFR 100.23 are met for this area of review if every significant surface fault and feature associated with a blind fault, any part of which lies within the site area, is investigated in sufficient detail to demonstrate, or allow relatively accurate estimates of the age of the most recent fault displacement, and enable identification of geologic evidence for previous displacements (if such evidence exists).

- Relationship of Tectonic Structures in the Site Area to Regional Tectonic Structures: Requirements of 10 CFR 100.23 are satisfied for this area of review by discussion of structural and genetic relationships between site area faulting or other tectonic deformation and the regional tectonic framework.

- Characterization of Capable Tectonic Sources: Requirements of 10 CFR 100.23 are met for this area of review when it has been demonstrated that investigative techniques employed by the applicant are sufficiently sensitive to identify all potential capable tectonic sources, such as faults or structures associated with blind faults, within the site area; and when fault geometry, length, sense of movement, amount of total displacement and displacement per faulting event, age of latest and any previous displacements, recurrence rate, and limits of the fault zone are provided for each capable tectonic source.

- Designation of Zones of Quaternary Deformation in the Site Region: Requirements of 10 CFR 100.23 regarding designation of zones of Quaternary deformation in the site region are met if the zone (or zones) designated by the applicant as requiring detailed faulting investigations is of sufficient length and width to include all Quaternary deformation features potentially significant to the site as described in RG 1.208.

- Potential for Surface Tectonic Deformation at the Site Location: To meet requirements of 10 CFR 100.23 for this area of review, information must be presented by the applicant in this section if field investigations reveal that surface or near-surface tectonic deformation along a known capable tectonic structure (i.e., a known capable tectonic feature related to a fault or blind fault) must be taken into account at the site location.

In addition, the geologic characteristics should be consistent with appropriate sections from RG 1.208; RG 1.132, Revision 2; RG 1.198; RG 4.7, Revision 2; and RG 1.206.

2.5.3.4 *Technical Evaluation*

The NRC staff reviewed Section 2.5.3 of the VCSNS COL FSAR and checked the referenced DCD to ensure that the combination of the DCD and the COL application represents the complete scope of information relating to this review topic.[1] The NRC staff's review confirmed that information in the application and incorporated by reference addresses the required information relating to surface faulting. The results of the NRC staff's evaluation of the information incorporated by reference in the VCSNS COL application are documented in NUREG-1793 and its supplements.

The staff reviewed the following information in the VCSNS COL FSAR:

AP1000 COL Information Item

- VCS COL 2.5-4

The NRC staff reviewed VCS COL 2.5-4 in regard to evaluation of surface faulting information included in Section 2.5.3 of the VCSNS COL FSAR. The COL information item from AP1000 DCD Section 2.5.3 states:

> Combined License applicants referencing the AP1000 certified design will address the following surface and subsurface geological, seismological, and geophysical information related to the potential for surface or near-surface faulting affecting the site: (1) geological, seismological, and geophysical investigations, (2) geological evidence, or absence of evidence, for surface deformation, (3) correlation of earthquakes with capable tectonic sources, (4) ages of most recent deformation, (5) relationship of tectonic structures in the site area to regional tectonic structures, (6) characterization of capable tectonic sources, (7) designation of zones of Quaternary deformation in the site region, and (8) potential for surface tectonic deformation at the site.

The technical information presented in VCSNS COL FSAR Section 2.5.3 resulted from the applicant's surface and subsurface geologic investigations performed within an 8-km (5-mi) radius of the site (i.e., the site area), supplemented by aerial and field reconnaissance studies undertaken within a 40-km (25-mi) radius of the site (i.e., the site vicinity). Through the review of the VCSNS COL FSAR Section 2.5.3, the staff determined whether the applicant had complied with the applicable regulations and conducted the investigations at an appropriate level of detail in accordance with RG 1.208.

The NRC staff focused the review of VCSNS COL FSAR Section 2.5.3 on the applicant's descriptions of previous studies and data collected during those studies, as well as on the results of investigations conducted by the applicant to assess the potential for surface and near-surface tectonic and nontectonic deformation at the site. During the early site investigation stage in June 2006, the staff visited the site and interacted with the applicant and its consultants in regard to the geologic, seismic, and geophysical investigations being performed for the VCSNS COL application. On a second site visit in March 2009, the staff obtained assistance from experts at the USGS to enable a thorough evaluation of the geologic, seismic, and geophysical information presented by the applicant for confirming the interpretations, assumptions, and conclusions made about the potential for surface and near-surface tectonic and nontectonic deformation at the site. The staff's evaluation of the information presented by the applicant in VCSNS COL FSAR Section 2.5.3 and in responses to RAIs on that FSAR section is presented below.

2.5.3.4.1 Geologic, Seismic, and Geophysical Investigations

VCSNS COL FSAR Section 2.5.3.1 summarizes the geologic, seismic, and geophysical investigations performed by the applicant to assess the potential for tectonic and nontectonic surface or near-surface deformation within 8 km (5 mi) and 40 km (25 mi) of the site (i.e., the site area and site vicinity, respectively). The applicant compiled and reviewed existing data and literature, including information on geologic maps published by the USGS and the South Carolina Department of Natural Resources; interpreted aerial photographs and satellite imagery;

conducted field and aerial reconnaissance; reviewed data on historical and recorded seismicity; and held discussions with researchers currently working in the site vicinity. In addition, the applicant used information from the previous VCSNS site investigations performed for Unit 1 and presented in the FSAR for that unit.

The NRC staff focused the review of VCSNS COL FSAR Section 2.5.3.1 on completeness of the information used by the applicant to assess the potential for surface or near-surface faulting and nontectonic deformation at the site. Based on the review of VCSNS COL FSAR Section 2.5.3.1, assessment of information gained during the site visits in June 2006 and March 2009, and independent examination of recent pertinent literature, the staff concludes that the applicant presented the data appropriate for assessing the potential for surface and near-surface faulting and nontectonic deformation at the VCSNS site. The staff draws this conclusion because of the thorough and up-to-date nature of the data sources used by the applicant.

Based on the review of VCSNS COL FSAR Section 2.5.3.1, the staff further concludes that the applicant provided a thorough and accurate description of the data sources related to the potential for surface and near-surface tectonic and nontectonic deformation in support of the VCSNS COL application. The following sections document how the applicant characterized the potential for surface and near-surface faulting and nontectonic deformation at the VCSNS site.

2.5.3.4.2 Geologic Evidence, or Absence of Evidence, for Surface Deformation

VCSNS COL FSAR Section 2.5.3.2 summarizes the information presented by the applicant related to geologic evidence, or the absence of evidence, for surface deformation at the site. The applicant specifically addressed 12 bedrock faults, located within 40 km (25 mi) of the site, which are interpreted to range from Paleozoic (542-251 Ma) to Cenozoic (65.5 Ma to present) in age. These 12 faults, located on SER Figure 2.5.3-1, include the Chappells, Beaver Creek, and Modoc Shear Zones; the Wateree Creek, Summers Branch, Cross Anchor, Ridgeway, and Longtown faults; the Gold Hill fault extension; Fault #67 of Prowell (Prowell, 1983); and unnamed faults near Ridgeway, South Carolina (Secor and others, 1998) and Parr, South Carolina (Dames and Moore, 1972). The applicant stated that no deformational or geomorphic features suggesting Quaternary (2.6 Ma to present) displacement has been reported for any of these 12 faults. Based on the results of aerial and field reconnaissance and interpretation of aerial photographs and satellite imagery performed for the VCSNS site, the applicant concluded that no geomorphic features indicate Quaternary activity along any of these 12 faults.

The NRC staff focused the review of VCSNS COL FSAR Section 2.5.3.2 on these 12 bedrock faults. In RAI 2.5.3-1, the staff asked the applicant to summarize the logic used to qualify the ages of these structures.

In the response to RAI 2.5.3-1, the applicant provided a map showing the locations of these 12 bedrock faults. The applicant also provided a table, which summarized the information used to constrain ages of these faults, and document that none are interpreted to exhibit Quaternary (2.6 Ma to present) deformation.

Based on the review of the applicant's response to RAI 2.5.3-1, the staff concludes that the applicant presented adequate descriptions of the 12 bedrock faults, including information on age constraints documenting a lack of Quaternary deformation along any of these structures. The staff draws this conclusion because the applicant documented a pre-Quaternary (> 2.6 Ma) age for the structures based on existing field information. Consequently, the staff considers RAI 2.5.3-1 to be resolved.

Based on the review of VCSNS COL FSAR Section 2.5.3.2 and the applicant's response to RAI 2.5.3-1, the staff concludes that the applicant provided a thorough and accurate description of the geologic evidence, or the absence of evidence, for surface deformation at the site in support of the VCSNS COL application.

2.5.3.4.3 Correlation of Earthquakes with Capable Tectonic

VCSNS COL FSAR Section 2.5.3.3 discusses the correlation of earthquakes with capable tectonic sources within 80 km (50 mi) of the VCSNS site. Based on an analysis of the distribution of seismic events within 80 km (50 mi) of the site, the applicant concluded that no spatial correlation exists between earthquake epicenters and any known or postulated tectonic features, and that no historical earthquakes are associated with bedrock faults. The applicant indicated that no faults within 40 km (25 mi) of the site are classified as capable tectonic sources. The applicant also stated that three historical earthquakes with $m_b \geq 3.0$ occurred within 40 km (25 mi) of the site. The staff noted that two of these three earthquakes may be spatially related to the Modoc Shear Zone as shown in FSAR Figure 2.5.1-212.

The staff focused the review of VCSNS COL FSAR Section 2.5.3.3 on the three minor historical earthquakes which occurred within 40 km (25 mi) of the site. In RAI 2.5.3-3, the staff asked the applicant to discuss the significance of the two earthquakes, which appear to lie along the trace of the Modoc Shear Zone in the site vicinity.

In the response to RAI 2.5.3-3, the applicant indicated that large uncertainties exist in the locations of instrumentally recorded earthquakes in the area covered by VCSNS COL FSAR Figure 2.5.1-212 because the seismograph stations are sparse and widely separated. The applicant also pointed out that the Modoc Shear Zone dips northwest, while the two earthquakes epicenters are presently located southeast of the shear zone. Therefore, the applicant concluded that no definitive association between the two earthquakes and the Modoc Shear Zone could be established.

Based on the review of the applicant's response to RAI 2.5.3-3, the staff concludes that no definitive association can be established between the Modoc Shear Zone and the two earthquakes. The staff makes this conclusion because there are large uncertainties in the locations of instrumentally recorded earthquakes in the area covered by FSAR Figure 2.5.1-212 due to the widely separated positions of the seismograph stations. Consequently, the staff considers RAI 2.5.3-3 to be resolved.

Based on the review of VCSNS COL FSAR Section 2.5.3.3 and the applicant's response to RAI 2.5.3-3, the staff concludes that the applicant provided a thorough and accurate description of the correlation of earthquakes with capable tectonic sources in support of the VCSNS COL application.

2.5.3.4.4 Ages of Most Recent Deformation

VCSNS COL FSAR Section 2.5.3.4 presents data related to the ages of most recent deformation, concentrating on the 12 bedrock faults which occur within 40 km (25 mi) of the site. Based on field relationships, the applicant concluded that six of these faults are Paleozoic (> 251 Ma) in age (i.e., the Chappells, Beaver Creek, and Modoc Shear Zones; the Cross

Anchor fault; the Gold Hill fault extension; and the postulated unnamed fault near Parr, South Carolina, if it exists); five are at least Mesozoic (251-65.5 Ma) in age (i.e., the Wateree Creek, Summers Branch, Ridgeway, and Longtown faults; and the unnamed fault near Ridgeway, South Carolina); and one, Fault #67 of Prowell (Prowell, 1983), is possibly Cenozoic (65.5 Ma to present) in age, if it exists. The applicant stated in FSAR Section 2.5.3.2 that Fault #67 of Prowell (Prowell, 1983) does not appear on more recent geologic maps of the area; has not been correlated with any other fault of known tectonic origin beyond its single exposure; and was not shown to offset units younger than Pliocene (5.3-2.6 Ma) in age. The applicant also discussed the Camden fault, which occurs about 64 km (40 mi) east of the VCSNS site and exhibits Cenozoic activity. Based on field data, the applicant concluded that the Camden fault is no younger than Oligocene (33.9-23 Ma).

The staff focused the review of VCSNS COL FSAR Section 2.5.3.4 on the data used by the applicant to document ages of most recent deformation for the 12 bedrock faults, and the applicant's conclusions that Fault #67 of Prowell (Prowell, 1983) and the postulated unnamed fault near Parr, if it exists, may be nontectonic in origin. In RAI 2.5.3-4, the staff asked the applicant to summarize the information used to conclude that Fault #67 and the postulated unnamed fault near Parr are nontectonic features.

In the response to RAI 2.5.3-4, the applicant stated that neither Fault #67 of Prowell (Prowell, 1983), nor the postulated unnamed fault near Parr, should be classified as nontectonic features based on existing data, and deleted this descriptor in Revision 1 of VCSNS COL FSAR Section 2.5.3. The applicant acknowledged that Fault #67 is Cenozoic (65.5 Ma to present) in age, if it exists, but possibly not younger than Pliocene (5.3-2.6 Ma) based on information presented in FSAR Section 2.5.3.2; and that the unnamed fault near Parr, South Carolina, if it exists, is Paleozoic (> 251 Ma) in age.

Based on the review of the applicant's response to RAI 2.5.3-4 and VCSNS COL FSAR Section 2.5.3.2, which discusses the two faults in more detail, the staff concludes that the applicant documented probable pre-Quaternary (i.e., > 2.6 Ma) ages for Fault #67 and the postulated unnamed fault near Parr. The staff draws this conclusion because field information presented by the applicant supports the interpretation that neither of these two faults is Quaternary (2.6 Ma to present) in age. In addition, based on age constraints from field data presented by the applicant, the staff concludes that none of the 12 faults which occur within 30 km (25 mi) of the site are Quaternary in age or represent capable tectonic features. Consequently, the staff considers RAI 2.5.3-4 to be resolved.

Based on the review of VCSNS COL FSAR Section 2.5.3.4 and the applicant's response to RAI 2.5.3-4, the staff concludes that the applicant provided a thorough and accurate description of the ages of most recent deformation in support of the VCSNS COL application.

2.5.3.4.5 Relationship of Tectonic Structures in the Site Area to Regional Tectonic Structures

VCSNS COL FSAR Section 2.5.3.5 discusses the relationship of tectonic structures in the site area to regional tectonic structures. The applicant stated that some of the 12 bedrock faults which occur within 40 km (25 mi) of the VCSNS site have been associated with regional tectonic structures. Based on West (1998), the applicant indicated that the Beaver Creek Shear Zone is part of the larger Lowdensville Shear Zone, and the Cross Anchor fault is part of the regional CPSZ. Based on Hatcher and others (1977), the applicant also stated that the Modoc Shear Zone is associated with the larger EPFZ. In FSAR Section 2.5.3.2, the applicant documented

Paleozoic (> 251 Ma) ages for the Beaver Creek and Modoc Shear Zones and the Cross Anchor fault, and the regional structures with which they may be associated.

The staff focused the review of VCSNS COL FSAR Section 2.5.3.5 on possible associations of faults and shear zones within 40 km (25 mi) of the site with regional tectonic structures. In RAI 2.5.3-5, the staff asked the applicant to summarize the information used to conclude that the Beaver Creek and Modoc shear zones and the Cross Anchor fault show a relationship to regional tectonic structures. The staff also asked the applicant to discuss whether the Chappells Shear Zone and the Gold Hill fault are related to regional tectonic structures and the potential implications of such a relationship for the VCSNS site.

In the response to RAI 2.5.3-5, the applicant indicated that the Beaver Creek and Lowndesville Shear Zones may be extensions of one another based on field data. The applicant added that the Cross Anchor fault, interpreted to be part of the CPSZ, connects with the Lowndesville and Kings Mountain Shear Zones to define the western boundary of the Charlotte Terrane; and that the Modoc Shear Zone, considered as part of the EPFZ, is mapped based on linear magnetic anomalies and similarities in deformation fabrics. The applicant also stated that the Chappells Shear Zone is not associated with other structures in the site vicinity, but that the Gold Hill and Silver Hill faults form the Gold Hill-Silver Hill Shear Zone, which is located to the northeast, outside the site vicinity, in North Carolina. Based on Allen and others (2007), the applicant indicated that the Gold Hill-Silver Hill Shear Zone is not associated with any other regional tectonic structure. Based on age constraints from field data, the applicant documented that the Gold Hill-Silver Hill and the Chappells Shear Zones are Paleozoic (> 251 Ma) in age and are not capable tectonic structures. The applicant provided Figure 2.5.3-5.1, which illustrates the relationships between structures in the site vicinity and the regional tectonic features

Based on the review of the applicant's response to RAI 2.5.3-5, the staff concludes that the applicant documented the associations between the Beaver Creek and Modoc Shear Zones and the Cross Anchor fault with regional tectonic structures in the site area, as well as the lack of an association of the Chappells and the Gold Hill-Silver Hill Shear Zones with other regional tectonic structures. The staff draws this conclusion because Figure 2.5.3.5-1 and the descriptions provided clarify the suggested associations between tectonic features in the site vicinity and regional tectonic elements. In addition, the staff notes that, in FSAR Section 2.5.3.2, the applicant documented a Paleozoic (>251 Ma) age for the tectonic structures discussed in VCSNS COL FSAR Section 2.5.3.5 and in the response to RAI 2.5.3-5. Therefore, none of these structures are capable tectonic features. Consequently, the staff considers RAI 2.5.3-5 to be resolved.

Based on the review of VCSNS COL FSAR Section 2.5.3.5 and the applicant's response to RAI 2.5.3-5, the staff concludes that the applicant provided a thorough and accurate description of the relationship of tectonic structures in the site area to regional tectonic structures in support of the VCSNS COL application.

2.5.3.4.6 Characterization of Capable Tectonic Sources

VCSNS COL FSAR Section 2.5.3.6 addresses the characterization of capable tectonic sources within the site vicinity. The applicant concluded that no capable tectonic sources exist within 40 km (25 mi) of the VCSNS site.

The staff focused the review of VCSNS COL FSAR Section 2.5.3.6 on documentation of the applicant's conclusion that no capable tectonic sources exist within the site vicinity. In RAI 2.5.3-6, the staff asked the applicant to provide the basis for this conclusion.

In the response to RAI 2.5.3-6, the applicant stated that the conclusion regarding no capable faults within 40 km (25 mi) of the site was based on review of pertinent literature presenting geologic, seismic, and geophysical data for the site region, vicinity, and area; interviews with experts familiar with geology and seismology of the site area; aerial photograph interpretation in the site area; and geologic field reconnaissance of the site vicinity and site area performed for the COL application. The applicant indicated that particular attention was paid to 12 bedrock faults mapped in the site area, and that age constraints on these features demonstrated none are capable tectonic structures.

Based on the review of the VCSNS COL FSAR Section 2.5.3.6 and the applicant's response to RAI 2.5.3-6, the staff concludes that the applicant documented the statement that no capable tectonic sources exist within 40 km (25 mi) of the VCSNS site. The staff draws this conclusion because the applicant provided age constraint data indicating none of the features are capable tectonic structures. Consequently, the staff considers RAI 2.5.3-6 to be resolved.

