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 used to demonstrate that the applicant has accurately described the site characteristics and site parameters together with site-related design parameters and design characteristics in accordance with Title 10 of the *Code of Federal Regulations* (CFR) 10 CFR Part 52. The review is focused on the site characteristics and site-related design characteristics needed to enable the Nuclear Regulatory Commission (NRC) staff to reach a conclusion on all safety matters related to siting of Bellefonte (BLN) Nuclear Plant, Units 3 and 4 (BLN 3 and 4). 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 parameters 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 BLN COL FSAR incorporates by reference Section 2 of the AP1000 DCD, Revision 17.

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

<u>*Supplemental Information*</u>

- BLN Supplemental (SUP) 2.0-1

The applicant provided supplemental information within BLN COL FSAR Section 2.0, "Site Characteristics," which describes the characteristics and site-related design parameters of BLN 3 and 4.

In addition, this BLN COL FSAR section addresses Interface Item 2.1, related to the envelope of AP1000 plant site-related parameters.

2.0.3 Regulatory Basis

The regulatory basis of the information incorporated by reference is addressed within the "Final Safety Evaluation Report Related to Certification of the AP1000 Standard Design," (FSER) related to the DCD, (NUREG-1793).

In addition, the relevant requirements of the Commission regulations for the site characteristics, and the associated acceptance criteria, are given in Section 2.0 of NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants," (SRP).

The applicable regulatory requirements for site characteristics are as follows:

- 10 CFR 52.79(a)(1)(i) - (vi) provides 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, 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.

2.0.4 Technical Evaluation

The NRC staff reviewed Section 2.0 of the BLN COL FSAR and checked the referenced DCD to ensure that the combination of the DCD and the information in the COL represent the complete scope of information relating to this review topic.[1] The NRC staff's review confirmed that the information contained in the application and incorporated by reference addresses the required information relating to the site characteristics. Section 2 of the AP1000 DCD is being reviewed by the staff under Docket Number 52-006. The NRC staff's technical evaluation of the information incorporated by reference related to site characteristics will be documented in the staff safety evaluation report (SER) on the DC application for the AP1000 design.

The staff reviewed the information contained in the BLN COL FSAR:

Supplemental Information

- BLN SUP 2.0-1

The NRC staff reviewed supplemental information BLN SUP 2.0-1 in BLN COL FSAR Section 2.0, "Site Characteristics," describing the characteristics and site-related design parameters of BLN 3 and 4. The DCD site parameters in DCD Table 2-1 are compared to the site-specific site characteristics in BLN COL FSAR Table 2.0-201. This supplemental information also is added to other sections in the BLN COL FSAR as shown in this table. In addition, control room atmospheric dispersion factors for accident dose analysis are presented in BLN COL FSAR Table 2.0-202.

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

The NRC staff reviewed and compared the site-specific characteristics included in BLN COL FSAR Tables 2.0-201 and 2.0-202 against DCD Table 2-1. The staff's evaluation of the site characteristics associated with air temperature, 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 site boundary atmospheric dispersion value, the site-specific parameters listed in BLN COL FSAR Tables 2.0-201 and 2.0-202 are enveloped by the DCD values addressed in DCD Table 2-1. In response to request for additional information (RAI) 15.00.3-1, Tennessee Valley Authority (TVA or the applicant) requested an exemption to this parameter. The staff's evaluation of this exemption request is addressed in Sections 2.3, Chapter 6, and Chapter 15 of this SER. The staff's evaluation of the exemption request is **Open Item 2.0-1.**

As set forth above, the NRC staff reviewed the application to ensure that sufficient information was presented to demonstrate that the characteristics of the site fall within the site parameters specified in the DC. Until open items associated with the site characteristics contained in FSAR Table 2.0-201 and 2.0-202 and open items associated with the exclusion area boundary atmospheric dispersion value exemption request are closed, the staff can not conclude, that the applicant has demonstrated that the site characteristics either fall within the DC site parameters or adequate justification has been provided for the exclusion area boundary atmospheric dispersion value falling outside the DC site parameter.