Based on the review of VCSNS COL FSAR Section 2.5.3.6 and the applicant's response to RAI 2.5.3-6, the staff concludes that the applicant provided a thorough and accurate description of the characterization of capable tectonic sources in support of the VCSNS COL application.

2.5.3.4.7 Designation of Zones of Quaternary Deformation Requiring Detailed Fault Investigations

VCSNS COL FSAR Section 2.5.3.7 addresses the designation of zones of Quaternary (2.6 Ma to present) deformation in the site region which may require detailed investigations. The applicant concluded that no evidence exists for Quaternary deformation in the site area, and that further detailed fault investigations were not required.

The staff focused the review of VCSNS COL FSAR Section 2.5.3.7 on the applicant's conclusion that no evidence exists for Quaternary deformation within in the site area. In RAI 2.5.3-7, the staff asked the applicant to provide the basis for this conclusion.

In the response to RAI 2.5.3-7, the applicant indicated the conclusion that no evidence exists for Quaternary deformation within the site area was based on review of pertinent literature presenting geologic, seismic, and geophysical data for the site area; interviews with experts familiar with geology and seismology of the site area; aerial photograph interpretation in the site area; and geologic field reconnaissance of the site vicinity and site area performed for the COL application. The applicant indicated that particular attention was paid to 12 bedrock faults mapped in the site area, and that age constraints on these features demonstrated none exhibit Quaternary (2.6 Ma to present) deformation requiring further investigations.

Based on the review of the VCSNS COL FSAR Section 2.5.3.7 and the applicant's response to RAI 2.5.3-7, the staff concludes that the applicant documented the statement that no evidence exists for Quaternary deformation within the site area. The staff draws this conclusion because the applicant provided age constraint data indicating none of the features are Quaternary in age. Consequently, the staff considers RAI 2.5.3-7 to be resolved.

Based on the review of VCSNS COL FSAR Section 2.5.3.7 and the applicant's response to RAI 2.5.3-7, the staff concludes that the applicant provided a thorough and accurate description of the designation of zones of Quaternary deformation in the site region in support of the VCSNS COL application.

2.5.3.4.8 Potential for Surface Tectonic Deformation at the Site

VCSNS COL FSAR Section 2.5.3.8 discusses the potential for surface tectonic deformation at the site, as well as the potential for nontectonic surface deformation. The applicant concluded that the potential for tectonic deformation at the VCSNS site is negligible because no Quaternary or currently active faults or capable tectonic structures occur within 40 km (25 mi) of the site. The applicant further concluded that the potential for nontectonic surface deformation within the site area is negligible, because rock units in the site area are igneous and metamorphic crystalline rocks and not susceptible to karst-type dissolution collapse or subsidence due to fluid withdrawal.

The staff focused the review of VCSNS COL FSAR Section 2.5.3.8 on the applicant's conclusions that the potential for tectonic and nontectonic deformation is negligible at the site. Based on the review of FSAR Section 2.5.3.8, the staff concludes that the potential for tectonic and nontectonic deformation is negligible at the site. The staff makes this conclusion because no Quaternary or currently active faults or capable tectonic structures occur within 40 km (25 mi) of the site, and rock units in the site area are igneous and metamorphic crystalline rocks that are not susceptible to nontectonic deformation due to dissolution or fluid withdrawal.

Based on the review of VCSNS COL FSAR Section 2.5.3.8, the staff concludes that the applicant provided a thorough and accurate description of the potential for tectonic and nontectonic surface deformation at the site in support of the VCSNS COL application.

2.5.3.5 *Post-Combined License Activities*

There are no post-COL activities related to FSAR Section 2.5.3.

2.5.3.6 *Conclusion*

The NRC staff reviewed the application and checked the referenced DCD. The staff's review confirmed that the applicant addressed the required information relating to surface faulting, and there is no outstanding information expected to be addressed in the VCSNS COL FSAR related to this section. The results of the staff's technical evaluation of the information incorporated by reference in the VCSNS COL application are documented in NUREG-1793 (U.S. NRC, 2004) and its supplements.

As set forth above, the staff has reviewed the information in VCS COL 2.5-4 and finds that the applicant provided a thorough characterization of the potential for surface deformation at the VCSNS site as required by 10 CFR 100.23 and 10 CFR 52.79 (a)(1)(iii). The staff considered the information gathered by the applicant during the regional and site-specific investigations. As a result of this review, the staff concludes that the applicant performed its investigations in accordance with10 CFR 100.23 and 10 CFR 52.79(a)(1)(iii) by following the guidance provided in RG 1.208. The staff concludes that the applicant provided an adequate basis to establish that there are no known capable tectonic sources in the site vicinity that would cause surface or near-surface deformation in the site area. The staff concludes that the site is suitable from the perspective of tectonic and nontectonic surface deformation and meets the requirements of 10 CFR 100.23 and 10 CFR 52.79(a)(1)(iii).

2.5.4 Stability of Subsurface Materials and Foundations

2.5.4.1 *Introduction*

Section 2.5.4 of this SER provides information on the static and dynamic stability of subsurface materials and foundations that relate to the VCSNS Units 2 and 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 related to the stability of subsurface materials and foundations covers the following specific areas: (1) geologic features in the vicinity of the site; (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 seismic refraction and reflection surveys, including in-hole and cross-hole explorations; (5) safety-related excavation and backfill plans and engineered earthwork analysis and criteria; (6) groundwater conditions and piezometric pressure in all critical strata as to 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; and (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.

SER Section 2.5.4.2 summarizes the relevant geotechnical information in VCSNS COL FSAR Section 2.5.4. SER Section 2.5.4.3 summarizes NRC regulations and regulatory guidance used by the applicant to prepare FSAR Section 2.5.4 and by the staff to perform evaluations. SER Section 2.5.4.4 describes the detailed evaluation performed by NRC staff of FSAR Section 2.5.4 and includes an evaluation by the staff of the applicant’s responses to RAIs, as well as the results of site visits and any confirmatory analyses performed by the NRC staff. SER Section 2.5.4.5 discusses any post-COL activities. Finally, SER Section 2.5.4.6 summarizes the conclusions made by the NRC staff, concerning FSAR Section 2.5.4, restates the bases for the conclusions, documents whether the applicant properly characterized the site, and confirms that the applicant met the requirements defined in the NRC regulations.

2.5.4.2 *Summary of Application*

Section 2.5.4 of the VCSNS COL FSAR, Revision 5, incorporates by reference Section 2.5.4 of the AP1000 DCD, Revision 19.

In addition, in VCSNS FSAR Section 2.5.4, the applicant provided the following:

AP1000 COL Information Items

- VCS COL 2.5-5

The applicant provided additional information in VCS COL 2.5-5 to address COL Information Item 2.5-5 (COL Action Item 2.5.1-1). VCS COL 2.5-5 addresses the provision of site-specific information regarding the underlying site conditions and geologic features, including site topographical features and the locations of seismic Category I structures.

- VCS COL 2.5-6

The applicant provided additional information in VCS COL 2.5-6 to resolve COL Information Item 2.5-6 (COL Action Item 2.6-3). VCS COL 2.5-6 addresses the properties of the foundation soils to be within the range considered for design of the nuclear island basemat.

- VCS COL 2.5-7

The applicant provided additional information in VCS COL 2.5-7 to resolve COL Information Item 2.5-7 (COL Action Item 2.5.4-1). VCS COL 2.5-7 addresses the information concerning the extent (horizontal and vertical) of seismic Category I excavations, fills, and slopes.

- VCS COL 2.5-8

The applicant provided additional information in VCS COL 2.5-8 to resolve COL Information Item 2.5-8 (COL Action Item 2.4.1-1). VCS COL 2.5-8 addresses the ground water conditions relative to the foundation stability of the safety-related structures at the site.

- VCS COL 2.5-9

The applicant provided additional information in VCS COL 2.5-9 to resolve COL Information Item 2.5-9 (COL Action Item 2.5.4.3-1). VCS COL 2.5-9 addresses the provision of demonstration that the potential for liquefaction is negligible.

- VCS COL 2.5-10

The applicant provided additional information in VCS COL 2.5-10 to resolve COL Information Item 2.5-10 (COL Action Item 2.6-4). VCS COL 2.5-10 addresses the verification that the minimum allowable bearing capacity of the site is greater than that specified in the AP1000 DCD with an adequate factor of safety.

- VCS COL 2.5-11

The applicant provided additional information in VCS COL 2.5-11 to resolve COL Information Item 2.5-11 (COL Action Item 2.5.2-2). VCS COL 2.5-11 addresses the methodology used in determination of static and dynamic lateral earth pressures and hydrostatic groundwater pressures acting on plant safety-related facilities using soil parameters as evaluated in previous sections.

- VCS COL 2.5-12

The applicant provided additional information in VCS COL 2.5-12 to resolve COL Information Item 2.5-12 (COL Action Item 2.5.5-1). VCS COL 2.5-12 addresses soil characteristics affecting the stability of the nuclear island including foundation rebound, settlement, and differential settlement.

- VCS COL 2.5-13

The applicant provided additional information in VCS COL 2.5-13 to resolve COL Information Item 2.5-13 (COL Action Item 2.6-5). VCS COL 2.5-13 addresses the provision for instrumentation for monitoring the performance of the foundations of the nuclear island, along with the location for benchmarks and markers for monitoring the settlement.

- VCS COL 2.5-16

The applicant provided additional information in VCS COL 2.5-16 to resolve COL Information Item 2.5-16. VCS COL 2.5-16 addresses the verification that both total and differential settlements of the nuclear island, and the differential settlements between the nuclear island and other buildings do not exceed the AP1000 standard design.

- VCS COL 2.5-17

This COL Information Item was provided in a letter dated July 2, 2010 to reflect a response from Westinghouse dated July 21, 2009, to NRC RAI AP1000 DCD RAI-TR85-SEB1-36 R2, Westinghouse proposed COL Information Item 2.5-17 to provide a waterproofing system used for the below grade, exterior walls exposed to flood and groundwater under seismic Category I structures. COL Information Item 2.5-17 states that:

> The Combined License applicant will provide a waterproofing system used for the below grade, exterior walls exposed to flood and groundwater under seismic Category I structures. Waterproofing membrane should be placed immediately beneath the upper Mud Mat, and on top of the lower Mud Mat. The performance requirements to be met by the COL applicant for the waterproofing system are described in subsection 3.4.1.1.1.1.

Evaluation of the waterproofing capability of the system presented in VCS COL 2.5-17 occurs in Section 3.8 of this SER. The evaluation of the system's ability to meet the seismic requirements outlined in DCD Section 3.4.1.1.1.1 is located in Section 3.8 of this SER.

Supplemental Information

- VCS SUP 2.5-3

The applicant provided supplemental information in VCS SUP 2.5-3 related to the results of the subsurface investigation program implemented at the Units 2 and 3 site, used as a basis to evaluate the stability of subsurface materials and foundations at the site.

2.5.4.2.1 Description of Site Geologic Features

In VCSNS COL FSAR Section 2.5.4.1, the applicant referred to FSAR Sections 2.5.1.1 and 2.5.1.2 for a detailed description of the regional geologic setting, site-specific geologic conditions, potential geologic hazards, and the potential for tectonic and nontectonic deformation at the VCSNS COL application site. The applicant stated that 7.6 to 21.3 m (25 to 70 ft) of residual and saprolitic soils overlie weathered igneous and metamorphic rocks that grade into sound basement rock. The proposed VCSNS Units 2 and 3 seismic Category I structures will be founded on sound rock, or on concrete placed on top of the sound rock.

2.5.4.2.2 Properties of Subsurface Materials

VCSNS COL FSAR Section 2.5.4.2 describes the static and dynamic engineering properties of the subsurface materials at VCSNS Units 2 and 3, including overviews of the subsurface profile and materials, the applicant's field investigations, and the laboratory testing performed. The applicant stated that the design plant grade will be approximately Elevation (El.) 122 m (400 ft) (NAVD88). The overlying residual and saprolitic soils will be removed down to rock and the seismic Category I nuclear island basemat for each proposed unit (2 and 3) will be founded at El. 109 m (360 ft) (NAVD88), either on sound rock or on concrete placed on top of the sound rock.

Description of Subsurface Materials

VCSNS COL FSAR Section 2.5.4.2.2 provides an overview of the subsurface profile and materials, including detailed descriptions of the underlying strata. The applicant categorized the soils underlying the VCSNS site as Layer I Residuum; Layer II Saprolite; Layer III Partially Weathered Rock; Layer IV Moderately Weathered Rock; and Layer V Sound Rock.

<u>Layers I and II Residuum and Saprolite</u>

VCSNS COL FSAR Section 2.5.4.2.2.3 describes the top residual soil layer (Layer 1) at the VCSNS site as composed of primarily fine-grained silts and coarse-grained silty sands. The saprolitic soil layer (Layer II) is similar in composition to Layer I, even though it is completely weathered rock. The applicant plans to remove Layers I and II in order to found the safety-related structures on sound rock or on concrete placed on sound rock. The applicant plans to use the excavated residual and saprolitic soils as common fill, placed outside of the structural backfill and not in contact with seismic Category I structures.

<u>Layers III and IV Partially and Moderately Weathered Rock</u>

The partially and moderately weathered rock units are composed of hard igneous and metamorphic parent rock fragments mixed with decomposed rock matrix. The weathered rock units reflect a transition zone between the overlying soils and the underlying bedrock. The applicant used standard penetration test (SPT) measurements, V_S measurements, and rock quality designation (RQD) values to estimate the top of the partially weathered (Layer III) and moderately weathered (Layer IV) rock units. The applicant estimated that the top of Layer IV is at El. 113 m (370 ft) and El. 110 m (360 ft) for VCSNS Units 2 and 3, respectively, and that the overlying Layer III is about 1.5 m (5 ft) thick. The foundation for the nuclear island basemats will be at El. 110 m (360 ft) and the applicant will replace any of the weathered rock, above the sound rock, with concrete.

<u>Layer V Sound Rock</u>

VCSNS COL FSAR Section 2.5.4.2.2.1 states that the sound bedrock (Layer V) underlying Units 2 and 3 is igneous rock with numerous metamorphic inclusions and RQD values typically exceeding 70 percent. The RQD values reflect the quality of rock core recovered from borehole investigations. Based on the borehole data, the applicant estimated that the top of Layer V beneath Units 2 and 3 ranges from El. 90.2 to 117 m (296 to 384 ft) and 96.3 to 117 m (316 to

384 ft), respectively. For its seismic analyses, the applicant selected El. 108m (355 ft) as the top of Layer V beneath the nuclear islands of both Units 2 and 3. Layer V will support the seismic Category I structures for Units 2 and 3.

Field Investigations

VCSNS COL FSAR Section 2.5.4.2.3 describes the applicant's subsurface exploration program, which included 111 exploratory borings (88 within the PBA for Units 2 and 3), 31 observation wells, and 36 cone penetration test (CPT) soundings. The applicant drilled two 106 m (350 ft) boreholes, one at the center of each planned containment for Units 2 and 3. The applicant followed the guidance in RG 1.132, Revision 2 for conducting its field investigation program.

Exploratory Boring and Samples/Core

VCSNS COL FSAR Section 2.5.4.2.3.1 states that the applicant drilled 88 borings within the PBA of Units 2 and 3 that ranged in depth from 3 to 106 m (10 to 350 ft). The applicant collected soil and rock samples using an SPT sampler in accordance with relevant American Society for Testing and Materials (ASTM) standards, and either a Shelby tube sampler or a rotary pitcher sampler to retrieve undisturbed samples and rock core samples. The applicant used the borehole data to determine minimum, maximum and average depths for the five soil and rock layers beneath Units 2 and 3.

Observation Wells

The applicant installed 33 observation wells. Twenty-seven observation wells were placed in separate borings at distances of 1.5 to 6m (5 to 20 ft) from each of 27 geotechnical borings. Four geotechnical boreholes were modified for installation of observation wells. The applicant screened 22 of the 33 wells in the soils and weathered rock layers and the remaining 9 wells in sound rock. In addition, the applicant used the slug test method to perform permeability tests in all but one of the observation wells.

Cone Penetrometer Tests

The applicant conducted 36 CPTs in accordance with ASTM D 5778-95, to measure tip resistance, sleeve friction and pore water pressure. The applicant noted that refusal was typically encountered at depths ranging from 6 to 23 m (20 to 76 ft). The applicant performed seismic tests in 7 of the 36 CPTs and pore pressure dissipation tests in 6 of the 36 CPTs.

Test Pits

The applicant collected soil samples for laboratory analysis from four test pits, ranging in depth from 0.91 to 1.8 m (3 to 6 ft), in order to determine soil properties and backfill suitability.

Laboratory Testing

VCSNS COL FSAR Section 2.5.4.2.4 describes the laboratory testing of soil and rock samples completed in accordance with the guidance in RG 1.138, Revision 2 as part of the applicant's subsurface investigation. The applicant discussed the results of the laboratory tests with respect to engineering properties of the soil and rock in FSAR Section 2.5.4.2.5.

Engineering Properties of Soils and Rocks

VCSNS COL FSAR Section 2.5.4.2.5 describes the engineering properties of the materials in the subsurface layers based on the outcome of the Unit 2 and 3 field exploration and laboratory testing programs.

Layers I and II: Soils

In VCSNS COL FSAR Section 2.5.4.2.5.2, the applicant presented a summary of the engineering properties for the top two soil layers encountered at the VCSNS site. The applicant stated that it provided the engineering properties of Layers I and II for completeness, even though these layers will be removed beneath the nuclear islands for planned Units 2 and 3.

Layers III, IV and V: Weathered and Sound Rock

In VCSNS COL FSAR Section 2.5.4.2.5.1, the applicant described RQD and recovery values of Layers IV and V (moderately weathered and sound rock) based on the results obtained from a series of 30 boring logs. SER Table 2.5.4-1 provides the range of RQD and average recovery for the subsurface layers, from which the applicant concluded that the quality of the sound rock in Layer V (the foundation bearing unit for safety-related structures) at Units 2 and 3 was "good to excellent."

Based on rock strength test results, the applicant adopted an unconfined compressive strength (U) of 172,000 kilopascals (kPa) (25 kips per square inch [ksi]) and a unit weight for the sound rock of Layer V of 2,915 kilograms per cubic m (kg/m^3) (182 pounds per cubic foot (pcf)) for design purposes. The applicant also adopted unit weights of 2,562 and 2,322 kg/m^3 (160 and 145 pcf) for the moderately weathered and partially weathered rock, respectively, and determined that the high and low strain shear modulus values are essentially the same for Layer V.