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 BLN COL FSAR related to this subsection.

The Westinghouse application to amend Appendix D to 10 CFR Part 52 includes changes to Table 2.1 of the AP1000 DCD, as stated in Revision 17 of the AP1000 DCD. The staff is reviewing this information on Docket Number 52-006. The results of the NRC staff's technical evaluation of the information incorporated by reference in the BLN COL FSAR will be documented in a supplement to NUREG-1793. The supplement to NUREG-1793 is not yet complete, and this is being tracked as part of Open Item 1-1. The staff will update 2.0 of this SER to reflect the final disposition of the DC application.

However, as a result of Open Item 2.0-1 concerning the exclusion area boundary atmospheric dispersion value exemption request and pending resolution of other open items associated with other site characteristics (e.g., hydrology), the staff is unable to finalize its conclusions on BLN SUP 2.0-1.

2.1 Geography and Demography

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 within the "Contents of Application" sections of the applicable subparts to 10 CFR Part 52. The purpose of the review is to ascertain the accuracy of the applicant's description for use in independent evaluations of the exclusion area authority and control, the surrounding population, and nearby manmade hazards.

2.1.1.2 Summary of Application

Section 2.1 of the BLN COL FSAR incorporates by reference Section 2.1 of the AP1000 DCD, Revision 17.

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

Tier 2 Departure

- STD DEP 1.1-1

The applicant proposed the following Tier 2 standard (STD) departure (DEP) from the AP1000 DCD. BLN COL FSAR Section 2.1.1, "Site Location and Description," identifies instances where the FSAR sections are renumbered to include content consistent with Regulatory Guide (RG) 1.206, "Combined License Applications for Nuclear Power Plants ([light-water reactor] LWR Edition)," as well as NUREG-0800. Here, Section 2.1.1 of the DCD is renumbered as Section 2.1.4.

AP1000 COL Information Item

- BLN COL 2.1-1

The applicant provided additional information in BLN 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.

This site-specific information included in the BLN COL FSAR describes the following:

- Specification of state, county, and political subdivisions, in which the site is located, and location of site with respect to prominent features (natural and man-made, i.e., rivers, lakes, industrial, military and transportation facilities)

- Universal transverse Mercator (UTM) co-ordinates (zone no., northing, easting), meters, and latitude and longitude

- Site Area Map consisting of the following:

  - Plant property lines, stating the area of plant property (in acres)

  - Location of site boundary

  - Location and orientation of principal plant structures within site

  - Area (e.g., reactor building, auxiliary building, turbine building)

  - Location of any industrial, military, or transportation facilities and commercial, institutional, recreational, or residential structures within the site area

  - Exclusion area distance (feet [ft.]/meters [m]) in all 16 cardinal compass directions

  - Scale that permits measurement of distances

  - True north

  - Prominent natural and man-made features in the site area

2.1.1.3 Regulatory Basis

The regulatory basis of the information incorporated by reference is addressed within the FSER related to the DCD.

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

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

- 10 CFR Part 50 and 10 CFR Part 52, 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 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 100.2(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.

- In addition, in accordance with Section VIII, "Processes for Changes and Departures," of Appendix D to 10 CFR Part 52—Design Certification Rule for the AP1000 Design, the applicant identified a Tier 2 departure, which does not require prior Commission approval. This departure is subject to the requirements in Section VIII, which are similar to the requirements in 10 CFR 50.59.

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 NUREG-0800, 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 BLN COL FSAR and checked the referenced DCD to ensure that the combination of the DCD and the information in the COL represent the complete scope of information relating to this review topic.[1] The NRC staff's review confirmed that the information contained in the application and incorporated by reference addresses the required information relating to the site location and description. Section 2.1 of the AP1000 DCD is being reviewed by the staff under Docket Number 52-006. The NRC staff's technical evaluation of the information incorporated by reference related to site location and description will be documented in the staff SER on the DC application for the AP1000 design.