2.5.4.2.3 Foundation Interfaces

VCSNS COL FSAR Section 2.5.4.3 presents an outline of FSAR figures that detail the locations of borings, observation wells, CPTs, electrical resistivity tests, and test pits made inside and outside of the PBA for the VCSNS Unit 2 and 3 subsurface investigation. The applicant also provided cross section views of the structural foundations and the excavation and backfill limits associated with planned Units 2 and 3. SER Figure 2.5.4-1 (reproduced from FSAR Figure 2.5.4-220) and SER Figure 2.5.4-2 (reproduced from FSAR Figure 2.5.4-221) shows the locations of the reactor containment and surrounding buildings for Unit 2, with respect to the planned excavation. These figures show where concrete will be placed beneath Unit 2 and above the Layer V (sound rock) foundation unit. The figures also show where compacted structural backfill will be placed with respect to the safety-related structures. As previously stated in the SER, the foundation grade for Units 2 and 3 will be at El. 110 m (360 ft), on top of sound rock with average V_S values of 3,048 m/s (10,000 fps).

2.5.4.2.4 Geophysical Surveys

VCSNS COL FSAR Section 2.5.4.4 describes the field electrical resistivity testing, geophysical down-hole testing, and seismic CPTs conducted for Units 2 and 3. The applicant used field electrical resistivity test results to estimate the corrosion potential of the Layer I and II soils but noted that that these soils will be removed as part of the nuclear island excavation and will not affect the nuclear island or the buried utilities in the PBA. The following paragraphs describe the results of the applicant's geophysical down-hole tests, CPTs, V_S, and compression wave velocity (V_P) tests.

Geophysical Down-hole Testing

VCSNS COL FSAR Section 2.5.4.4.2 describes the applicant's geophysical down-hole tests conducted in eight borings in the PBA of planned Units 2 and 3. These tests range in depth from 53 to 106 m (175 to 350 ft) and include natural gamma, 3-arm caliper, resistivity, spontaneous potential, borehole acoustic televiewer, boring deviation, and suspension P-S velocity logging.

The applicant used a 3-arm caliper probe to continuously measure the natural gamma emission from the borehole walls. In addition, the applicant used an electric log probe to measure single point resistance, short and long normal resistivity, spontaneous potential and natural gamma. This combination of tests is useful in locating hard and soft formations and fissures within the measured units; identifying geometries within measured units; and identifying boundaries between different units as well as making correlations between the units. The applicant used a high resolution acoustic televiewer probe to measure boring inclination and deviation from vertical as well as to identify fractures, dikes and weathered zones acoustically imaged in the boreholes. Finally, the applicant performed suspension P-S velocity logging tests to directly determine the average in-situ horizontal shear and compressional wave velocities of soil and rock columns surrounding the test boreholes. The applicant provided a best estimate average V_S of 3,048 m/s (10,000 fps) and a best estimate average V_P of 5,300 m/s (17,500 fps).

Seismic Cone Penetrometer Tests

VCSNS COL FSAR Section 2.5.4.4.3 describes the seven seismic CPTs that the applicant conducted for Units 2 and 3; six in the area of Units 2 and 3 and one in the general area of the cooling tower. The applicant performed the seismic CPTs to measure the V_S values of the soil at the site.

Results of Shear and Compression Wave Velocity Tests

The applicant used results from suspension P-S logging tests and seismic CPTs to determine V_S values for Layers I through V. SER Table 2.5.4-2 summarizes the range of V_S for each layer. For the nuclear island foundation-bearing layer (Layer V), below El. 108 m (355 ft), the applicant first used the results of the suspension P-S logging to determine a best estimate average V_S of 3,048 m/s (10,000 fps). The applicant then used the same suspension P-S logging results to determine the average Poisson's ratio value (μ = 0.23 to 0.25). The applicant then used the best-estimate average V_S of 3,048 m/s (10,000 fps) and an average Poisson's ratio of 0.24 to calculate a best-estimate average V_P of 5,300 m/s (17,500 fps).

2.5.4.2.5 Excavation and Backfill

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

Extent of Excavations, Fills and Slopes

VCSNS COL FSAR Section 2.5.4.5.1 describes the extent of excavations, fills and slopes at the VCSNS Units 2 and 3 site. The applicant plans to excavate up to 8.5 m (28 ft) of soil, mostly residuum and saprolite, to reach the design plant grade of El. 122 m (400 ft). The applicant also stated that it would excavate the remainder of the natural soils at Units 2 and 3 to the top of sound rock.

Excavation Methods and Stability

VCSNS COL FSAR Section 2.5.4.5.2 describes the methods of excavation and plans to maintain stability along the excavation surfaces.

Excavation in Soil

In VCSNS COL FSAR Section 2.5.4.5.2.1, the applicant stated that it will use conventional equipment for the excavation of soil Layers I and II as well as any existing fills. For excavations of less than 6 m (20 ft) in height, the applicant stated that it would follow Occupational Safety and Health Administration (OSHA) regulations and use a 2H:1V slope to support the power block excavation benched every 6 m (20 ft) of height. Due to the erosive potential of the saprolitic soils, the applicant concluded that it will need to seal and protect even the temporary slopes cut into the saprolite.

Excavation in Rock

The applicant stated that it would use conventional earthmoving Equipment for Layer III (PWR) rock excavation and temporary retaining walls would be used to support the near-vertical excavations. Since sound (nonrippable) rock extends as high as EL. 374 ft (114 m) in Unit 2, which is about 14 ft (4 m) above the bottom of the nuclear island basemat, limited hard-rock excavation may be needed. For hard-rock excavation, proper techniques will be used to reduce vibrations thus to preserve the integrity of the in-situ rock.

Backfill Sources, Compaction and Quality Control

VCSNS COL FSAR Section 2.5.4.5.3 describes the sources of backfill, compaction requirements and quality controls for the planned VCSNS Units 2 and 3 site.

Structural Fill

The applicant stated that it would use either concrete or a well-graded granular material for structural fill at Units 2 and 3. The applicant plans to use concrete fill mainly to replace the partially weathered rock (Layer III) and moderately weathered rock (Layer IV) exposed at the bottom of the excavations for the seismic Category I nuclear island foundation basemat. The applicant will not use the excavated residual and saprolitic soils for structural fill. Instead, those excavated soils will be used as common fill. The applicant plans to import the granular structural fill from an identified quarry located approximately 32 km (20 mi) from the VCSNS Units 2 and 3 site. The granular structural fill will be compacted to at least 95 percent of the maximum dry density, following ASTM D 1557-02. The applicant selected representative values of N = 60 blows per foot (bpf), as well as an effective internal friction angle φ' = 36 degrees and a unit weight = 2,002 kg/m^3 (125 pcf) for the compacted structural fill. The applicant stated that structural fill placement and testing follow American Society of Mechanical Engineers (ASME)

NQA-1-1994, “Quality Assurance Requirements for Nuclear Facility Applications” guidelines and the applicant addressed the structural fill placement and compaction in a technical specification.

<u>Common Fill</u>

The applicant plans to use the excavated residual and saprolitic soils (Layers I and II, respectfully) as common fill that will be placed and compacted outside of the structural fill surrounding Units 2 and 3. The common fill does not affect safety-related structures.

2.5.4.2.6 Ground Water Conditions

VCSNS COL FSAR Section 2.5.4.6 describes the groundwater conditions at the Unit 2 and 3 sites. The applicant included 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 site of Units 2 and 3 in greater detail.

Groundwater Measurements and Elevations

VCSNS COL FSAR Section 2.5.4.6.1 describes the groundwater measurements and elevations at proposed VCSNS Units 2 and 3. The applicant stated that groundwater is present in unconfined conditions in both the superficial sediments and the underlying bedrock. The applicant installed 31 observation wells as part of the subsurface investigation plan and measured the groundwater levels monthly between June of 2006 and June of 2007. The measured groundwater levels ranged from El. 106.9 and 111.5 m (351 and 366 ft) in the area of Unit 2, and from El. 109 and 114 m (359 and 374 ft) in the area of Unit 3. The applicant performed slug tests and Packer tests in the deep bedrock in order to obtain mean hydraulic conductivity values for the bedrock. The slug tests indicated a geometric mean hydraulic conductivity value of 2.13 cm/day (0.07 ft/day), while the Packer tests indicated a geometric mean value of 5.06 cm/day (0.166 ft/day). The applicant explained the difference in the two hydraulic conductivity values as being related to the different depths at which it conducted the tests. Finally, the applicant stated that although it does not anticipate the need for a permanent groundwater dewatering system for Units 2 and 3, the site will likely require temporary dewatering during plant foundation excavation and construction, which can be accomplished using temporary sumps and pumps.

Construction Dewatering and Seepage

VCSNS COL FSAR Section 2.5.4.6.2 describes the dewatering plans during construction and the method by which seepage will be reduced in both the soil and rock zones at the site. The applicant stated that, due to the relatively low permeability of the saprolite and the underlying rock, it will use gravity-type systems to accomplish the necessary dewatering for all major excavations. Specifically, the applicant concluded that sump-pumping of ditches will be adequate to dewater the soil and sump-pumping to collect water from ditches below the progressive excavation grade will be sufficient to dewater the rock.

Effect of Groundwater Conditions on Foundation Stability

The applicant assumed the highest anticipated groundwater level to be at El. 115.8 m (380 ft), and used this water level to compute the hydrostatic pressures on the buried structure walls. The applicant concluded that, due to the appreciable dead loads imposed by the structures and the large diameter buried piping designed to resist buoyancy when empty, there are no buoyancy issues associated with the deep buried structures.

2.5.4.2.7 Response of Soil and Rock to Dynamic Loading

VCSNS COL FSAR Section 2.5.4.7 states that Layer V (sound rock) will be foundation for the planned Units 2 and 3 nuclear islands. As described in FSAR Sections 2.5.4.7.1 through 2.5.4.7.3, the applicant used V_S profiles, variations of shear modulus and damping with strain, and site-specific seismic acceleration time histories to estimate the amplification or attenuation of seismic acceleration of weathered rock and soil column.

Shear Wave Velocity Profiles

VCSNS COL FSAR Section 2.5.4.7.1 describes the V_S profiles developed for both soil and rock at the VCSNS site. The applicant considered Layer V first since the Layer V sound rock supports the seismic Category I structures.

<u>Bedrock</u>

During the subsurface investigation, the applicant obtained estimates of V_S of the bedrock beneath the nuclear island and beneath the planned locations of the surrounding major power block structures of each unit. SER Figure 2.5.4-3 (reproduced from VCSNS COL FSAR Figure 2.5.4-226) shows the V_S profiles beneath Units 2 and 3 with 5-foot distance imaging. Based on this figure, the applicant concluded that the average mean V_S of Layer V over the measured range is greater than 3,048 m/s (10,000 fps), confirming that Layer V is a sound foundation rock.

<u>Soil and Weathered Rock</u>

The applicant stated that the partially and moderately weathered rock units (Layers III and IV) reflect the transition zone from soil to sound rock. The applicant stated that the average top of the partially and moderately weathered rock for Units 2 and 3 is around El. 114 m (375 ft) and 111.2 m (365 ft), respectively. The applicant will remove all of the soil and weathered rock beneath the safety-related structures at planned Units 2 and 3 in order to found these structures on sound rock, or on concrete above the sound rock.

Variation of Shear Modulus and Damping with Strain

VCSNS COL FSAR Sections 2.5.4.7.2.1 and 2.5.4.7.2.2 describe the shear modulus and damping ratio properties for the Layer I and Layer II soils, as well as for the compacted structural fill. The applicant performed resonant column torsional shear (RCTS) testing on soils and fill samples and compared the RCTS results with generic shear modulus and damping curves as a function of shear strain developed by EPRI (1993). The applicant stated that the RCTS results showed reasonable agreement with the EPRI curves; therefore, it concluded that additional analysis was not necessary. The applicant considered the shear modulus and damping ratio values of the partially and moderately weathered rock, as well as the sound rock and concluded that only the Layer III partially weathered rock could be strain dependent. However, the applicant also concluded that strain dependency of the partially weathered rock will not affect the safety-related structures because Layer III will be removed in the PBAs of Units 2 and 3.

Rock and Soil Column Amplification/Attenuation Analysis

VCSNS COL FSAR Section 2.5.4.7.3 describes the applicant's site response analysis to determine the site dynamic responses for the soil profiles described in FSAR Section 2.5.4.7.1. Because of minor variations in the Vs below the average top of sound rock elevation of 355 ft (108 m), especially in Unit 2, the applicant performed site response analysis by placing sound rock response spectrum input at various depths above and below El. 355 ft (108 m) for the randomized soil and rock profiles. The analyses obtained acceleration at El. 400 ft (122 m) is about .55g for Unit 2 and .42g for Unit 3, and the maximum mean peak ground acceleration was later used as input into the liquefaction analysis for the Units 2 and 3 site soils.

2.5.4.2.8 Liquefaction Potential

VCSNS COL FSAR Section 2.5.4.8 describes the liquefaction potential of the soil at the VCSNS Units 2 and 3 site, including the analyses performed and the conclusions reached based on the results. The applicant concluded that the site materials capable of liquefying are Layers I and II, which will be completely removed; therefore, they will not affect the stability of the seismic Category I structures. The applicant analyzed the liquefaction potential of Layers I and II, regardless, and concluded that the potential for liquefaction to occur in the planned VCSNS Units 2 and 3 site area is very low.

2.5.4.2.9 Earthquake Design Basis

VCSNS COL FSAR Section 2.5.4.9 refers to FSAR Sections 2.5.2.6 in which the horizontal and vertical GMRS are derived and discussed.

2.5.4.2.10 Static Stability

VCSNS COL FSAR Section 2.5.4.10 describes the allowable bearing capacities and the estimated settlement for the site, as well as the lateral earth pressures on below-ground plant walls. The applicant stated that it plans to found the nuclear islands of Units 2 and 3 on the Layer V sound rock. The soils and weathered rock units (Layers I through IV) in the PBA will be removed. The applicant further stated that if any moderately or partially weathered rock is encountered beneath the foundation grade for Units 2 and 3, it will be removed and concrete will be place above the sound rock to reach the foundation grade level at El. 110 m (360 ft).

Bearing Capacity

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

<u>Bearing Capacity of Rock</u>

To determine an acceptable bearing capacity for the nuclear island structures at VCSNS Units 2 and 3, the applicant first reviewed the Updated Final Safety Analysis Report (UFSAR) for the existing VCSNS Unit 1. The Unit 1 UFSAR recommends an allowable bearing capacity of 9,576 kPa (200 kips per square foot [ksf]) for the Layer V sound rock. The applicant then reviewed several building codes provided in D'Appolonia et al. (1975) to estimate the allowable bearing capacity for structural concrete, which will replace any partially or moderately weathered rock beneath the nuclear island foundation grade at Units 2 and 3. The applicant estimated an allowable bearing capacity of 6,894 kPa (144 ksf) for the concrete. The applicant then compared the recommended allowable bearing capacity value of 9,576 kPa (200 ksf) for Layer V with the estimated bearing capacity value of 6,894 kPa (144 ksf) for the concrete fill to arrive at a conservative allowable bearing capacity value of 7,660 kPa (160 ksf) for the planned nuclear islands at Units 2 and 3. Based on the design criteria for the AP1000 design, the maximum allowable static bearing capacity for the safety-related structures (i.e., the nuclear island) at the VCSNS Units 2 and 3 site is 426 kPa (8.9 ksf) and the maximum allowable dynamic bearing capacity for safety-related structures is 1,676 kPa (35 ksf). Therefore, the applicant concluded that the estimated allowable bearing capacity value of 7,660 kPa (160 ksf) for the seismic Category I nuclear island is both reasonable and conservative.

Bearing Capacity of Soil

The applicant used Terzaghi's bearing capacity equations modified by Vesic (1975) to determine the bearing capacity for granular soils, including engineered structural fill, by inputting parameters such as: (1) undrained shear strength for clay; (2) cohesion intercept for soil; (3) effective overburden pressure at the foundation base; (4) effective unit weight of soil; (5) depth from the surface to the base of the foundation; (6) width of foundation; and (7) multiple bearing capacity and shape factors to determine a different bearing capacity for each foundation. The applicant did not provide a value for the bearing capacity of the granular structural fill.

Allowable Bearing Capacity for Structures

The applicant estimated allowable bearing capacity, using a factor of safety of 3, for the seismic Category I nuclear island, seismic Category II annex building, and major nonseismic but important structures (turbine and radwaste buildings). The applicant concluded that the estimated value for the seismic Category I foundation (7,660 kPa (160 ksf)) exceeds the design bearing capacities for soil or rock as given in Table 2.0-1 of the AP1000 DCD.

Groundwater Effects

Assuming the groundwater table is at El. 122 m (400 ft), the applicant stated that there may be a hydrostatic uplift force on any buried structure. However, the applied foundation loads are well in excess of hydraulic uplift pressures resulting in no net uplift forces. The applicant indicated that uplift forces can be significant in the design of buried piping, and concluded that it would analyze the weight and strength of the backfill above the pipe to ensure satisfactory resistance to uplift forces (factor of safety = 3).

Settlement Analysis

VCSNS COL FSAR Section 2.5.4.10.2 describes the pseudo-elastic method of analysis used by the applicant to estimate settlement, an approach suitable for both granular soils and for bedrock. The applicant calculated the settlement of discrete layers using a stress-strain model of analysis. For the nuclear island founded on sound rock, the applicant estimated settlement values of 0.05 cm (0.02 inches) at the center of the nuclear island and 0.254 cm (0.1 inches) at the middle of the side. The applicant estimated the mean settlement for the nuclear island to be 0.038 cm (0.015 inches). The applicant concluded that the settlement of the structures founded on Layer V was negligible; therefore, total and differential settlements under the nuclear island are well within the design limits of the AP1000 DCD.

Earth Pressures

VCSNS COL FSAR Section 2.5.4.10.3 describes a number of methods used to estimate static and seismic lateral earth pressures for below-ground plant walls. The applicant considered both active and at-rest cases and assumed that structural backfill will be level and the friction angle between the soil and the wall will be zero. The applicant used the anticipated maximum level at El. 380 ft (116 m) to determine the hydrostatic pressures, and conservatively assumed the area-wide surcharge pressures of 23.94 and 119.7 kPa (500 and 2,500 psf) for active and at-rest conditions, respectively. The applicant also included lateral pressures due to compaction in the pressure diagrams. For the active lateral earth pressure case, the applicant used the peak horizontal ground acceleration of 0.55g, and used the Mononobe-Okabe method to establish seismic lateral active earth pressures, and used the Ostadan method to compute seismic soil pressure on building walls, or at-rest condition. The applicant's estimated active and at-rest lateral earth pressures are best-estimates and have a factor of safety of 1.0. The applicant stated that the factor of safety against the sliding of a gravity wall or structure, as well as for the overturning of a wall, is normally 1.1, when seismic pressures are included.

2.5.4.2.11 Design Criteria

VCSNS COL FSAR Section 2.5.4.11 summarizes the geotechnical design criteria discussed throughout the FSAR. FSAR Section 2.5.4.8 specifies that the acceptable factor of safety against liquefaction of site soils was greater than or equal to 1.25. For static bearing capacity and to prevent the failure of a buried pipe due to uplift forces, the applicant indicated that a minimum factor of safety of 3 is required. For soils, the applicant reduced this factor of safety to 2.25 under dynamic or transient loading conditions. FSAR Section 2.5.4.10 also specifies a factor of safety of 1 for lateral earth pressures and a factor of safety of 1.1 for sliding and overturning due to lateral loading when the seismic component is included.