The staff reviewed the information contained in the BLN COL FSAR:

AP1000 COL Information Item

- BLN COL 2.1-1

The NRC staff reviewed BLN COL 2.1-1 related to the site location and description, including political subdivisions, natural and man-made features, population, highways, railways, waterways, and other significant features of the area included under Section 2.1 of the BLN COL FSAR. Additional aspects of this information item are addressed in Sections 2.2.1

and 2.4.1 of this SER. The specific text of this COL information item in Section 2.1.1 of the AP1000 DCD, Revision 17, 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.

2.1.1.4.1 Site Location

The applicant provided the following information regarding the site location:

- The site layout and boundary for the proposed BLN 3 and 4

- The location of site with respect to political subdivisions and prominent natural man-made features of area within 5 and 50 miles from the center of the site

The proposed BLN site is approximately 7 miles northeast of downtown Scottsboro, in Jackson Country, Alabama. The BLN site is located approximately 38 miles east of downtown Huntsville, Alabama; 44 miles southwest of downtown Chattanooga, Tennessee; and 48 miles north of downtown Gadsden, Alabama. The Tennessee River borders the site from approximately Tennessee River mile (TRM) 390 to 393, with the site located on the western bank. BLN COL FSAR Figure 2.1-201 depicts the BLN site plan with principal structures on site. The Town Creek embayment and Tennessee River surround the site to the north, east and south.

The BLN site lies completely within the 7.5-minute Hollywood Quadrangle. The quadrangles that bracket the site are Wannville, Stevenson, Henagar, Sylvania, Dutton, Langston, Scottsboro, and Mud Creek.

The NRC staff has independently estimated and verified the following latitude and longitude and UTM coordinates of the proposed BLN 3 and 4 as provided in the BLN COL FSAR.

UTM coordinates	latitude/longitude (deg/min/sec)
Unit 3: Zone 16, NAD 83; 3,841,787 N; 598,376 E	34 42 48.3 N; 85 55 32.4 W
Unit 4: Zone 16, NAD 83; 3,841,636 N; 598,568 E	34 42 43.3 N; 85 55 25.0 W

The NRC staff reviewed the information addressed in the BLN COL FSAR, conducted a confirmatory review of pertinent information generally available in the literature, and collected information during a site visit. On the basis of its review and the information provided by the applicant, the staff concludes that the site location meets the acceptance criteria of Section 2.1.1 of NUREG-0800.

2.1.1.4.2 Site Description

The applicant provided the following information regarding the site area description:

- The topography and characteristics of the land surrounding the site for the proposed units

- The shortest exclusion area boundary (EAB) distance and direction from the proposed units

- The distance of proposed BLN 3 and 4 from regional U.S. and state highways, railroads, and waterways that traverse or lie adjacent to the site

Figure 2.1-202 in the BLN COL FSAR depicts the BLN vicinity with population centers, principal highways and waterways within a radius of six miles from the center of the site, and Figure 2.1-203 is a BLN regional map extending to 50 miles from the site covering the tri-state region of Alabama, Tennessee and Georgia. Figure 2.1-204 in the BLN COL FSAR depicts the topography of the site area.

The outer boundary of the nearest population center to the BLN site is Huntsville, Alabama, 29 miles to the west of the site. The city of Scottsboro, Alabama is the largest city within 10 miles of the BLN site. The closest communities to the BLN site are the towns of Hollywood, Alabama, 3 miles to the west, and Pisgah, Alabama, 5 miles to the east.

Interstate 59 connects Birmingham, Alabama, with Chattanooga, Tennessee, and its closest point to the BLN site is approximately 18 miles east to southeast. U.S. Highway 72 is located approximately 1.5 miles northwest of the site at its closest point. In addition to U.S. Highway 72, segments of Alabama State Highways 40 and 278 are located within 5 miles of the site. Jackson County Road 33 is adjacent to the western border of the BLN site.

Figure 2.1-201 in the BLN COL FSAR depicts the reactor buildings, turbine building, the cooling towers and the auxiliary buildings. There is no industrial, transportation, commercial, institutional, recreational or residential facilities within the site area. The property boundary is the same as the property line, or the site boundary, both of which define the site area and the area of control. The total area contained by the site boundary is approximately 1600 acres of land. Figure 2.1-205 in the BLN COL FSAR illustrates the distance from the effluent release boundary, the boundary on which limits for the release of radioactive effluents are based to the EAB in each cardinal direction (22.5° segment). The shortest distance to the EAB is 2805 ft. in the northwest direction.

There are no residents living in the exclusion area. No unrestricted areas within the site boundary area are accessible to members of the public. The Town Creek portion of the EAB is controlled by TVA. The NRC staff reviewed the information addressed in the BLN COL FSAR, conducted a confirmatory review of pertinent information generally available in the literature, and collected information during a site visit. On the basis of its review and the information provided by the applicant, the staff concludes that the site description meets the acceptance criteria of Section 2.1.1 of NUREG-0800 because of the following:

- The information in the FSAR describes highways, railroads, and waterways that traverse the exclusion area in sufficient detail to allow the staff to determine that the applicant has met the requirements in 10 CFR 100.3.

- The information in the FSAR describes the site location, including the exclusion area and the location of the plant within the area, in sufficient detail to enable the staff to evaluate the applicant's analysis of a postulated fission product release.

However, the applicant identified the following Tier 2 departure. This departure also appears in BLN COL FSAR Sections 2.2.1 and 2.4.1.

Tier 2 Departure

- STD DEP 1.1-1, in BLN COL FSAR Section 2.1.1, identifies instances where the BLN COL FSAR sections are renumbered to include content consistent with RG 1.206, as well as NUREG-0800. Here, Section 2.1.1 of the DCD is renumbered as Section 2.1.4.

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 NRC staff agrees. This departure and a related exemption are also evaluated in Section 1.5.4 of this report.

As set forth above, the applicant has presented and substantiated information to establish the site location and description. The staff has reviewed the information provided 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 Part 52.79(a)(1) and 10 CFR Part 100 with respect to determining the acceptability of the site. This addresses COL Information Item 2.1-1.

In addition, the applicant identified a departure, STD DEP 1.1-1. The staff finds that this departure is adequately characterized as not needing prior NRC approval. In conclusion, the applicant has provided sufficient information for satisfying 10 CFR Part 50, 10 CFR Part 52, and 10 CFR Part 100.

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 BLN COL FSAR related to this subsection.

Section 2.1 of Revision 17 of the AP1000 DCD is identical to Section 2.1 of Revision 15 of the AP1000 DCD, which is incorporated by reference into 10 CFR Part 52, Appendix D. This subsection is not affected by the changes that Westinghouse proposed in Revision 17 to the AP1000 DCD. Pursuant to 10 CFR 52.63(a)(5) and 10 CFR Part 52, Appendix D, Section VI.B.1, all nuclear safety issues relating to the site location and description that were incorporated by reference have been resolved.

In addition, the staff concludes that the relevant information presented within the BLN COL FSAR is acceptable and meets the requirements of 10 CFR Part 50, 10 CFR Part 52, and 10 CFR Part 100. The staff based its conclusion on the following:

- BLN COL 2.1-1 is acceptable to the staff because the applicant provided sufficient details about the site location and site description to allow the staff to conclude that the applicant has met the relevant requirements of 10 CFR Part 52.79(a)(1) and 10 CFR Part 100 with respect to determining the acceptability of the site. This addresses COL Information Item 2.1-1.

- STD DEP 1.1-1 is acceptable because the staff finds that this departure is adequately characterized as not needing prior NRC approval.

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 that 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) 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) 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 of 10 CFR Part 52.

2.1.2.2 Summary of Application

Section 2.1.2 of the BLN COL FSAR incorporates by reference Section 2.1.1 of the AP1000 DCD, Revision 17.