2.5.4.2.12 Techniques to Improve Subsurface Conditions

In VCSNS COL FSAR Section 2.5.4.12, the applicant stated that it plans to remove any residuum or saprolite beneath or within the zone of influence of seismic Category I or II structures and replace it with compacted structural fill. The applicant also plans to remove zones of weathered or fractured rock beneath the nuclear island basemat and replace it with concrete.

2.5.4.2.13 Subsurface Instrumentation

In VCSNS COL FSAR Section 2.5.4.13, the applicant stated that since it will found the nuclear island on sound bedrock, or on concrete placed on sound bedrock, the VCSNS site does not require settlement monitoring of the nuclear island.

2.5.4.3 *Regulatory Basis*

The regulatory basis of the information incorporated by reference is addressed in NUREG-1793 and its supplements.

In addition, the acceptance criteria associated with the relevant requirements of the Commission regulations for the stability of subsurface materials and foundations are given in Section 2.5.4 of NUREG-0800.

The applicable regulatory requirements for reviewing the applicant's discussion of stability of subsurface materials and foundations are:

- 10 CFR Part 50, Appendix A, GDC 2, "Design Bases for Protection Against Natural Phenomena," 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 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 from Section 2.5.4 of NUREG-0800 are as follows:

- Geologic Features: In meeting the requirements of 10 CFR Parts 50 and 100, the section defining geologic features is acceptable if the discussions, maps, and profiles of the site stratigraphy, lithology, structural geology, geologic history, and engineering geology are complete and are supported by site investigations sufficiently detailed to obtain an unambiguous representation of the geology.

- 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.

- 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 there from 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) and these data are included, interpreted, and summarized; (2) the extent (horizontally and vertically) of all Category I excavations, fills, and slopes are clearly shown on plot plans and profiles; (3) compaction specifications and embankment and foundation designs are justified by field and laboratory tests and analyses to ensure stability and reliable performance; (4) the impact of compaction methods are incorporated into the structural design of the plant facilities; (5) quality control methods are discussed and the quality assurance program described and referenced; and (6) control of groundwater during excavation to preclude degradation of foundation materials and properties is described and referenced.

- Ground Water 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 section or cross-referenced to the appropriate sections in Section 2.4 of the SAR: (1) discussion of critical cases of groundwater conditions relative to the foundation settlement and stability of the safety-related facilities of the nuclear power plant; (2) plans for dewatering during construction and the impact of the dewatering on temporary and permanent structures; (3) analysis and interpretation of seepage and potential piping conditions during construction; (4) records of field and laboratory permeability tests, as well as dewatering induced settlements; and (5) history of groundwater fluctuations as determined by periodic monitoring of 16 local wells and piezometers.

- Response of Soil and Rock to Dynamic Loading: In meeting the requirements of 10 CFR Parts 50 and 100, descriptions of the response of soil and rock to dynamic loading are acceptable if: (1) an investigation has been conducted and discussed to determine the effects of prior earthquakes on the soils and rocks in the vicinity of the site; (2) field seismic surveys (surface refraction and reflection and in-hole and cross-hole seismic explorations) have been accomplished and the data presented and interpreted to develop bounding P-S wave velocity profiles; and (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.

- Liquefaction Potential: In meeting the requirements of 10 CFR Parts 50 and 100, if the foundation materials at the site adjacent to and under Category I structures and facilities are saturated soils and the water table is above bedrock, then an analysis of the liquefaction potential at the site is required.

- Static Stability: In meeting the requirements of 10 CFR Parts 50 and 100, the discussions of static analyses are acceptable if the stability of all safety-related facilities has been analyzed from a static stability standpoint, including bearing capacity, rebound, settlement, and differential settlements under deadloads of fills and plant facilities, and lateral loading conditions.

- 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, dental work, rock bolting, or anchors).

In addition, the geotechnical characteristics should be consistent with appropriate sections from: RG 1.27; RG 1.28, "Quality Assurance Program Requirements (Design and Construction)," Revision 4; RG 1.132, Revision 2; RG 1.138, Revision 2; RG 1.198; and RG 1.206.

2.5.4.4 *Technical Evaluation*

The NRC staff reviewed Section 2.5.4 of the VCSNS COL FSAR and checked the referenced DCD to ensure that the combination of the DCD and the COL application represents the complete scope of information relating to this review topic.[1] The NRC staff's review confirmed that the information in the application and incorporated by reference addresses the required information relating to the stability of subsurface materials and foundations. The results of the NRC staff's evaluation of the information incorporated by reference in the VCSNS COL application are documented in NUREG-1793 and its supplements.

AP1000 COL Information Items

- VCS COL 2.5-5, VCS COL 2.5-6, VCS COL 2.5-7, VCS COL 2.5-8, VCS COL 2.5-9, VCS COL 2.5-10, VCS COL 2.5-11, VCS COL 2.5-12, VCS COL 2.5-13, and VCS COL 2.5-16

Evaluation of the information provided in VCS COL 2.5-5, VCS COL 2.5-6, VCS COL 2.5-7, VCS COL 2.5-8, VCS COL 2.5-9, VCS COL 2.5-10, VCS COL 2.5-11, VCS COL 2.5-12, VCS COL 2.5-13, and VCS COL 2.5-16 is discussed below.

Supplemental Information

- VCS SUP 2.5-3

The staff reviewed the information in VCS SUP 2.5-3 relating to the results of the subsurface investigation program implemented at the Units 2 and 3 site.

The NRC staff reviewed all of the information presented in VCSNS COL FSAR Section 2.5.4 related to COL Information Items 2.5-5, 2.5-6, 2.5-7, 2.5-8, 2.5-9, 2.5-10, 2.5-11, 2.5-12, 2.5-13, and 2.5-16. The staff's review of this information is presented below.

2.5.4.4.1 Description of Site Geologic Features

VCSNS COL FSAR Section 2.5.4.1 refers to FSAR Section 2.5.1 for a complete description of the regional and site geology. Section 2.5.1.4 of this SER presents the staff's evaluation of the regional and site geology.

2.5.4.4.2 Properties of Subsurface Materials

The staff focused its review of VCSNS COL FSAR Section 2.5.4.2 on the applicant's description of the geotechnical engineering properties of the subsurface materials beneath the planned VCSNS Units 2 and 3, as well as the applicant's field investigations and laboratory testing program.

The applicant determined the geotechnical engineering properties of the five principle layers (Layers I through V), as well as the properties of the planned structural fill, through field investigations and laboratory testing performed in accordance with RG 1.132, Revision 2 and RG 1.198. VCSNS COL FSAR Table 2.5.4-209 summarizes the geotechnical engineering properties of the site strata as determined during the field and laboratory investigations.

Description of Subsurface Materials

The applicant stated that the subsurface profile consists of shallow residual and saprolitic soils underlain by partially and moderately weathered rock grading downward into sound bedrock. The applicant divided the subsurface materials into five layers for stability and foundation purposes: Layer I and Layer II, residuum and saprolite, respectively; Layer III, partially weathered rock; Layer IV, moderately weathered rock; and Layer V, sound rock. The applicant stated that the Layer I residual soils and the Layer II saprolitic soils will be completely removed beneath the planned VCSNS Units 2 and 3 nuclear islands. Furthermore, the partially and moderately weathered rock (Layers III and IV, respectively) will also be removed and in some cases, replaced with concrete fill.

In VCSNS COL FSAR Section 2.5.4.2.2.1, applicant stated that the Layer V sound rock will be the foundation layer and will support the seismic Category I structures for Units 2 and 3. Layer V is mostly igneous rock with numerous metamorphic inclusions, as described in FSAR Section 2.5.1.2. Based on the RQD values and V_S measurements obtained during the applicant's subsurface exploratory investigations, the applicant estimated that the top of Layer V beneath Units 2 and 3 ranges from El. 90.2 to 117 m (296 to 384 ft) and 96.3 to 117 m (316 to 384 ft), respectively. For its seismic analyses, the applicant selected El. 108 m (355 ft) as the top of Layer V beneath the nuclear islands of both Units 2 and 3. The foundation grade for the nuclear island basemats at both Units 2 and 3 will be El 110 m (360 ft). The applicant stated that the foundation basemats will be placed either on sound rock or on concrete fill placed directly on top of the sound rock.

The staff reviewed the RQD data presented by the applicant on VCSNS COL FSAR Figures 2.5.4-202, 2.5.4-204 through 207 and 2.5.4-211 (which show the top of sound rock for Layer V) and the V_S measurements on Figures 2.5.4-224 through 226, which show V_S values in excess of 2,438 m/s (8,000 fps) and average V_S values for the entire Layer V in excess of 2,804 m/s (9,200 fps).

Based on its review of the V_S measurements for Layer V, in particular those shown on VCSNS COL FSAR Figure 2.5.4-224, the staff noted that the V_S values are variable across the planned PBA for Unit 2 and that RG 1.132, Revision 2 recommends more closely spaced boreholes where variability is identified in the subsurface. Therefore, in RAI 2.5.4-10, the staff asked the applicant to justify not having a smaller spacing of borings within the Unit 2 PBA in order to better define the V_S and RQD values for the underlying units.

In response to RAI 2.5.4-10 (dated March 12, 2009), the applicant presented a figure (Figure 2.5.4-10-1 of the RAI response) to show that the variations in RQD values, as well as percent recovery in the sound rock beneath Unit 2 are small. The applicant stated that RQD values are mostly on the order of 90 to 100 percent, with values ranging from 80 to 90 percent closest to the top of Layer V. With respect to V_S values for the Layer V sound rock, the applicant stated that it expected the average V_S values toward the top of Layer V (2,590 m/s [8,500 fps], between El. 99 m [325 ft] and 108 m [355 ft]) to be smaller than those at depth (greater than 2,895 m/s [9,500 fps], beneath El. 99 m [325 ft]). The applicant further stated that even in the strongest of rocks in the Piedmont geologic setting (such as the Layer V unit), some degradation and increase in variability toward the top of rock is inevitable. The applicant concluded that the small differences in RQD values, percent recovery, and V_S values do not represent the level of variability that necessitates a more closely spaced boring investigation.

The staff reviewed the applicant's response to RAI 2.5.4-10. Based on the limited variability in RQD values and percent recovery toward the top of Layer V, as well as the natural variability expected in V_S values, due to the transition from weathered to sound rock (as evidenced at the top of Layer V), the staff concludes that the variation in geotechnical engineering properties of the sound rock layer is within a normal range and that the applicant adequately justified not performing additional borings beneath the planned Unit 2 PBA. Accordingly, the staff considers RAI 2.5.4-10 closed.

Based on the staff's review of the information presented in VCSNS COL FSAR Section 2.5.4.2.2 and the applicant's response to RAI 2.5.4-10, the staff concludes that the applicant adequately characterized the properties of the five soil and rock layers underlying the VCSNS Units 2 and 3 site, identified the foundation bearing layer unit for the Units 2 and 3 nuclear islands, and discussed its plans to remove all soil and weathered rock units above the Layer V sound rock.

Field Investigations

The applicant stated that, because the subsurface investigations should be site-specific, RG 1.132, Revision 2 recognizes the need for flexibility and the need to exercise sound engineering judgment. To that end, the applicant noted three exceptions to RG 1.132, Revision 2 in FSAR Appendix 1AA. The first exception states that "only borings used for down-hole geophysical logging were surveyed for deviations." The staff finds this exception acceptable because the vertical deviation does not have great effect on the data obtained from primary shear suspension logging and the surveys conducted in the boreholes where down-hole geophysical loggings were performed showed minimal deviations. The second exception states that "only color photographs of rock cores were taken – no soil sample photographs." The staff finds this exception to RG 1.132, Revision 2 acceptable because the rock foundation bearing layer (rock layer) was characterized adequately with color photographs. Soil layers will be completely removed beneath the safety related structure foundations. The final exception states that "one or more borings for each major structure was not continuously sampled." The staff finds this exception acceptable because even though continuous sampling was not performed in one or more borings for each major structure, the applicant fully characterized the site subsurface materials by obtaining samples from adjacent borings under the same major structure to form complete sample series throughout the subsurface materials. Also, the applicant provided detailed cross-sections of the subsurface showing the horizontal uniformity of the subsurface materials. Apart from the exceptions noted, the applicant performed its subsurface investigations during field operations in accordance with RG 1.132, Revision 2, so that the plan reflected site-specific conditions. The applicant stated that the plan included field testing locations, as well as types, depths, and frequency of sampling. The applicant stated that it performed all fieldwork under an audited and approved quality assurance program and work procedures. The scope of the work included 111 borings, 31 observation wells, four packer tests, 36 CPTs plus seven down-hole seismic cone tests and eight sets of suspension P-S velocity logging, six sets of field soil electrical resistivity tests, four test pit excavations, and a survey of all field exploration points.

The staff reviewed both the power block and out of power block boring location plans and logs, the site subsurface profiles, and the results of the applicant's site exploration tests. Based on its review of VCSNS COL FSAR Section 2.5.4.2.3, and the applicant's response to RAI 2.5.4-10 (discussed above) the staff concludes that the applicant appropriately followed the guidance in RG 1.132, Revision 2 and conducted an adequate boring exploration program based on the location and number of borings and the number and types of testing performed in accordance with the appropriate ASTM standards.

Laboratory Testing

The applicant conducted a laboratory testing program in accordance with an approved quality assurance program following the guidance presented in RG 1.138, Revision 2. The staff reviewed the types and number of tests performed by the applicant, the locations from where the samples were taken, and the results of the tests. The staff concludes that the information provided by the applicant in VCSNS COL FSAR Section 2.5.4.2.4, particularly with respect to the laboratory test results, is acceptable. The staff further concludes that the applicant conducted sufficient laboratory tests to adequately characterize the engineering properties of the subsurface materials, based on the fact that the laboratory testing program included a variety of conventional index and geotechnical engineering tests; as well as dynamic soil tests, such as RCTS.

Engineering Properties of Soils and Rocks

The applicant derived the engineering properties of Layers I through V from the field and laboratory testing programs and provided the results in VCSNS COL FSAR Section 2.5.4.2.5.

<u>Layers III, IV, and V: Partially Weathered Rock, Moderately Weathered Rock, and Sound Rock</u>

The applicant obtained the RQD and percent recovery values for the VCSNS Units 2 and 3 nuclear island, annex, and radwaste buildings from 30 borehole logs. Based on the RQD values, the applicant concluded that the Layer V sound rock beneath Units 2 and 3 is generally very hard and intact, and, based on the ASTM D 6032 standard, the applicant classified the sound rock quality as good to excellent.

The applicant tested 95 rock cores for unconfined compression, the results of which it used to adopt a total unit weight of 2,915 kg/m^3 (182 pcf) for sound rock, and recommended total unit weights of 2,562 and 2,322 kg/m^3 (160 and 145 pcf) for moderately weathered rock and partially weathered rock, respectively. The applicant derived the elastic modulus for each layer from the results of suspension P-S velocity logging tests. The applicant then derived the shear modulus values from the elastic modulus by using the Poisson's ratio values of 0.33 for the partially and moderately weathered rock, and 0.24 for sound rock. The applicant indicated that the elastic moduli computed from the P-S logger measurements agree reasonably well with the results generated from the laboratory unconfined compression tests. The staff noted that the moduli for materials such as weathered rock can be significantly influenced by rock fracturing; therefore, they may yield values that do not agree with laboratory test samples. Accordingly, in RAI 2.5.4-17, the staff asked the applicant to explain the strong correlation between moduli values for the partially and weathered rock and the laboratory test samples.

In its response to RAI 2.5.4-17 (dated March 16, 2009), the applicant stated that all of the samples used in unconfined compression strength tests belong to the Layer V sound rock and not to the partially and moderately weathered rock. Accordingly, the applicant planned to update the VCSNS COL FSAR to state that the agreement between the elastic moduli determined from P-S suspension logging and compression tests applies only to the Layer V rock.

The staff reviewed and accepts the applicant's clarification that the reasonable agreement between the elastic moduli, based on P-S suspension logger measurements and from compression tests, applies only to the Layer V sound rock. Therefore, the staff considers RAI 2.5.4-17 closed.

Layers I and II: Residuum and Saprolite

VCSNS COL FSAR Section 2.5.4.2.5.2 provides a summary of the engineering properties for the top two soil layers encountered at the VCSNS site. The applicant stated that it provided the engineering properties of Layers I and II for completeness, even though these layers will be removed beneath the nuclear islands for planned Units 2 and 3. The staff reviewed the information in FSAR Section 2.5.4.2.5.2 and concludes that the applicant provided sufficient information to characterize the geotechnical engineering properties of the residual and saprolitic soils and acknowledges that these units will be removed from beneath the planned Units 2 and 3 PBAs.

Conclusions Regarding the Properties of Subsurface Materials

The staff concludes that the applicant's description of the subsurface materials is acceptable in that the applicant followed the guidance provided in RG 1.132, Revision 2 and RG 1.138, Revision 2, investigated and tested the subsurface materials to determine the geotechnical engineering properties of the soil and rock beneath the planned VCSNS Units 2 and 3. Furthermore, the staff concludes that the applicant obtained sufficient undisturbed samples to allow for the adequate characterization of each of these soil/rock groups and determined the extent, thickness, hardness and density, consistency, strength, and engineering and static design properties. The staff also concludes that the applicant provided sufficient information in the form of plots, plans, and boring logs; and laboratory test results that enabled the staff to determine that the applicant had adequately characterized the subsurface soil and rock materials and determined the engineering and design properties.

Therefore, the staff concludes that the applicant's description of the subsurface materials and properties at the proposed VCSNS Units 2 and 3 site is acceptable and meets the requirements of 10 CFR 100.23.

2.5.4.4.3 Foundation Interfaces

VCSNS COL FSAR Section 2.5.4.3 presents cross section views of the structural foundations and the excavation and backfill limits associated with planned Units 2 and 3. SER Figure 2.5.4-1 shows the locations of the reactor containment and surrounding buildings for Unit 2, with respect to the planned excavation. These figures show where concrete will be placed beneath Unit 2 and above the Layer V (sound rock) foundation unit. The figures also show where compacted structural backfill will be placed with respect to the safety-related structures. As previously stated in the SER, the foundation grade for Units 2 and 3 will be at El. 110 m (360 ft), on top of sound rock with average V_S values of 3,048 m/s (10,000 fps).

Nuclear Island Foundation

As shown in Figure 2.5.4-1, the foundation for the nuclear island is located at El. 360 ft (110 m) and will be on hard sound bedrock or a generally thin layer of concrete placed between the top of the rock and the bottom of the foundation. In RAIs 2.5.4-3 and 2.5.4-12, the staff asked the applicant to provide further detail on the uniformity of the hard-rock layer across the base of the nuclear island and how it affects the foundation/rock interface. In its response, the applicant stated that beneath the approximately 160 ft x 255 ft (49 m x 78 m) nuclear island foundation, after excavation, the top of sound rock will range from foundation level to about 17 ft (5 m) below foundation level. Concrete with V_S of about 9,000 fps will extend from the top of sound rock to the bottom of the foundation to provide a uniform bearing surface. With regard to the AP1000 DCD requirement in Tier 1, Table 5.0-1, "Site Parameters," that there should be less than 20 percent variation in the V_S from the average velocity of any layer, the applicant stated that the only materials beneath the nuclear island foundation will be the sound rock of Layer V and, where required, a layer of high strength concrete with a V_S close to the average velocity of the sound rock. The applicant further clarified that up to 17 ft (5 m) of the lower V_S material (partially-weathered or moderately weathered rock) will be removed and replaced with the higher V_S concrete. After review of the applicant's response, the staff finds that the applicant's plans to replace the lower V_S weathered rock with high-strength concrete will provide for a uniform and solid foundation for the nuclear island. Accordingly, the staff considers RAIs 2.5.4-3 and 2.5.4-12 closed with respect to the uniformity of the nuclear island foundation interface.

Location of Structural and Common Fill

As shown above in Figure 2.5.4-2, structural and common fill will be placed on the side of the nuclear island structures. In RAIs 2.5.4-6, 2.5.4-7 and 2.5.4-37, the staff asked the applicant to provide further detail concerning the locations of these two types of fill with respect to the seismic Category I structures. In its response, the applicant stated that the concrete fill will extend a few ft out from beyond the footprint of the nuclear island and structural fill will be placed above it. In addition, the applicant stated that structural fill (with 95 percent modified Proctor compaction) will be placed beneath the seismic Category II turbine, annex, and radwaste buildings that extends down to sound rock and approximately 50 ft (15 m) horizontally beyond the foundation footprint of these buildings. As such, the applicant concluded that any common fill or native soil and weathered rock located beyond the structural fill will experience no loading effects. Based on its review of the applicant's responses to RAIs 2.5.4-6, 2.5.4-7 and 2.5.4-37, the staff finds that the applicant's plan not to place any common fill (which will only be compacted to 90 percent of the maximum dry density) beneath seismic Category I or II structures to be acceptable. This is necessary since the common fill is not suitable for use as structural fill because it is susceptible to excessive settlement under high loading and saturated conditions due to its potentially high mica content. Accordingly, the staff considers RAIs 2.5.4-6, 2.5.4-7 and 2.5.4-37 closed with respect to the location and use of the structural and common fill. SER Section 2.5.4.4.5 provides the staff's evaluation of the properties and suitability of the compacted structural fill material.

Foundation Interface Conclusions

In accordance with NUREG-0800, the staff compared the applicant's plot plans and profiles of seismic Category I facilities with the subsurface profile and material properties. Based on the comparison, the staff determined that the applicant performed sufficient exploration of the subsurface materials and provided sufficient information on foundation design plans that included figures and descriptions regarding the results of the subsurface investigations and laboratory testing conducted by the applicant at the VCSNS site. Accordingly, the staff concludes that, because the applicant conducted its program following the guidelines presented in RG 1.132, Revision 2, and since the foundation design assumptions are consistent with regulatory guidelines and accepted industry practices, the foundation design plan for safety related structures is adequate. In summary, the staff concludes that the foundation base will be properly excavated to remove any weathered rock and the proposed concrete fill has adequate properties to be placed underneath the safety-related structures.

2.5.4.4.4 Geophysical Surveys

The staff reviewed VCSNS COL FSAR Section 2.5.4.4 and focused on the applicant's description of the geophysical survey program for the VCSNS Units 2 and 3 site. The applicant stated that this program consisted of: (1) six field electrical resistivity tests; (2) geophysical down-hole testing performed in eight borings in the PBA; and (3) seven seismic CPTs in the Layer I and Layer II soils. The applicant discussed the six electrical resistivity tests with respect to the corrosion potential of the Layer I and Layer II soils in FSAR Section 2.5.4.2.5.5.

Geophysical Down-Hole Testing

The applicant performed a range of geophysical down-hole tests including natural gamma, three-arm caliper, long and short normal resistivity, spontaneous potential, borehole acoustic televiewer logging, boring deviation, and suspension P-S velocity logging. The applicant fully described its procedures for conducting the geophysical down-hole tests in VCSNS COL FSAR Section 2.5.4.4.2. The applicant stated that it installed steel or polyvinyl chloride (PVC) casing in the eight holes when conducting suspension P-S velocity logging tests. Acceptable P-S suspension velocity readings were obtained when the casing was well grouted in the soil. When lack of coupling between the casing and the soil caused poor quality velocity measurements for some of the borings the applicant drilled additional uncased holes approximately 3.048 m (10 ft) from the original holes to obtain acceptable measurements. In RAI 2.5.4-20, the staff asked the applicant to provide further details regarding the applicant's use of the uncased holes for the down-hole testing. Specifically, the staff asked the applicant how it determined if a value was acceptable, or not, and then how the use or removal of the casings would affect measurements in the rock at depth.

In response to RAI 2.5.4-20 (dated April 29, 2009), the applicant provided a list of five criteria used to judge the data quality of P-S suspension logging velocity measurements. The applicant stated that Attachment E of the MACTEC Geotechnical Data Report, from Part 11 of the VCSNS COL application, lists and describes the five criteria. The applicant also provided an assessment of the quality of the soil velocity data based on the five criteria. Finally, the applicant stated that the casings were only used to conduct soil velocity measurements and that it obtained all rock velocity measurements using uncased holes. Therefore, the quality of the coupling between the casing and the soil did not affect the quality of the velocity measurements in the rock layers.

The staff reviewed the applicant's response to RAI 2.5.4-20 and Attachment E to the VCSNS COL application, and found that the applicant provided adequate criteria on data acceptance for P-S suspension logging velocity measurements to ensure the quality of soil velocity data used in the application. Based on clarifications made in the RAI response, the staff concludes that the quality of the velocity data for soil and rock obtained from the suspension P-S logging tests is acceptable. The staff confirmed that appropriate changes from the RAI were captured in Revision 2 to the VCSNS COL FSAR. Therefore, the staff considers RAI 2.5.4-20 closed.

In VCSNS COL FSAR Section 2.5.4.4.2.3, the applicant stated that it collected acoustic image and boring deviation data by using a high resolution acoustic televiewer probe. This probe is able to measure boring inclination and deviation from vertical and determine the need to correct logging depths to true vertical. The staff noted that the applicant did not provide any specific details regarding borehole deviation measurements for the down-hole tests at Units 2 and 3. Therefore, in RAI 2.5.4-21, the staff asked the applicant to provide a description of the process used to measure borehole deviation and the results obtained from the deviation measurements.

In response to RAI 2.5.4-21 (dated March 16, 2009), the applicant stated that it made borehole deviation measurements in all eight boreholes used for down-hole geophysical testing at the planned VCSNS site. In addition, the applicant noted that these measurements were made in conjunction with the acoustic televiewer measurements. The applicant stated that Part 11 of the VCSNS COL application includes detailed procedures of the borehole deviation measurements, as well as the obtained results. The applicant provided a detailed description of the High Resolution Acoustic Televiewer probe used for the measurements and explained the key characteristics of the instrument and its functions. Finally, the applicant provided a table in its RAI response that summarizes the borehole deviation measurements, expressed in terms of deviation of the bottom of the borehole from the borehole location at the surface, to the north and to the east.

After reviewing the applicant’s additional information on the measurement device and measurement procedures, as well as results of the borehole measurements, the staff concludes that the borehole deviation measurements performed at the site meet the guidelines of RG 1.132, Revision 2. Accordingly, the staff considered RAI 2.5.4-21 closed.

Based on the staff’s review of the geophysical down-hole testing that the applicant conducted at the VCSNS site and the applicant’s responses to RAIs 2.5.4-20 and 2.5.4-21, the staff concludes that the applicant’s geophysical down-hole tests as part of the applicant’s overall subsurface investigation program are acceptable and in accordance with the guidance provided in RG 1.132, Revision 2.

Seismic Cone Penetrometer Tests

In VCSNS COL FSAR Section 2.5.4.4.3, the applicant briefly describes seven seismic CPTs that it performed on the Layer I and Layer II soils at the VCSNS site. In RAI 2.5.4-15, the staff asked the applicant to describe how it used the results of the seven CPT tests in the site-specific evaluation and in comparison with the AP1000 design.

In its response to RAI 2.5.4-15 (dated March 16, 2009), the applicant stated that seismic cones cannot penetrate hard rock; therefore, the seismic cones reached refusal in the Layer III partially weathered rock.. The applicant further stated that it will remove Layers I, II and III beneath the planned PBAs for VCSNS Units 2 and 3. Because these layers will be removed, the applicant did not use the seismic CPT tests in the site-specific plant evaluation or in comparison with the AP1000 design. The applicant clarified that it used the data obtained from the seismic cone tests as part of the characterization of the overall subsurface conditions.

After reviewing the applicant’s response to RAI 2.5.4-15 and considering that the upper soils and weathered rock will be removed underneath the nuclear island foundation, the staff determined that the seismic CPTs are not needed in the site-specific plant evaluation, therefore RAI 2.5.4-15 is closed. Accordingly, the staff concludes that the seismic CPT tests were used only for completeness in the applicant's overall subsurface characterization and do not affect the staff's review of the seismic Category I structures for planned VCSNS Units 2 and 3.

2.5.4.4.5 Excavation and Backfill

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

Structural Fill

The applicant stated that it would use a well-graded granular material for structural fill at Units 2 and 3. The applicant plans to import the granular structural fill from an identified quarry located approximately 32 km (20 mi) from the VCSNS Units 2 and 3 site. The granular structural fill will be compacted to at least 95 percent of the maximum dry density, following ASTM D 1557-02. The applicant selected representative SPT values of N_{60} = 30 bpf, as well as an effective internal friction angle φ' = 36 degrees and a unit weight = 2,002 kg/m^3 (125 pcf) for the compacted structural fill.

In RAI 2.5.4-1, the staff asked the applicant to provide the basis for selecting a blow count value of N_{60}=30 bpf for the structural fill. In response, the applicant stated that the 95 percent modified Proctor compaction value for the fill correlates to a relative density of 70 percent, which in turn correlates with an average N_{60} value of 40 bpf. Therefore, the applicant concluded that the N_{60} value of 30 bpf assumed in the VCSNS COL FSAR is conservative. The staff noted that since the structural fill material will be granitic sand produced from crushing operations, is well graded, and will be compacted to 95 percent modified Proctor that it is adequate to support the seismic Category II annex, turbine, and radwaste buildings. The staff verified that the applicant used established correlation values to determine the blow count value for structural fill and accordingly considers RAI 2.5.4-1 closed.

VCSNS COL FSAR Section 2.5.4.5.3 states that compaction tests for the structural fill will be performed at a rate of 1 per 10,000 square ft of fill. In RAIs 2.5.4-5 and 2.5.4-24, the staff asked the applicant to provide the basis for selecting this testing frequency and whether this rate will result in the uniform density of the placed fill. In response, the applicant stated that it will follow the guidelines in Table 5.6 of ASME NQA-1-1994 (ASME 1994) in which at least one field density test will be performed per lift and per shift, and for no more than every 191 m^3 (250 cubic yards (yd^3)) of fill placed. The applicant further stated that Table 5.6 of ASME NQA-1-1994 provides a listing of various field density testing frequencies depending on the circumstances of the fill placement and that the most stringent requirement is one field test every 153 to 229 m^3 (200 to 300 yd^3) of fill placed. Since the applicant will perform one field density test for no more than every 191 m^3 (250 yd^3), the staff concludes that the proposed structural backfill placement and density testing procedures will ensure that the properties of the structural backfill meet the criteria of the AP1000 DCD. Accordingly, the staff considers RAIs 2.5.4-5 and 2.5.4-24 closed.

VCSNS COL FSAR Section 2.5.4.7.1.2 states that there are no measured V_S for the structural fill and instead describes the process used by the applicant to estimate a V_S of about 800 fps for the structural fill. In RAI 2.5.4-7, the staff asked the applicant to justify the lack of measured V_S for the structural fill and in RAI 2.5.4-25, the staff asked applicant for more details regarding the estimated value of 244 m/s (800 fps) for the fill. In response, the applicant stated that since there will be no compacted structural fill placed beneath the seismic Category I nuclear island, it is not necessary to measure the V_S for the placed structural fill. To justify this conclusion, the applicant cited Section 3.7.2.1.2 in the AP1000 DCD, which states that for the evaluation of the seismic response of the AP1000, the effects of the fill surrounding the nuclear island are neglected. Regarding the estimated value of 244 m/s (800 fps) for the structural fill, the applicant provided the equations used to determine the value, which are based on determining the shear modulus based on the N_{60} blow count value of 30 bpf assumed for the fill. The applicant also based its computed V_S value for the structural fill on a comparison with the V_S values that it measured for the saprolite (Layers I and II), which will be replaced by the fill. For the saprolite, the applicant measure V_S values that range from 177 to 310 m/s (582 to 1017 fps) over 1.5 m (5 ft) depth intervals from surface to 15m (50 ft). The applicant also recorded an average blow count value of 20 bpf for the saprolite, which is about 10 bpf lower than the assumed value for the structural fill. The saprolite are generally silty fine sands, with some mica, while the structural fill will be a much cleaner, coarser, and better graded material.

Using the assumed V_S value of 244 m/s (800 fps) for the structural fill and accounting for variation in V_S by developing 60 randomized V_S profiles through the fill, the applicant computed FIRS for the nonseismic Category I annex building for comparison with the AP1000 CSDRS. Further discussion regarding the comparison of the FIRS with the CSDRS is provided in SER Section 3.7.2.

The staff reviewed the applicant's responses to RAIs 2.5.4-7 and 2.5.4-25 and concludes that: (1) the V_S for the structural fill is based on a conservatively assumed blow count value of 30 bpf; (2) the equations used to estimate the V_S for the fill are commonly used and acceptable since the fill will not be placed under the seismic Category I nuclear island; and (3) the V_S value for the structural fill is reasonable based on a comparison with the V_S values for the saprolitic soils. Accordingly, the staff considers RAIs 2.5.4-7 and 2.5.4-25 closed.

Common Fill

The applicant plans to use the excavated residual and saprolitic soils (Layers I and II, respectfully) as common fill that will be placed and compacted outside of the structural fill surrounding Units 2 and 3 and will be compacted to 90 percent of the maximum dry density as determined by ASTM D 1557. The applicant stated that this material is unacceptable for use as structural fill since it is susceptible to excessive settlement under high loading and saturated conditions due to its potentially high mica content. VCSNS COL FSAR Figures 2.5.4-221 and 2.5.4-223 appear to show that the common fill may be in close proximity to the turbine and radwaste buildings. Since the failure of those structures could affect the safety of the nuclear island, in RAI 2.5.4-6, the staff asked the applicant to provide justification for the selection of 90 percent as the minimum required compaction, and also provide justification of the apparently close proximity to the turbine and radwaste buildings. In response to RAI 2.5.4-6, the applicant stated that since the common fill is outside the stress influence zone caused by structure and associated loadings from the turbine and radwaste buildings, that 90 percent compaction is acceptable. The staff reviewed the applicant's response, especially the clarification that the 90 percent compaction common fill will not be used beneath major structures, and that the common fill and native soil and weathered rock will be beyond the loading influence zone, and concludes that this information is sufficient. Since the 90 percent compaction fill will not adversely affect the stability of the foundation, the staff considers RAI 2.5.4-6 closed.

Concrete Fill

High strength concrete fill will be placed beneath the nuclear island extending from the top of sound rock to the bottom of the foundation to provide a uniform bearing surface. The applicant stated that it will use concrete with V_S of about 2743 m/s (9000 fps) in order to match the V_S for the sound rock (Layer V) layer. The applicant stated that it plans on removing up to about 5 m (17 ft) of the lower V_S rock and replacing it with the concrete fill.

In RAI 2.5.4-4, the staff asked the applicant to provide the target properties of the concrete fill and their expected uniformity, a description of the extent of the concrete fill, and the governing design standard for the concrete fill. In response to RAI 2.5.4-4, the applicant stated that the concrete will have a strength of about 34,474 kPa (5 ksi), which corresponds to a V_S of about 2743 m/s (9000 fps). The concrete will have an allowable bearing capacity of 6,895 kPa (44 ksf), which is much greater than the maximum bearing pressure (static and dynamic) from the nuclear island of 426 and 1,676 kPa (8.9 and 35 ksf) respectively. To address the extent of the concrete fill, the applicant stated that the maximum thickness of concrete fill would be 5 m (17 ft) at Unit 2 and 1.5 m (5 ft) beneath Unit 3, and would extend approximately 1.5 m (5 ft) from the nuclear island for both units. Finally, the applicant stated that it will follow the guidelines of American Concrete Institute (ACI) 318, "Building Code Requirements for Structural Concrete," in the design of the concrete fill.

The staff reviewed the applicant's response to RAI 2.5.4-4 and asked for further clarification, as part of RAI 2.5.4-36, concerning the empirical relation between the strength of concrete and its V_S and the applicant's plans to ensure that cracking within the concrete will not occur. Specifically, in response to RAI 2.5.4-4, the applicant stated the relationship between the strength of concrete and its V_S is based from actual measurements on concrete specimens by Boone (2005). For comparison, the staff used a relationship in ACI 318-08 between strength and elastic modulus, which can then be converted to V_S, to obtain a V_S value of 2,225 m/s (7,300 fps) for 34,474 kPa (5 ksi) concrete, which is less than the V_S of 2743 m/s (9000 fps) obtained by the applicant.

In response to the different V_S values, the applicant stated that since concrete itself consists of different proportions of different coarse and fine aggregates, cement and water, it is to be expected that there will be different empirical relationships between strength and V_S in the literature. The applicant further stated that concrete strength further increase with age therefore, "whether a shear wave velocity of 2,740 m/s (8,990 ft/sec) (Boone), 2,225 m/s (7300 ft/sec) (ACI), or 2,483 m/s (8,145 ft/sec) (average) for 34,474 kPa (5,000 psi) concrete is used, this value will increase during the lifetime of the plant."

In response to the staff's concern about cracking within the concrete, the applicant proposed revising Section 2.5.4.12 of the VCSNS COL FSAR to state:

> American Concrete Institute (ACI) defines mass concrete as "any volume of concrete with dimensions large enough to require that measures be taken to cope with generation of heat from hydration of the cement and attendant volume change to minimize cracking." The definition is intentionally vague because many factors, including the concrete mix design, the dimensions, the type of the placement, and the curing methods, affect whether or not cracking will occur. ACI 207, "Mass Concrete," prepared by ACI Committee 207, governs the design and construction of mass concrete. There are: (1) the maximum temperature inside a concrete pour and (2) the maximum temperature difference between the

hottest spot and the surface of a concrete pour. Specifications of mass concrete typically limit the maximum temperature to 155° F and the maximum temperature difference between the interior and the surface to 36° F, so that early-age thermal cracks in mass concrete will be minimized. It is a common practice to limit the least dimension of each concrete pour so that the temperature and temperature difference of the pour can stay within their respective limits.

According to the ACI mass concrete definition, the fill concrete under the Nuclear Island of V.C. Summer Unit 2 is a mass concrete. A thermal control plan considering the geometry of Unit 2 fill concrete, the proposed 5,000 psi strength, total volume of fill concrete placement, and rate of concrete production, will be prepared to make sure that the rule-of-thumb temperature limits will not be exceeded.