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

AP1000 COL Information Item

- BLN COL 2.1-1

The applicant provided additional information in BLN COL 2.1-1 to address COL Information Item 2.1-1 (COL Action Item 2.1.2-1). BLN COL 2.1-1 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.

This site-specific information included in the BLN COL FSAR describes the following:

- Establishment of Authority, which determines the legal authority of land, and also mineral rights and easements
- Legal authority for all activities, including exclusion and removal of personnel and property from area
- Minimum distance and direction of EABs for present and proposed ownership
- Description of activities unrelated to plant operation that are permitted in EAB, their location, nature of activities, number of persons involved and plans for evacuation in the event of an emergency
- Description of traffic control arrangements on highways, railroads and waterways traversing through EAB in the event of emergency
- Procedures for abandonment, relocation and understanding with other authorities for control

2.1.2.3 Regulatory Basis

The regulatory basis of the information incorporated by reference is addressed within the FSER related to the DCD.

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

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

- 10 CFR Part 50 and 10 CFR Part 52, as they relate to the inclusion in the SAR of a detailed description and safety assessment of the site on which the facility is to be located, with appropriate attention to features affecting facility design (10 CFR 50.34(a)(1), 10 CFR 52.17(a)(1), and 10 CFR 52.79(a)(1)).
- 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: The information submitted by the applicant is adequate and meets the requirements of 10 CFR 50.33, 10 CFR 50.34(a)(1), 10 CFR 52.79, and

10 CFR Part 100 if it provides sufficient detail to enable the staff to evaluate the applicant's legal authority within the designated exclusion area.

- 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 BLN COL FSAR and checked the referenced DCD to ensure that the combination of the DCD and the information in the COL represent the complete scope of information relating to this review topic.[1] The NRC staff's review confirmed that the information contained in the application and incorporated by reference addresses the required information relating to exclusion area authority and control. Section 2.1.1 of the AP100 DCD is being reviewed by the staff under Docket Number 52-006. The NRC staff's technical evaluation of the information incorporated by reference related to exclusion area authority and control will be documented in the staff SER on the DC application for the AP1000 design.

The staff reviewed the information contained in the BLN COL FSAR:

AP1000 COL Information Item

- BLN COL 2.1-1

The NRC staff reviewed BLN 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 under Section 2.1 of the BLN COL. The specific text of this COL information item in Section 2.1.1 of the AP1000 DCD, Revision 17, 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 provided the information concerning the following:

- Complete legal authority to regulate access and activity within the EAB
- Identification of any facilities within the EAB that have activities unrelated to plant operation being controlled and considered for emergency planning
- Arrangements for traffic control
- Abandonment or relocation of roads

The property is clearly posted and the postings include actions to be taken in the event of emergency conditions at the plant. The BLN EAB is greater than 0.5 mile at its narrowest width and, thus, bounds the DCD site parameter exclusion area distance identified in DCD Table 2-1.

2.1.2.4.1 Authority

The land and water inside the exclusion area is owned or controlled by TVA and is in the custody of TVA. Additionally, TVA controls activities within the EAB including exclusion and removal of personnel and property from the area. TVA owns mineral rights on the BLN site. There is a 30 ft. easement on either side of the road centerline along County Road 33 on the southern boundary. There are no other easements affecting the BLN site.

The NRC staff verified the applicant's description of the exclusion area as well as the authority under which all activities within the exclusion area can be controlled. The NRC staff also verified for consistency that the EAB is the same as being considered for the radiological consequences in Chapters 15 and 13.3 of the FSAR by the applicant. The staff concludes that the applicant has acquired authority to control all activities within the designated exclusion area and meets the acceptance criteria of Section 2.1.2 of NUREG-0800.

2.1.2.4.2 Control of Activities Unrelated to Plant Operation

There are no residences, commercial activities not associated with the BLN site, or recreational activities within the exclusion area. No public highways or railroads traverse the exclusion area.