The applicant further states that the thermal control plan will be developed based on ACI 207 series guidelines. The staff reviewed the applicant's responses to RAIs 2.5.4-4 and 2.5.4-36 and concludes that since the relationship between the strength of concrete and its V_S is empirical, the V_S for 34,474 kPa (5,000 psi) concrete likely has a range of about 2,134 to 2,743 m/s (7,000 to 9,000 fps), and since this value will increase during the lifetime of the plant, the V_S of the proposed concrete fill will be similar to that of the in-situ rock below the foundation (i.e., >9200 fps) and is, therefore, acceptable. Regarding the potential for cracking, the staff concludes that the applicant adequately addressed the concerns associated with thermal cracks in mass concrete by providing a detailed thermal control plan to ensure that the design properties of the concrete fill will be met. The applicant committed to revise FSAR Section 2.5.4.12 to provide detailed concrete fill design, the thermal cracking control, and the concrete monitoring plan. The commitment to update the FSAR to include this information is being tracked as **Confirmatory Item 2.5.4-1**. In summary, the foundation base will be properly excavated to remove any weathered rock and the proposed concrete fill has adequate properties to be placed underneath the safety-related structures with a thermal control plan to ensure the quality of concrete fill. Finally, the allowable bearing capacity of the concrete fill is much greater than the maximum bearing pressure (static and dynamic) from the nuclear island. Accordingly, the staff considers RAIs 2.5.4-4 and 2.5.4-36 closed.

Resolution of Confirmatory Item 2.5.4-1

Confirmatory Item 2.5.4-1 is an applicant commitment to update its FSAR to provide detailed concrete fill design, the thermal cracking control, and the concrete monitoring plan. The staff verified that the VCSNS COL FSAR was appropriately updated. As a result, Confirmatory Item 2.5.4-1 is now closed.

Excavation Plans

VCSNS COL FSAR Section 2.5.4.5.1 describes the extent of excavations, fills and slopes at the VCSNS Units 2 and 3 site. The applicant plans to excavate up to 8.5 m (28 ft) of soil, mostly residuum and saprolite, to reach the design plant grade of El. 122 m (400 ft). The applicant also stated that it will excavate the remainder of the natural soils at Units 2 and 3 to the top of sound rock. Regarding the criteria for defining sound rock, in RAIs 2.5.4-3, 2.5.4-13, 2.5.4-14, and 2.5.4-22, the staff asked the applicant to indicate whether it would use RQD or V_S values, the correlation between these two parameters, and the effect of the variability in these two parameters on determining the location of sound rock. In its response, the applicant stated:

> Sound rock can be defined in different ways. FSAR Section 2.5.4.2.2.1 defines the Layer V sound rock as having an RQD of at least 50% but typically exceeding 70%. However, when excavating the site, RQD is not a practical measure to use. A more practical approach is to define sound rock as rock that cannot be ripped by a large dozer or excavated with a large trackhoe. FSAR Section 2.5.4.4.4.1 defines sound rock as rock that is nonrippable with a very large ripper. For a Caterpillar Single Shank no. 11 Ripper on a D11N dozer, the upper limit for an igneous or metamorphic rock corresponds to a seismic (compression, V_P) wave velocity of about 3,353 m/s (11,000 ft/sec) (equivalent to a shear wave velocity [V_S] of about 1,981 m/s (6,500 ft/sec). Comparison of the depth to sound rock using the 70% RQD criterion and the 11,000 ft/sec compression wave velocity criterion shows agreement to within an average of about 5 ft depth in Unit 2 and 3 ft depth in Unit 3.
>
> After excavation using a very large ripper (and/or trackhoe) at the nuclear island footprint, there will still be some portions of sound (nonrippable) rock left above the foundation base level. This will be removed down to the foundation base using controlled blasting as summarized in FSAR Subsection 2.5.4.5.2.2.

The applicant also stated that high-strength concrete will be placed between the top of the sound rock and the base of the nuclear island.

Regarding the uniformity of the sound rock, the applicant stated that Layer V is a massive pluton of igneous rock that has no dip and that the excavated surface of the sound rock has almost no variation beneath the Unit 3 nuclear island while up to 5 m (17 ft) of weathered rock will be removed below Unit 2 and backfilled with high strength concrete.

Concerning the correlation between RQD and V_S for sound rock, the applicant stated that there is a general correlation between RQD and V_S. For the Unit 2 borings, when RQD drops below about 80 percent, there is a noticeable reduction in V_S and similarly in the Unit 3 borings, when RQD drops below about 90 percent, there is a noticeable reduction in V_S.

For moderately weathered rock, the applicant stated that very few rock cores were obtained as RQD values are less than 50 percent. The applicant further stated that through heavy-duty ripping and excavation with a large trackhoe that it will be able to remove most if not all of the moderately weathered rock. In summary, the applicant stated that:

> Rock that cannot be removed with a large ripper or trackhoe (and confirmed by a geologist using a rock hammer and visual inspection) will be the criterion used to define sound rock during excavation. This may result in having a thin transition layer of strong moderately weathered rock (estimated to be no more than about 5 ft under Unit 2 and less under Unit 3) above the Layer V rock. At this non-rippable horizon, moderately weathered rock is rapidly transitioning into sound rock – as indicated in FSAR Table 2.5.4-209 the best estimate unconfined strength for moderately weathered rock is 68,947 kPa(10,000 psi), which is a strong rock.

The staff reviewed the applicant's responses to RAIs 2.5.4-3, 2.5.4-13, 2.5.4-14, and 2.5.4-22 and concludes that the applicant's commitment to apply an engineering practice method - using heavy-duty ripper to remove all of the partially weathered rock and most of the moderately weathered rock in the site excavation is adequate. The staff notes that the applicant plans on using an onsite geologist to confirm that the nonrippable rock at the bottom of the excavation will be strong and that at most, a thin layer of moderately weathered rock will be left in place. Regarding this residual layer of moderately weathered rock, the staff concludes that since the moderately weathered rock has a V_S above 1,981 m/s (6,500 fps), based on the site investigation, and the applicant will use this value as the cut-off velocity for defining “sound rock,” the definition of “sound rock” at the site is reasonable and it will ensure that the underlying rock possesses the requisite properties to meet the AP1000 DCD requirements in Tier 1, Table 5.0-1, “Site Parameters.” Furthermore, as pointed out by the applicant, the rock beneath the nuclear island is a massive igneous pluton that is very uniform with no dip. Therefore, the staff considers RAIs 2.5.4-3, 2.5.4-13, 2.5.4-14, and 2.5.4-22 closed.

Conclusions Regarding Excavation and Backfill

In summary, the staff concludes that the applicant provided detailed information on structural and common fill properties and compaction requirements; provided an adequate plan of structural backfill compaction related field testing; and described concrete fill properties that will ensure that the proposed concrete fill will have similar properties of the underlying rock to meet the strength and stability requirements, therefore the proposed fills for this site are adequate for meeting design and engineering standards.

Regarding the applicant’s excavation plans, the staff concludes that the applicant’s plan to use a heavy-duty ripper to remove all partially weathered rock and most of the moderately weathered rock with the placement of high-strength concrete fill will result in a solid foundation for the nuclear island that meets the requirements specified in the AP1000 DCD, Tier 1, Table 5.0-1, “Site Parameters.”

2.5.4.4.6 Ground Water Conditions

In VCSNS COL FSAR Section 2.5.4.6, the staff reviewed the information provided by the applicant concerning the basic groundwater conditions at the VCSNS Units 2 and 3 site. The applicant stated that groundwater was present in unconfined conditions in both the saprolitic soils (Layer II) and in the underlying bedrock at the site, and, based on well observations, the applicant projected the maximum groundwater level to be at El. 116 m (380 ft). The applicant explained that as the ground surface is reduced during construction, the groundwater levels in the PBA would be similarly reduced. The applicant stated that it did not anticipate the need for a permanent dewatering system for Units 2 and 3, but that it expected that localized temporary dewatering would be required during excavation and construction and would be performed in a manner that minimized drawdown effects. Based on its review of the provided information, including the hydraulic conductivity values, the staff concurs with the applicant’s assessment that, due to the relatively low permeability of the saprolite and underlying rock, temporary sumps and pumps, using gravity type dewatering systems, would be sufficient for successful construction dewatering.

Since the applicant provided sufficient information to address groundwater level condition at the site during and after construction and dewatering plan during excavation, the staff concludes that the applicant adequately addressed those issues and will meet design and engineering standards. The effects of groundwater conditions on foundation stability are discussed in VCSNS COL FSAR Section 2.5.4.10 and the staff‘s evaluation is presented in Section 2.5.4.4.10 of this SER.

2.5.4.4.7 Response of Soil and Rock to Dynamic Loading

VCSNS COL FSAR Section 2.5.4.7 states that Layer V (sound rock) will be the foundation unit for the planned Units 2 and 3 nuclear islands. As described in FSAR Sections 2.5.4.7.1 through 2.5.4.7.3, the applicant used V_S profiles, variations of shear modulus and damping with strain, and site-specific seismic acceleration time histories to estimate the amplification or attenuation of seismic acceleration within the sound rock layer.

Shear Wave Velocity Profiles

VCSNS COL FSAR Section 2.5.4.7.1 describes the V_S profiles developed for both soil and rock at the VCSNS site. During the subsurface investigation, the applicant obtained estimates of V_S of the bedrock (Layer V) beneath the nuclear island and beneath the planned locations of the surrounding major power block structures of each unit. The applicant stated that the partially and moderately weathered rock units (Layers III and IV) reflect the transition zone from soil to sound rock. The applicant stated that the average top of the partially and moderately weathered rock for Units 2 and 3 is around El. 114 m (375 ft) and 111.2 m (365 ft), respectively. The applicant will remove all of the soil and weathered rock beneath the safety-related structures at planned Units 2 and 3 in order to found these structures on sound rock, or on concrete above the sound rock.

In RAI 2.5.4-11, the staff asked the applicant to provide additional information concerning VCSNS COL FSAR Figure 2.5.4-226, "Shear Wave Velocity of Layer V with 5-Foot Vertical Distance Averaging." The staff asked for clarification if the applicant used the data shown in FSAR Figure 2.5.4-224 to develop V_S profile for Layer V, as shown in FSAR Figure 2.5.4-226, and if Borings B-201 and B-206 from FSAR Figure 2.5.4-224 exhibit the lowest V_S recorded between El. 96 and 108 m (315 and 355 ft) of the four V_S profiles shown. The staff also noted that the locations of Borings B-201 and B-206 are within the footprint of the nuclear island, but B-207 and B-211 are considerably outside of the nuclear island footprint. Averaging the four V_S profiles (Borings B-201, B-206, B-207 and B-211) yields a higher mean V_S profile than if only B-201 and B-206 were used. Therefore, the staff requested that the applicant provide information to address any potential effects of using the lower V_S values from B-201 and B-206 on the site response amplification or attenuation.

In its response to RAI 2.5.4-11 (dated April 29, 2009), the applicant confirmed that it used the data shown in VCSNS COL FSAR Figure 2.5.4-224 to develop FSAR Figure 2.5.4-226 and stated that the V_S data was from the four boreholes, two within the nuclear island footprint, and two outside the footprint. Because the V_S values below El. 330 are 2,804 m/s (9200 fps) or more with little variability, the applicant stated that only the upper 7.6 m (25 ft) of rock (El. 330 to the top of sound rock at El. 355 ft) is necessary to evaluate. Over this 7.6 m (25 ft), the average V_S is about 2,438 m/s (8000 fps), which is about 13 percent lower than 2,804 m/s (9200 fps). The applicant stated, "Considering the huge mass of high velocity rock involved and the wavelength of the shear waves (hundreds of thousands of ft, depending on the layer thickness considered), 7.6m (25 ft) thickness of V_S 2,438 m/s (8,000 fps) rock (defined as hard rock in the AP1000 DCD) should have minimal amplification effects." The applicant further stated that the average V_S values between about El. 315 ft and El. 355 ft are less for the two Unit 2 nuclear island V_S profiles than for all four V_S profiles and that this decrease in V_S is correlated with a zone of sub horizontal, slightly weathered fractures observed in the rock core and noted on the borings as a decrease in RQD values. These sub horizontal fractures at Unit 2 are not observed at Unit 3. The applicant stated that it used the four boreholes (two within the footprint and two outside) to better represent the mean V_S and its variability within the granitic pluton.

The staff reviewed the applicant's response to RAI 2.5.4-11, and noted that although the V_S profile developed using two borings within the footprint of nuclear island yields lower values of V_S, the difference is only about 13 percent. To evaluate the amplification effects, the staff performed a confirmatory site response analysis, which showed only very small amplification effects (see Section 2.5.2.4.6). Therefore, the staff concludes that the use of V_S data from the four borings does not have a significant impact on the site response to dynamic loading and, in fact, accounts for the variability of the subsurface materials at site. Accordingly, the staff considers RAI 2.5.4-11 closed.

Variation of Shear Modulus and Damping with Strain

VCSNS COL FSAR Sections 2.5.4.7.2.1 and 2.5.4.7.2.2 describe the shear modulus and damping ratio tests that the applicant performed for the Layer I and Layer II soils, as well as for the compacted structural fill. The applicant performed RCTS testing on soils and fill samples and compared the RCTS results with generic shear modulus and damping curves developed by EPRI (1993). The applicant stated that the RCTS results showed reasonable agreement with the EPRI curves; therefore, concluded that additional analysis was not necessary. The applicant considered the shear modulus and damping ratio values of the partially and moderately weathered rock, as well as the sound rock and concluded that only the Layer III partially weathered rock could be considered strain dependent. However, the applicant also concluded that strain dependency of the partially weathered rock will not affect the safety-related structures because Layer III will be removed in the PBAs at Units 2 and 3.

In RAI 2.5.4-2, the staff asked the applicant to justify performing only three RCTS Tests, one on saprolite and two on the proposed structural fill materials. In addition, the staff asked the applicant to justify its conclusion regarding the adequacy of the selected EPRI (1993) generic curves based on a relatively small site-specific data set. In its response, the applicant stated that it performed the RCTS test on the saprolite to complete the characterization of the site. The results do not impact the safety of the site as the soil layers (Layer I and II) will be completely excavated. With regard to the structural fill, the applicant pointed out that the RCTS site-specific data agree well with the EPRI curves with slight divergence at higher strain results for one of the samples (MM-2). The applicant stated that the structural fill will not be placed under the seismic Category I nuclear island, but only for other structures such as the seismic Category II Annex Building. Because neither the saprolite nor structural fill will be placed underneath the seismic Category I nuclear island, the staff finds the number of RCTS tests adequate. The staff notes that the applicant used the RCTS test results on the saprolite material in order to determine the PGA motion value within the saprolites for a liquefaction analysis of the site soils. However, since the site soils are being excavated, the liquefaction analysis is also unnecessary. Accordingly, the staff considers RAI 2.5.4-2 closed.
The applicant used the RCTS test results from the structural fill to develop the FIRS for the Annex Building for comparison to the AP1000 CSDRS, which is described in Section 3.7.2.

Rock and Soil Column Amplification/Attenuation Analysis

VCSNS COL FSAR Section 2.5.4.7.3 describes the applicant's site response analysis to determine the site seismic responses for the soil profiles, with associated rock and soil column amplification/attenuation analysis, described in FSAR Section 2.5.4.7.1. The applicant performed site seismic response analyses by following the guidance provided in RGs 1.165 and 1.208, placing sound rock response spectrum input at various depths above and below El. 355 ft for the 60 randomized soil and rock profiles. The analyses obtained maximum mean peak acceleration at El. 400 feet was about 0.55g for Unit 2 and 0.42g for Unit 3. The staff has reviewed VCSNS COL FSAR Section 2.5.4.7.3 and concludes that the site seismic responses analyses are adequate because the applicant followed the guidance provided in RGs 1.165 and 1.208 and correctly used the maximum mean peak ground acceleration as input in the liquefaction analysis for the Units 2 and 3 site soils, to meet the requirements of 10 CFR 100.23. Detailed technical evaluation of the site seismic response analysis is presented in Section 2.5.2.4.6 of this SER.

Conclusions Regarding Response of Soil and Rock to Dynamic Loading

In summary, the staff concludes that the applicant developed soil and rock dynamic properties for the VCSNS site based on field and laboratory tests in accordance with RG 1.132, Revision 2 and RG 1.138, Revision 2. In addition, the staff concludes that the applicant conducted sufficient tests to determine soil and rock dynamic properties, considered the variation of these properties parameters when conducting its analyses; therefore, the soil and rock dynamic property parameters used in design are reasonable.

2.5.4.4.8 Liquefaction Potential

VCSNS COL FSAR Section 2.5.4.8 describes the liquefaction potential of the soil at the VCSNS Units 2 and 3 site, including the analyses performed and the conclusions reached based on the results. The applicant concluded that the only site materials capable of liquefying are Layers I and II, which will be completely removed; therefore, they will not affect the stability of the seismic Category I structures. The applicant analyzed the liquefaction potential of Layers I and II, regardless, and concluded that the potential for liquefaction to occur in the planned VCSNS Units 2 and 3 site area is very low.

Based on VCSNS COL FSAR Section 2.5.4.8, the applicant did not perform a liquefaction analysis for the common backfill because the common backfill was outside of any load-bearing structures adjacent to the nuclear island. However, since the common fill abuts the structural fill, in RAI 2.5.4-8, the staff requested that the applicant provide additional information to clarify whether there are areas where the common fill will extend from the structural fill to the edges of the plant site. The staff also requested that the applicant provide information to address the possible effects that flow liquefaction failure could have on the structural fill.

In response to RAI 2.5.4-8 (dated April 29, 2009), the applicant clarified that the common fill will be placed beyond the zone of loading influence for the seismic Category I structures. The applicant also stated that it plans to use the common fill to a limited extent as part of temporary excavations and that the common fill will always be bound by either structural fill or in-situ rock and will never extend to the edge of the plant site. The applicant further stated that those bounding materials, the structural fill and in-situ rock, will preclude any flow liquefaction or lateral spreading. Finally, the applicant noted that, due to the compaction of the common fill to at least 90 percent of the maximum dry density, as well as the limited use of this type of fill, it is highly unlikely that the common fill could liquefy.

The staff reviewed the applicant's response to RAI 2.5.4-8 and concluded that the applicant adequately addressed the staff's concerns in RAI 2.5.4-8 and clarified that the common fill materials will not impact the stability of seismic Category I and Category II structures. Therefore, RAI 2.5.4-8 is closed.

Based on VCSNS COL FSAR Section 2.5.4.8, the applicant did not perform a liquefaction analysis for the structural backfill adjacent to the nuclear island because the backfill was dense and well compacted and would not liquefy. However, RG 1.206, states that, if the foundation materials at the site adjacent to and under safety-related structures are soils or soils that have a potential to become saturated and the water table is above bedrock, the applicant should provide an appropriate state-of-the-art analysis of the potential for liquefaction at the site. Accordingly, in RAI 2.5.4-9 and RAI 2.5.4-38, the staff asked the applicant to perform a liquefaction analysis to confirm the stability of the structural fill.