<u>Arrangements for Traffic Control</u>

Since no publicly used transportation modes cross the EAB, except on Town Creek, no traffic arrangements with Jackson County are required. Town Creek is owned and controlled by TVA, and, therefore, no arrangements with Jackson County are needed.

<u>Abandonment or Relocation of Roads</u>

No public roads cross the exclusion area; therefore, neither relocation nor abandonment of roads is needed.

As set forth above, the applicant has provided and substantiated information concerning its plan to obtain legal authority and control of all activities within the designated exclusion area. The staff has reviewed the information provided 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 Part 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's 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. This addresses COL Information Item 2.1-1. In conclusion, the applicant has provided sufficient information for satisfying the applicable requirements of 10 CFR Part 50, 10 CFR Part 52, and 10 CFR Part 100.

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 exclusion area authority and control, and there is no outstanding information expected to be addressed in the BLN COL FSAR related to this subsection.

Section 2.1.1 of Revision 17 of the AP1000 DCD is identical to Section 2.1.1 of Revision 15 of the AP1000 DCD, which is incorporated by reference into 10 CFR Part 52, Appendix D. This subsection is not affected by the changes that Westinghouse proposed in Revision 17 to the AP1000 DCD. Pursuant to 10 CFR 52.63(a)(5) and 10 CFR Part 52, Appendix D, Section VI.B.1, all nuclear safety issues relating to exclusion area authority and control that were incorporated by reference have been resolved.

In addition, the staff concludes that the relevant information presented within the BLN COL FSAR is acceptable and meets the applicable requirements of 10 CFR Part 50, 10 CFR Part 52, and 10 CFR Part 100. The staff based its conclusion on the following:

- BLN COL 2.1-1, involving the evaluation of exclusion area authority and control, is acceptable to the staff because the applicant has provided and substantiated information concerning its plant to obtain legal authority and control of all activities within 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 within the “Contents of Application” sections of the applicable subparts to 10 CFR Part 52.

2.1.3.2 Summary of Application

Section 2.1.3 of the BLN COL FSAR incorporates by reference Section 2.1.1 of the AP1000 DCD, Revision 17.

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

AP1000 COL Information Item

- BLN COL 2.1-1

The applicant provided additional information in BLN COL 2.1-1 to address COL Information Item 2.1-1 [COL Action Item 2.1.3-1]. BLN COL 2.1-1 addresses the provision of site-specific information related to population distribution for the site environs.

This site-specific information included in the BLN COL FSAR describes the following:

- Nearest population center boundary (having 25,000 or more residents) at least one and one-third times the distance from the reactor units to the outer boundary of LPZ

- Population Density within 20 miles less than 500 people/square mile consistent with the guidelines given in Regulatory Position C.4 of RG 4.7

- Population data in the site vicinity including transient populations

- Population projections at the year of plant approval and 5 years thereafter and up to life of the plant (40 years)

- Population data information that includes the following:

  - Maps showing concentric circles with distances 1.24, 2.5, 3.7, 5, 6.2 and 10 miles from the center of reactor units having background identifying cities, towns and counties within 10 miles. The circles are divided into 16 cardinal directions (e.g., true north through north-northwest)

  - Tables providing current resident population with each area of the map formed by concentric circles and radial distances within 10 miles

  - Projected population within 10 miles in similar tabular form for the first year of plant operation

- Decennial projected population within 10 miles through 2057 (40 years beyond the 2017 construction completion for the reactors)

- Description of basis and methodology for population projections, population data sources, including projections

- Tables and maps of suitable scale depicting the population distribution including projections at 10, 25, 37, and 50 mile intervals between 10 and 50 mile radii from the center of units, for first year of operation through plant life on the same decennial basis

- Descriptions of seasonal variations in population due to such as recreational and industrial activities and inclusion of this population in current and projected population determinations

- The Exclusion Area population that includes a discussion that the exclusion area contains no residences or commercial activities not associated with BLN

- The LPZ population distribution

2.1.3.3 Regulatory Basis

The regulatory basis of the information incorporated by reference is addressed within the FSER related to the DCD.

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

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

- 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 it relates 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 are acceptable under the following conditions: (1) the SAR contains population data from the latest census and projected population at the year of plant approval and 5 years thereafter, in the geographical format given in Section 2.1.3 of RG 1.70, “Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants (LWR Edition),” and in accordance with RG 1.206; (2) the SAR describes the methodology and sources used to obtain the population data, including the projections; and (3) the SAR includes information on transient populations in the site vicinity.

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

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

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

- Population Density: If the population density exceeds the guidelines 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 BLN COL FSAR and checked the referenced DCD to ensure that the combination of the DCD and the information in the COL represent the complete scope of information relating to this review topic.[1] The NRC staff's review confirmed that the information contained in the application and incorporated by reference addresses the required information relating to population distribution. Section 2.1.3 of the AP1000 DCD is being reviewed by the staff under Docket Number 52-006. The NRC staff's technical evaluation of the information incorporated by reference related to population distribution will be documented in the staff SER on the DC application for the AP1000 design.

The staff reviewed the information contained in the BLN COL FSAR:

AP1000 COL Information Item

- BLN COL 2.1-1

The NRC staff reviewed BLN COL 2.1-1 related to the population distribution for the site environs included under Section 2.1 of the BLN COL FSAR. The specific text of this COL information item in Section 2.1.1 of the AP1000 DCD, Revision 17, 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 applicant provided the estimated population surrounding the BLN site, to a 50-mile radius based on 2000 decennial census data from the United States Census Bureau (USCB). The population distribution is estimated in nine concentric rings at 0-1.24 miles, 1.24-2.5 miles, 2.5-3.7 miles, 3.7-5 miles, 5-6.2 miles, 6.2-10 miles, 10-25 miles, 25-37 miles, and 37-50 miles from the center of the site for each of the 16 cardinal directions. The staff notes that the information TVA provides in the FSAR figures regarding population data is in both metric units and English units. In Table 1.9-202 of the application TVA takes exception to conformance with the NUREG-0800 Section 2.1.3 acceptance criteria by providing the information in kilometers. TVA states that it provided the information in kilometers to be consistent with the information provided in the environmental report. The staff finds TVA's reporting of population information in kilometers to be acceptable.

Using linear regression, with respect to county population estimates, equations were developed for establishing population projections. These equations were used in conjunction with the U.S. Census 2000 population data to generate growth for each year. The growth was then weighed by area and summed into sectors to produce population by sector for up to a 50-mile region. The BLN 50-mile region includes ten counties in Alabama, seven counties in Georgia, and eight counties in Tennessee.

2.1.3.4.1 Population within 10 Miles

BLN COL FSAR Figure 2.1-208 illustrates the site area within 10 miles from the center of the site. The projected population distribution within 10 miles of the BLN site for the years 2007, 2017, 2027, 2037, 2047, and 2057 is presented in BLN COL FSAR Table 2.1-203.

The NRC staff notes that there are no residents in the exclusion area. The population projections have been verified for consistency with the population projections presented in Section 13.3 of this SER as part of emergency planning and preparedness. On the basis of its review and the information provided by the applicant, the staff concludes that the population data within 10 miles of the site meet the acceptance criteria of Section 2.1.3 of NUREG-0800.

2.1.3.4.2 Population between 10 and 50 Miles

The BLN COL FSAR shows the region within 50 miles from the center of the site. The map contains the sector grid, state boundaries, urban areas, and counties. The distances defining the sectors are 10 miles, 25 miles, 37 miles, and 50 miles. The population is projected to 40 years beyond the 2017 construction completion date for the reactors. BLN COL FSAR Table 2.1-204 shows the projected population for each sector for the years 2007, 2017, 2027, 2037, 2047, and 2057.