In response to RAI 2.5.4-9 (dated April 29, 2009) and RAI 2.5.4-38 (dated August 7, 2009), the applicant stated that for materials, such as the well-graded medium to coarse sand compacted to at least 95 percent of the maximum dry density structural fill, it did not observe or report any evidence of liquefaction. The applicant selected PGA of 0.55 g as the maximum PGA value based on seismic site response analyses for the two proposed units, and a factor of safety (FS) value of 1.25 for the liquefaction analysis of saprolitic soils. Using the N_{60} value of 40 bpf from the response to RAI 2.5.4-1, the applicant performed a liquefaction analysis and concluded that the compacted fill was nonliquefiable under the design basis earthquake at the VCSNS site. The applicant clarified that it selected the PGA of 0.55 g that is the maximum values based on site seismic response analyses for the two proposed units, and FS value of 1.25 for the liquefaction analyses used in the liquefaction analysis of saprolitic soils.

Based on the applicant's response to RAIs 2.5.4-9 and 2.5.4-38, and following a review of the study by Youd et al. (2001), as cited in the RAI responses, the staff agrees that for structural fill with SPT N_{60} values greater than about 30 bpf, the liquefaction potential can be neglected. The staff also considered the applicant's statement that no backfill soil will be placed beneath the nuclear island foundation; therefore, lateral stability from the adjacent backfill is not required.

In summary, the applicant provided sufficient details regarding the evaluation of liquefaction potential within the compacted structural fill to be placed at planned VCSNS Units 2 and 3. The staff concludes that the applicant used proper methodologies to evaluate the liquefaction potential and provided an adequate plan for excavation and backfill in order to ensure that there will be no liquefaction-induced damage to the safety-related structures under designed conditions. Therefore, the staff considers RAIs 2.5.4-9 and 2.5.4-38 closed.

Conclusion Regarding Liquefaction Potential

Based on the properties of the structural backfill materials described in VCSNS COL FSAR Section 2.5.4.5.3 and the results of field and laboratory testing, the applicant concluded that, for the design basis earthquake, liquefaction is not a concern within the compacted structural fill. The staff finds the applicant's conclusion, that liquefaction potential of the compacted backfill will not be a concern at the site, reasonable based on the fact that the backfill will be compacted to at least 95 percent of the maximum dry density and based on the relatively high blow counts and V_S values for the compacted structural backfill material. Therefore, the staff concludes that the assessment of the liquefaction potential at the planned VCSNS Units 2 and 3 site is adequate to satisfy the criteria of 10 CFR Part 50, Appendix A, GDC 2 and Appendix S, and 10 CFR 100.23 . Furthermore, the applicant's assessment of the potential for liquefaction in the structural backfill adequately satisfies the criteria of 10 CFR Part 50, Appendix A, GDC 2 and Appendix S, and 10 CFR 100.23 with respect to the liquefaction potential of the materials in contact with the seismic Category 1 structures at the site.

2.5.4.4.9 Earthquake Design Basis

VCSNS COL FSAR Sections 2.5.2.6 and 2.5.2.7 present the applicant's derivation of the horizontal GMRS. Because V_S profiles, soil modulus reduction curves, and damping curves, described in FSAR Section 2.5.4, are critical inputs to the site-specific seismic response; the staff's analysis of these inputs is fully discussed in Section 2.5.2.4 of this SER.

2.5.4.4.10 Static Stability

The staff focused its review of VCSNS COL FSAR Section 2.5.4.10 on the applicant's evaluation of bearing capacity and settlement values for the foundation bearing unit (Layer V sound rock) at the VCSNS site. The applicant used the following assumptions in calculating rock or soil-bearing capacity and structure settlement: (1) placing all safety-related structures on the Layer V sound rock and structural concrete; (2) conservatively assuming an allowable bearing capacity of 6,894 kPa (144 ksf) for concrete; (3) conservatively assuming the groundwater table to be at El. 122 m (400 ft) for bearing capacity and El. 116 m (380 ft) for earth pressure calculations; (4) best estimate of 287 kPa (6 ksf) applied pressure for settlement estimates for major structures other than seismic Category I or II structures; and (5) earth pressure coefficients are Rankine values assuming level backfill and a zero friction angle between the soil and wall. The applicant determined that the allowable bearing capacity of 9,576 kPa (200 ksf) for Layer V sound rock exceeds both the required design allowable static and dynamic bearing capacities, 426 kPa (8.9 ksf) and 1,676 kPa (35 ksf), respectively. The applicant anticipated the settlement of seismic Category I and II and major nonseismic structures would range from 0.05 to 0.254 cm (0.02 to 0.10 in.) for the nuclear island to 7.62 cm (3.0 in.) for the radwaste building, as shown on FSAR Table 2.5.4-220.

Bearing Capacity

The staff reviewed the applicant's bearing capacity estimates in VCSNS COL FSAR Section 2.5.4.10.2 and determined that allowable bearing capacity values for soil foundations are not typically governed by the general shear failure model used by the applicant. In RAI 2.5.4-27, the staff asked the applicant to explain how its bearing capacity estimates are appropriate for evaluating seismic response at Units 2 and 3.

In response to RAI 2.5.4-27 (dated March 16, 2009), the applicant clarified that the settlement estimates included in VCSNS COL FSAR Section 2.5.4.10 and in FSAR Table 2.5.4-220 are for static loading and that settlement estimates are associated with short term loads and typically are not used when evaluating seismic loading. Furthermore, the applicant stated that the planned nuclear islands at Units 2 and 3 will be founded on strong sound rock (or on concrete above sound rock) with negligible settlement potential.

Based on the applicant's response to RAI 2.5.4-27, the staff concludes that since the foundation of the safety-related structures is either on rock or concrete fill, seismic loading has very short duration, and the estimated static bearing capacity of the site is about 6 times of dynamic bearing capacity design requirements, therefore, the estimated bearing capacity value is acceptable and will meet the design requirements. Accordingly, RAI 2.5.4-27 is closed.

Settlement

During its review of VCSNS COL FSAR Section 2.5.4.10.2, the staff considered the applicant's assertion that the Annex and Radwaste buildings would be supported on deep soil, while the turbine building will be founded on deep soil at one end, and hard rock at the other. Since possible large differential settlement between nuclear island and adjacent buildings may exceed the standard design requirement, in RAI 2.5.4-28, the staff asked the applicant to indicate how it estimated the settlement for the sandy foundation soils; whether the applicant included dynamic effects in the estimates; and what the potential impact of the varying support conditions would have on the turbine building.

In response to RAI 2.5.4-28 (dated March 16, 2009), the applicant stated that, when loaded, the well-compacted, dense, medium to coarse, sandy structural fill will behave in an elastic or pseudo-elastic manner. The applicant also referenced the equations in VCSNS COL FSAR Section 2.5.4.10.2, which it used to calculate the settlement and pressure distribution beneath the foundations. The applicant noted that it did not make any settlement estimates for dynamic loading conditions since any dynamic loading would be very short term and evenly distributed across the structure. If any settlement occurs, the applicant stated that it will be elastic and of small magnitude.

With respect to the turbine building, the applicant stated that there will be two primary foundation levels, one closer to top of bedrock level and the other closer to grade level. Assuming that loading is uniform across the foundation and that there will be more soil under the portion of the foundation that is closer to the grade level, the applicant determined that there will be more settlement on the shallow portion of the foundation closer to grade level than in the deep portion closer to the top of bedrock, regardless of the material beneath the deep portion.

Based on the review of the applicant's response to RAI 2.5.4-28, and based on observations made during a site audit between March 31 and April 1, 2009, the staff noted that the settlement calculations of the VCSNS COL FSAR were based on Revision 15 to the DCD, not the current Revision 17, which has updated the maximum static foundation pressure and settlement design parameters. The staff also noted that, although the foundation shape is irregular, a rectangular shape was used for settlement calculations, the settlement calculations were only performed at two points for each foundation, the high strain modulus used in the settlement calculations was not specified, and the difference between foundation materials from one side of the turbine building to the other were not addressed. In supplemental RAI 2.5.4-35, the staff asked the applicant to re-evaluate the foundation settlement using the parameters in Revision 17 of the AP1000 DCD, verify the impact of using the irregular shape of the nuclear island foundation in the settlement calculations, confirm that the two-point foundation settlement method is adequate to describe the total and differential settlement over the whole foundation, clarify the shear strain level at which the shear moduli were determined and explain how this level compares to that of the site GMRS seismic load, and verify the potential impact on the settlement of the turbine building of the nonuniform conditions on which it is to be founded.

In its response (NND-09-0191, dated August 7, 2009), the applicant addressed each of the staff's five issues separately. With respect to the re-evaluation for the foundation settlement using the updated parameters in the AP1000 DCD, the applicant stated that only the static bearing demand over the footprint of the nuclear island changed in DCD Revision 17 from 411 to 426 kPa (8.6 to 8.9 ksf). The applicant noted that since it had rounded up the average total settlement based on 411 kPa (8.6 ksf) from 0.33 millimeters (mm) (0.013 in.) to 0.38 mm (0.015 in.) and the average total settlement based on 426 kPa (8.9 ksf) was 0.35 mm (0.014 in.), the VCSNS COL FSAR value of 0.38 mm (0.015 in.) would not change for the increased loading and would remain well within the DCD-specific total settlement of 7.62 cm (3 in.).

To verify the impact of the irregular shape on the settlement calculations, the applicant calculated the settlement using the maximum dimensions of the nuclear island with the same loading pressure. The applicant noted that using the actual shape of the nuclear island would result in the average total settlement of less than the 0.35 mm (0.014 in.) calculated using the revised DCD demand of 426 kPa (8.9 ksf).

To confirm that the two-point foundation settlement method is adequate, the applicant stated that although the corner settlements are less than the center and edge values for a uniformly loaded structure and would increase the differential settlement across the nuclear island, since the maximum calculated differential settlement is 0.1 mm per 15.24 m (0.004 in. per 50 ft) and the allowable differential settlement is 1.27 cm per 15.24 m (0.5 in. per 50 ft), this increase from the corner settlement would have no impact on the total differential settlement.

The applicant stated that, for sound bedrock, the elastic modulus is independent of strain and only calculated the settlement of structures underlain by structural fill that is affected by the strain level. The applicant concluded that the settlement values obtained using the high strain modulus are within tolerable limits and there is no need to use strain dependent modulus analysis that would give smaller settlements. The applicant revised the VCSNS COL FSAR to state the high strain value was used in the analysis.

Finally, the applicant referred to the response to RAI 2.5.4-28 for a discussion of the nonuniform support condition on settlement. The applicant noted that rock at or close to the bottom of the basemat is only relevant to differential settlement in a limited extent. The applicant concluded that since the underlying rock would have essentially no settlement, the differential settlement is attributable solely to the difference in thickness of structural fill.

After reviewing the response to supplemental RAI 2.5.4-35, the staff concludes that: (1) the total settlement increase caused by a 3.5 percent increase of static bearing demand over the footprint of the nuclear island is negligible because the estimated total settlement is much smaller than the 3 inches allowed according to the revised AP1000 DCD; (2) since uniformly distributed average loading pressure was used in the settlement analysis, using the actual foundation shape that has smaller area than the assumed area in the analysis, which was based on maximum dimension of the nuclear island footprint, will not yield bigger predicted settlement; (3) although corner settlement estimates will increase the computed maximum differential settlement across the nuclear island, that value is still much smaller than the standard design allowable differential settlement, about 0.004 in. per 50 ft versus 0.5 in. per 50 ft; therefore, not computing corner settlement will not alter the structure stability conclusion for this site; (4) the applicant clarified that the modulus values used in settlement calculation are high strain values, and this approach is adequate in settlement analysis; and (5) although a portion of the Turbine Building will be founded at or close to the rock, since the calculated total settlement is less than 0.015 inch for foundation sitting on structural fill, and the smallest dimension of the nuclear island foundation is about 90 ft, which results about 0.008 in. per 50 ft of the maximum differential settlement, which will not exceed the standard design values.

Furthermore, the staff reviewed Revision 2 of the VCSNS COL FSAR and confirmed that the applicant incorporated all proposed changes to reflect the revised standard design bearing capacity requirement and to clarify the elastic modulus used in settlement analysis is high strain value in the revised FSAR. Based on the above discussions, the staff considers RAI 2.5.4-35 closed.

Lateral Earth Pressure

As part of its review of VCSNS COL FSAR Section 2.5.4.10.3, the staff reviewed the active and at-rest pressures used in the evaluation of the lateral wall pressures, which the AP1000 design based on horizontal seismic loading and a total load distribution to both lateral wall loads and base shear. However, the pressure diagrams do not follow the anticipated results. In RAI 2.5.4-29, the staff asked the applicant to justify the calculation of these pressure diagrams and how it compared to the estimates used as part of the AP1000 design.

In response to RAI 2.5.4-29 (dated April 29, 2009), the applicant justified both the pressure calculations and diagrams in both the active and at-rest conditions. The applicant developed the active lateral earth pressure using the Mononobe-Okabe (M-O) method, a PGA input of 0.55 g to produce RAI Figure 2.5.4-29.2, the active pressure diagram, which includes a surcharge pressure of 23.9 kPa (500 psf), coefficient of active pressure, Ka, equal to 0.26, and a wall height at the standard AP1000 design value of 12.2 m (40 ft). Since the M-O method assumes that the foundation wall will move or rotate under lateral seismic pressure, it cannot realistically determine the seismic lateral earth pressure on the foundation wall when there is no movement, or at-rest condition. The applicant used the Ostadan method to estimate the at-rest seismic lateral earth pressure because the Ostadan method considers the at-rest condition of the foundation wall under seismic loadings. The applicant also determined the at-rest pressure using the method described in ASCE 4-98, and recalculated the total at-rest lateral earth pressure distribution, including the dynamic component and compaction-induced lateral earth pressures. The results are illustrated in Figure 2.5.4-4 (RAI Figure 2.5.4-29-4). Finally, the applicant compared the site-specific pressures and load combinations to the AP1000 design values in RAI Figure 2.5.4-29-7, which shows that the maximum design pressures envelope the site-specific total at-rest lateral earth pressures.

After reviewing the applicant's response to RAI 2.5.4-29, the staff found that: (1) the methods and procedures used to determine the lateral earth pressure are acceptable methods in nuclear power plant foundation design and analyses; (2) the maximum PGA values used in the analysis are conservative; (3) the supplementary at-rest earth pressure analysis using the ASCE 4-98 method provided additional confidence on the total lateral earth pressure estimate for considering possible maximum seismic loading induced earth pressure; and (4) the comparison of AP1000 maximum design pressure on below-grade wall and the estimated total site-specific at-rest lateral earth pressure indicates that the design pressure envelopes the site-specific estimated earth pressure. The staff concludes that the revised calculation of site-specific lateral earth pressure used an acceptable method and conservative approach, and yielded acceptable results. Accordingly, the staff considers RAI 2.5.4-29 closed.

The staff also noted that the applicant did not include the lateral pressure effects due to potential soil compaction in its original lateral pressure computation. Therefore, in RAI 2.5.4-30, the staff asked the applicant to provide the planned compaction procedures to be used, the impact on the lateral pressures, reduced compacted density, and V_S, which may impact the horizontal soil structure interaction (SSI) response.

In its response dated April 29, 2009, the applicant provided two procedures to evaluate the compaction-induced lateral earth pressures for at-rest conditions, which included the dimensions and loads of various compactors, vibratory rollers, and plate compactors, as well as the design charts for compaction-induced earth pressures. The applicant noted that it would be possible to use two different compaction methods resulting in the same density but different lateral pressures since heavy compaction equipment tends to result in higher pressures;

therefore, the applicant would not use this compaction method within 1.5 m (5 ft) of the structural walls. The applicant computed the at-rest pressures using the two methods described without considering active pressure conditions because no permanent retaining wall structures were planned. Finally, the applicant addressed compaction control and fill placement in the technical specifications.

The staff reviewed the applicant's response to RAI 2.5.4-30, especially the calculations of lateral pressure induced by soil compaction, and concludes that: (1) the applicant used an acceptable procedure to estimate the additional lateral earth pressure induced by soil compaction; (2) the soil properties used in the analysis are within the normal value range of engineering soil; and (3) the assumptions used in the analysis are conservative for considering possible worst-case scenario. Based on this information, as well as the proposed revision to the VCSNS COL FSAR to include the information provided in the RAI response, the staff considers RAI 2.5.4-30 closed.

The staff reviewed a summary of 22 observation wells locations and depths in VCSNS COL FSAR Table 2.5.4-202 and noted that there was an 18 m (60 ft) piezometric head variation in the observation wells. In RAI 2.5.4-16, the staff asked the applicant to describe the impact of the unbalanced pressure distribution on lateral sliding stability.

In response to RAI 2.5.4-16 (dated March 16, 2009), the applicant stated that it only considered the effects of the unbalanced pressure distribution encountered across the site for the nuclear island, which extends to about 12 m (40 ft) below grade; therefore, it experiences the greatest lateral pressure on buried walls from soil and groundwater. The applicant concluded that the piezometric elevations recorded in VCSNS COL FSAR Figure 2.5.4-237 for Units 2 and 3 translated to the minimum unbalanced hydrostatic pressures and will be negligible in terms of lateral sliding potential.

Based on the response and review of the ground water level recorded and the piezometric contours shown in VCSNS COL FSAR Figure 2.5.4-237 around the Unit 2 and 3 nuclear islands, the staff confirmed that the maximum differential water head is about 1.5 m (5 ft), which results in 14.94 kPa (312 psf) of unbalanced hydrostatic pressure around the nuclear island. The staff also compared the differential water head to the weight of the nuclear island and lateral pressure produced by surrounding soil, ground water, surcharge and seismic loading, which, at the maximum, is about 155 kPa (3,250 psf), and noted that the unbalanced hydrostatic pressure is less than 10 percent of the expected maximum lateral pressure on the nuclear island. The staff concludes that since this small amount of unbalanced hydrostatic pressure will not have notable negative impact on the stability of the nuclear island foundation and structure, the applicant's description of the effect of the unbalanced pressure distribution on lateral sliding stability is sufficient. Accordingly, the staff considers RAI 2.5.4-16 closed.

In summary, the staff concludes that the applicant provided sufficient information in VCSNS COL FSAR Section 2.5.4.10, "Static Stability," which includes static and dynamic bearing capacity evaluation, total and differential settlement evaluation, and lateral earth pressure evaluation, to meet the standard design values and satisfy the applicable criteria of 10 CFR Part 50, Appendix A, GDC 2 and Appendix S, and 10 CFR 100.23..

2.5.4.4.11 Design Criteria

In VCSNS COL FSAR Section 2.5.4.11, the applicant summarized the geotechnical design criteria presented in various sections of the FSAR that pertain to structural design (e.g., wall rotation, sliding, or overturning), which is discussed in detail in Section 3.8 of this SER. A list of the main design criteria is shown in Table 2.5.4-3.

The staff reviewed the information provided by the applicant regarding the applicable AP1000 geotechnical design criteria to determine if the applicant conducted an exploration and testing program sufficient to determine whether the site would support the design parameters. The staff focused on the applicant's efforts to determine whether the sound rock bearing layer would support the plant structures and whether the overall site geology met site parameters. Also, the staff verified whether the site properties met or exceeded site parameters and required factors of safety, whether the studies and designs supported AP1000 DCD, Tier 1, Table 5.0-1, "Site Parameters," minimum V_S requirements and whether the applicant sufficiently analyzed site liquefaction potential.

As discussed in the previous sections, the staff concludes that the applicant conducted an exploration and testing program consistent with the guidance presented in RG 1.132, Revision 2, RG 1.138, Revision 2, and RG 1.198, to adequately characterize the site and verify that the site would support the AP1000 design criteria discussed in and applied to Section 2.5.4. Furthermore, based on the applicant's inclusion of site-specific design criteria, including the factors of safety against events such as liquefaction or loading, the staff considers the design criteria acceptable for the application. The staff also concludes that the applicant has met the applicable criteria of 10 CFR Part 50, Appendix A, GDC 2 and Appendix S, because the VCSNS COL FSAR included a description and safety assessment of the site and the site evaluation factors identified in 10 CFR 100.23.

2.5.4.4.12 Techniques to Improve Subsurface Conditions

In VCSNS COL FSAR Section 2.5.4.12, the applicant stated that any residuum or saprolite beneath or within the zone of influence of seismic Category I or II structures would be removed and replaced with compacted structural fill. The applicant also stated that zones of weathered or fractured rock encountered beneath the nuclear island basement would be removed and replaced with structural concrete; therefore, no ground improvement techniques were considered beyond the removal and replacement of the Layers I and II and any other unsuitable material. Accordingly, the staff focused its review on the subsurface improvement plans, the most significant of which is the planned removal of the entirety of the Layers I and II residuum and saprolitic materials, and the placement of concrete fill. In responses to RAI 2.5.4-36, the applicant stated that since the excavation will reach the depth where all weathered and/or fractured rock will be removed, the V_S of the in-situ rock underneath the foundation, and the concrete fill with strength of 34,474 kPa (5,000 psi) to be used for foundation leveling, will be greater than 7,000 fps, which will also meet all foundation and structure stability requirements. The applicant also committed to provide a detailed thermal control and monitoring plan to control temperature based on ACI 207 guidelines during the concrete fill placement to prevent thermal cracking in concrete. In addition to the staff's evaluation on concrete fill properties and design specifications presented in SER Section 2.5.4.4.5, the staff concludes that the plan for subsurface improvement will ensure the stability of foundation and structures to be built at this site; hence it satisfies the criteria of 10 CFR 100.23.

2.5.4.4.13 Subsurface Instrumentation

In VCSNS COL FSAR Section 2.5.4.13 the applicant stated that, since the VCSNS Units 2 and 3 nuclear islands are founded directly on the sound rock or on concrete on sound rock, no settlement monitoring would be required. However, the applicant noted that it would conduct settlement monitoring of nonsafety-related structures not founded on bedrock or concrete. The staff concludes that this is acceptable because the nuclear island structures will rest on the competent Layer V sound rock and/or on quality controlled structural concrete directly in contact with the Layer V sound rock (bedrock); therefore, no settlement of structures is anticipated.

2.5.4.5 *Post Combined License Activities*

As identified above, the applicant has committed to developing a thermal control plan to be used during the placement of the fill concrete under the Nuclear Island of VCSNS Unit 2 based on ACI 207 series guidelines. The thermal control plan will have the elements described in VCSNS COL FSAR Section 2.5.4.12.

2.5.4.6 *Conclusion*

The NRC staff reviewed the application and checked the referenced DCD. The NRC staff's review confirmed that the applicant addressed the required information relating to stability of subsurface material and foundations, and there is no outstanding information expected to be addressed in the VCSNS COL FSAR related to this section. The results of the NRC staff's technical evaluation of the information incorporated by reference in the VCSNS COL application are documented in NUREG-1793 and its supplements.

Based on its review of VCS COL 2.5-5 through VCS COL 2.5-13 and VCS COL 2.5-16, and VCS SUP 2.5-3 described above, 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 VCSNS Units 2 and 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 has reviewed the engineering properties of materials at the VCSNS Units 2 and 3 site, 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 this section of the application adequately addressed COL Information Items 2.5-5 through 2.5-13 and 2.5-16, and VCS SUP 2.5-3; therefore, the applicant has provided sufficient information to meet the requirements of 10 CFR Part 50, Appendix A (GDC 2); Appendix S of 10 CFR Part 50; and 10 CFR 100.23.

2.5.5 Stability of Slopes

2.5.5.1 *Introduction*

VCSNS COL FSAR Section 2.5.5 addresses the stability of all earth and rock slopes both natural and manmade (cuts, fill, embankments, dams, etc.) whose failure, under any of the conditions to which they could be exposed during the life of the plant, could adversely affect the safety of the plant. The staff evaluated the following subjects using the data provided in the FSAR and information available from other sources: (1) slope characteristics; (2) design criteria and design analyses; (3) results of the investigations including borings, pits, trenches, and laboratory tests; (4) properties of borrow material, compaction and excavation specifications; and (5) any additional information deemed necessary in accordance with 10 CFR Part 52.

This SER section also evaluates the additional information provided by the applicant in VCSNS COL FSAR Section 2.5.6, which addresses embankments and dams in the site area.

Section 2.5.5 of this SER provides slope stability information related to the VCSNS site. SER Section 2.5.5.2 summarizes the relevant geologic and seismic information related to surface faulting in VCSNS COL FSAR Section 2.5.5. SER Section 2.5.5.3 summarizes NRC regulation and regulatory guidance used by the applicant to perform its investigation and prepare FSAR Section 2.5.5. SER Section 2.5.5.4 provides a detailed review of the evaluation performed by NRC staff of FSAR Section 2.5.5, including any requests for additional information and any corresponding open items, and any confirmatory analyses performed by NRC staff. SER Section 2.5.5.6 summarizes the conclusions made by the NRC staff concerning FSAR Section 2.5.5, restates the bases for the conclusions, documents whether the applicant properly characterized the site, and confirms that the applicant met the requirements defined in the NRC Regulation.

2.5.5.2 *Summary of Application*

Section 2.5.0 of the VCSNS COL FSAR, Revision 5, incorporates by reference Sections 2.5.5 and 2.5.6 of the AP1000 DCD, Revision 19.

In addition, in VCSNS FSAR Sections 2.5.5 and 2.5.6, the applicant provided the following:

AP1000 COL Information Items

- VCS COL 2.5-14

The applicant provided additional information in VCS COL 2.5-14 to address COL Information Item 2.5-14 (COL Action Item 2.5.5-1), which addresses the provision of site-specific information about the static and dynamic stability of soil and rock slopes, the failure of which could adversely affect the nuclear island.

- VCS COL 2.5-15

The applicant provided additional information in VCS COL 2.5-15 to address COL Information Item 2.5-15 (COL Action Item 2.5.6-1), which addresses the provision of site-specific information about the static and dynamic stability of embankments and dams, the failure of which could adversely affect the nuclear island.

2.5.5.2.1 Slope Characteristics

The applicant provided the finished grade plan and foundation excavation sections as shown on VCSNS COL FSAR Figures 2.5.4-245 and 2.5.4-220 through 2.5.4-223. The applicant stated that failure of any of the permanent and temporary cut slopes and any man-made slopes that exist in the site vicinity would not compromise the operation of the safety-related plant facilities.

2.5.5.2.1.1 Permanent Slopes Beyond the Plant Perimeter

The applicant stated that the Units 2 and 3 site main plant and cooling tower areas are located on an irregularly shaped, essentially level plateau with a nominal finished grade at just above El. 121 m (400 ft), and that the plateau is graded for drainage, typically reaching about El. 118 m (390 ft) at the perimeter. The applicant also stated that the plateau is located in an area that forms a ridge where the bedrock was at its highest point, and that the plateau resulted from cutting the higher elevations of the ridge and some limited filling, with the existing grade generally dropping off beyond the perimeter of the plateau. The largest slope described by the applicant descends to around El. 96 m (315 ft) beyond the southwestern perimeter of the site, and there are limited areas where the ground rises beyond the perimeter, notably around the parking lot to the west of the proposed Unit 3 site. The applicant stated that the slopes are graded and filled to form a typical 3 horizontal to 1 vertical (3h:1v) slope.

The applicant stated that, referring to VCSNS COL FSAR Figure 2.5.4-245, the two slopes closest to Units 2 and 3 are approximately 182 to 213 m (600 and 700 ft), respectively, from the closest point of the nuclear islands. The applicant noted that the typical 3h:1v slope is 13 m (45 ft) high to the northwest of Unit 2, descending from El. 118 to 105 m (390 to 345 ft), and the slope is 21.3 m (70 ft) high to the southwest of Unit 3, descending from El. 118 to 97 m (390 to 320 ft). The applicant concluded that it plans to found each nuclear island on the Layer V sound rock or on concrete placed on sound rock. The applicant does not expect that failure of perimeter slopes at distances at least 182 m (600 ft) away from the nuclear islands would have any impact on the stability of the nuclear islands.

For the seismic Category II annex buildings, which are founded on approximately 9 to 13 m (30 to 45 ft) of compacted structural fill placed on Layer V sound rock, the applicant noted that the nearest point of the top of the 13 m (45 ft) high slope to the Unit 2 annex building was about 152 m (500 ft), while the top of the 21 m (70 ft) high slope to the Unit 3 annex was over 243 m (800 ft). The applicant concluded that, as each of these slopes is less than 10 percent of the distance from the top of the slope to the nearest edge of the annex buildings, failure of the perimeter slope would not have any impact on the stability of the annex buildings.

2.5.5.2.1.2 Temporary Slopes for Plant Construction

SER Figures 2.5.4-220 through 2.5.4-223 illustrate excavation sections, as well as show the excavation from finished grade down to bedrock. The applicant concluded that the failure of any temporary construction slope would have no effect on the safety of the nuclear power plant facilities because the deepest construction excavation is made to the north of Unit 2, where the top of rock slopes down towards the north and the excavation would have to go deeper to reach the top of rock, and the construction slope would be 2h:1v with 3 m (10 ft) wide berms placed at approximately every 6 m (20 ft) of slope height.

2.5.5.2.1.3 Groundwater and Seepage

The applicant provided a detailed discussion of the site groundwater conditions in VCSNS COL FSAR Section 2.4.12, and noted that groundwater is present in unconfined conditions in both the saprolitic soils and the underlying bedrock of Units 2 and 3. FSAR Figure 2.5.4-237 shows the representative piezometric level contour for the shallow wells. The applicant noted that the groundwater contour map indicated that groundwater flowed in all directions from the top of the ridge, now plateau. The groundwater gradient in the saprolite/shallow bedrock ranged from 0.001 to 0.003 m/m (ft/ft) on the ridge, to 0.037 to 0.050 m/m (ft/ft) on the flanks. The applicant classified the saprolite as silty sand with a tight interlocking fabric, which gives it low permeability. Therefore, the applicant concluded that significant seepage did not occur on the perimeter slopes. The applicant also stated that the saprolitic soils would be subject to erosion but that the perimeter slopes are vegetation covered. Therefore, although some locally minor cutting of the slopes could occur during heavy runoff, the applicant concluded that the extent would be limited and would not produce any significant change in slope geometry over the plant lifetime.

2.5.5.2.1.4 Stability of Slopes Conclusion

The applicant concluded that because permanent perimeter slopes for Units 2 and 3 are at least 182 and 152 m (600 and 500 ft) away, respectively, from the nearest point on the nuclear islands and annex buildings, failure of those slopes under any of the conditions to which they would be exposed during the plant lifetime, would not affect the safety of the nuclear power plant facilities. Furthermore, the applicant stated that there would be no significant impact of erosion or seepage through the slopes, and any temporary slopes during construction would also not affect safety of the nuclear plant facilities.

2.5.5.2.2 Embankments and Dams

VCSNS COL FSAR Section 2.5.6 states that no embankments or dams are required to protect the PBA. The applicant also noted that there are no bodies of water near the PBA that would require dams or embankments. Furthermore, the applicant noted that, given the maximum flood elevation of the Parr Reservoir, no dams or embankments are needed for flood protection at the planned VCSNS Units 2 and 3.

2.5.5.3 *Regulatory Basis*

The regulatory basis of the information incorporated by reference is addressed in NUREG-1793 and its supplements.

In addition, the acceptance criteria associated with the relevant requirements of the Commission regulations for the stability of slopes are given in Section 2.5.5 of NUREG-0800.

The applicable regulatory requirements for reviewing the applicant's discussion of stability of slopes are:

- 10 CFR Part 50, Appendix A, GDC 2, as it 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 S, as it 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 from Section 2.5.5 of NUREG-0800 are as follows:

- Slope Characteristics: In meeting the requirements of 10 CFR Parts 50 and 100, the discussion of slope characteristics is acceptable if the section includes: (1) cross sections and profiles of the slope in sufficient quantity and detail to represent the slope and foundation conditions; (2) a summary and description of static and dynamic properties of the soil and rock comprised by seismic Category I embankment dams and their foundations, natural and cut slopes, and all soil or rock slopes whose stability would directly or indirectly affect safety-related and Category I facilities; and (3) a summary and description of groundwater, seepage, and high and low groundwater conditions.

- 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, Revision 2; RG 1.138, Revision 2; RG 1.198; and RG 1.206.

2.5.5.4 *Technical Evaluation*

The NRC staff reviewed Sections 2.5.5 and 2.5.6 of the VCSNS COL FSAR and checked the referenced DCD to ensure that the combination of the DCD and the COL application represents the complete scope of information relating to this review topic. The NRC staff's review confirmed that the information in the application and incorporated by reference addresses the required information relating to the stability of slopes. The results of the NRC staff's evaluation of the information incorporated by reference in the VCSNS COL application are documented in NUREG-1793 and its supplements.

The staff reviewed the information in the VCSNS COL FSAR:

AP1000 COL Information Items

- VCS COL 2.5-14

The NRC staff reviewed VCS COL 2.5-14 included under Section 2.5.5 of the VCSNS COL FSAR, related to the stability of all earth and rock slopes both natural and manmade (cuts, fill, embankments, dams, etc.) whose failure, under any of the conditions to which it could be exposed during the life of the plant, could adversely affect the safety of the plant. The COL information item in AP1000 DCD Section 2.5.5 states:

> Combined License applicants referencing the AP1000 design will address site-specific information about the static and dynamic stability of soil and rock slopes, the failure of which could adversely affect the nuclear island.

- VCS COL 2.5-15

The NRC staff reviewed VCS COL 2.5-15 included under Section 2.5.6 of the VCSNS COL FSAR, related to the stability of embankments and dams, the failure of which could adversely affect the plant. The COL information item in AP1000 DCD Section 2.5.6 states:

> Combined License applicants referencing the AP1000 design will address site-specific information about the static and dynamic stability of embankments and dams, the failure of which could adversely affect the nuclear island.

2.5.5.4.1 Slope Characteristics

The applicant provided descriptions of permanent and temporary slopes at the site. The applicant noted that there are two slopes located close to Category I structures, one about 13 m (45 ft) high and about 183 m (300 ft) away from Unit 2, and the other one 21 m (70 ft) high and about 211 m (700 ft) away from Unit 3, both with a slope of 3h:1v. For Category II annex buildings, the applicant stated that the height of the nearest slope is less than 10 percent of the distance from the structure to the top of the slope. However, the applicant noted that this is a temporary slope that will exist during excavation and the design will ensure its stability. The applicant also discussed the groundwater and seepage conditions at the site.

The staff reviewed the site grade plan and foundation excavation sections as provided in VCSNS COL FSAR Section 2.5.4, and the description of the slopes at the site. The staff also examined the existing slopes at the site during the site audit (between March 31 and April 1, 2009) to confirm the slope locations and their geographic characteristics. The staff also reviewed site boring logs, the site subsurface soil profile and the hydraulic conductivity property of the soil to evaluate the seepage condition. The staff's analysis of these inputs is fully discussed in Section 2.5.4 of this SER.

Based on the review, the staff determined that: (1) all existing slopes at the site have a slope height of less than 10 percent of the distance to safety-related structures that will be founded on sound rock; therefore, the slope failure will not affect the safety of structures; (2) the temporary slopes will no longer exist after construction, therefore, the temporary slopes will not affect the safety of structures; and (3) the permeability of the saprolite soil at the site is moderate, the groundwater gradient is small and no significant seepage is expect to occur; therefore, it is very unlikely that the slope geometry will have significant change caused by soil erosion. Based on these findings, the staff concludes that no slope failure at the site will adversely affect the safety of the nuclear power plant structures; therefore, no slope stability analysis is necessary for this site.

2.5.5.4.2 Embankments and Dams

The applicant referred to the discussions presented in VCSNS COL FSAR Sections 2.4.3, 2.4.4 and 2.5.5 regarding the maximum flood elevation of the Parr Reservoir and stability of slopes at the VCSNS site. The applicant concluded that there is no need to build either a dam or embankments to protect the power block and cooling tower area because of the high elevation of the plant's finished grade and the good drainage conditions at the site. The applicant further explained that the flooding protection measures for Unit 1 and natural swales between the reservoir and Units 2 and 3 would be sufficient to prevent flooding.

The staff reviewed the possible maximum flood elevation analysis presented in VCSNS COL FSAR Sections 2.4.3 and 2.4.4, the plant finish grade presented in FSAR Section 2.5.4, and the discussion of slope stability in FSAR Section 2.5.5, and agrees with the applicant's conclusion that there is no need for additional dams or embankments at the VCSNS site.

2.5.5.5 *Post Combined License Activities*

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

2.5.5.6 *Conclusion*

The NRC staff reviewed the application and checked the referenced DCD. The NRC staff's review confirmed that the applicant addressed the required information relating to stability of slopes, and there is no outstanding information expected to be addressed in the VCSNS COL FSAR related to this section. The results of the NRC staff's technical evaluation of the information incorporated by reference in the VCSNS COL application are documented in NUREG-1793 and its supplements.

Based on its review of VCS COL 2.5-14 and VCS COL 2.5-15, described above, the staff concludes that the applicant presented and substantiated information to assess the stability of all earth and rock slopes, both natural and man-made at the COL site., as well as the need for dam and embankments at the site to protect the nuclear power plant from flood. The staff has reviewed the site investigations and analyses related to slope stability, possible maximum flood, and flood protection measures at the site, and for the reasons given above, concludes that: (1) all slopes at the site have adequate distance from the power block and cooling tower area so that the failure of those slopes will not have an adverse effect on the safety of nuclear power plant facilities; and (2) there is no need for additional dam or embankments to be built at the site to protect the power plant facilities from possible maximum flood because the relatively high elevation of the plant finish grade, the adequate flooding protection measures for Unit 1 and natural swales between the reservoir and proposed new units. The staff further concludes that these sections of the application adequately addressed COL Information Items 2.5-14 and 2.5-15; therefore, the applicant has provided sufficient information to meet the requirements of 10 CFR Part 50, Appendix A (GDC 2); Appendix S of 10 CFR Part 50; and 10 CFR 100.23.