The NRC staff independently obtained from the USCB web site the population data for the ten Alabama counties (Blount, Cherokee, Cullman, DeKalb, Etowah, Jackson, Limestone, Madison, Marshall, and Morgan); the seven Georgia counties (Catoosa, Chattooga, Dade, Floyd, Gordon, Walker, and Whitfield); and the eight Tennessee counties (Coffee, Franklin, Grundy, Hamilton, Lincoln, Marion, Moore, and Sequatchie) that are within the 50-mile radius of the BLN site, for the years 2000 and 2006 (USCB, 2008). Based on these population data for the years 2000 and 2006, an annual average percent growth rate was determined for each county. By accounting for the percentage of each county falling within the 50-mile radius, and using annual average county growth rates determined above, the NRC staff estimated the 50-mile population for the years 2007, 2017, 2027, 2037, 2047, and 2057. The NRC used the applicant's estimated transient population projections in determining the cumulative total 50-mile population projections for the years considered above. The population projections estimated by the staff were compared with those provided by the applicant, and were found to be within 4 percent of each other. The NRC staff considers the applicant's methodology for estimating population projections appropriate, reasonable and acceptable. The NRC finds that the applicant's projections covering 40 years of plant operation with 2017 as the starting year of operation are reasonable. On the basis of its review and the information provided by the applicant, the staff concludes that the population data between 10 and 50 miles of the site meet the acceptance criteria of Section 2.1.3 of NUREG-0800.

2.1.3.4.3 Transient Population within 10 Miles

Though relatively rural in nature, the region surrounding the BLN site has numerous tourist attractions that contribute moderate levels of transient population. Within a 6-mile radius of the site, the largest draw is the Unclaimed Baggage Center in Scottsboro, Alabama. More than one million visitors each year pass through this facility, which is also one of the largest retail stores in the vicinity. There are numerous facilities within a 10-mile radius that host outdoor activities. These include Lake Guntersville Reservoir, Goose Pond Colony, and Buck's Pocket State Park. These facilities combined have approximately 353,000 visitors each year, concentrated during the summer months of June, July, and August. Transient population data has been gathered by the applicant through personal communications with businesses, companies, and local chambers of commerce within the BLN region. Transient population is projected to 40 years beyond the 2017 construction completion date for the reactors. BLN COL FSAR Table 2.1-208 illustrates the projected transient population for each sector for the years 2007 through 2057. On the basis of its review and the information provided by the applicant, the staff concludes that the transient population data within 10 mile of the site meet the acceptance criteria of Section 2.1.3 of NUREG-0800.

2.1.3.4.4 Transient Population between 10 and 50 Miles

The bulk of transient population within the range of 10 -50 miles comes from parks and lodging within the area. The six parks and three associated lodges host more than 1.5 million visitors per year. Huntsville International Airport, which is located 49 miles west-southwest of the BLN site, handles approximately 1.3 million passengers per year and Chattanooga Metropolitan Airport-Lovell Field, located at 47 miles northeast of the BLN site, handles approximately 480,000 passengers per year. The city of Chattanooga, Tennessee, which lies on the northeast periphery of the 50-mile radius, is home to many attractions and hosts 3.4 million visitors per year. BLN COL FSAR Table 2.1-208 provides the projected transient population for each sector within a 50-mile radius for the years 2007 through 2057. These data include transient population due to recreational activities comprising of hunting, fishing, golfing, wildlife watching, and others; seasonal population; transient workforce; and transient population in special facilities such as schools, hospitals, and nursing homes.

The NRC staff considers the applicant's assumptions and estimation of transient population projections to be reasonable and acceptable. On the basis of its review and the information provided by the applicant, the staff concludes that the transient population data between 10 and 50 miles of the site meets the acceptance criteria of Section 2.1.3 of NUREG-0800.

2.1.3.4.5 Low Population Zone

The LPZ at the BLN site is defined as a 2-mile radius from the center of site. Using this radius, portions of Hollywood, Alabama, Town Creek, and the adjacent Tennessee River bank are incorporated into the LPZ. Based on the USCB 2000 population data, the population distribution within the LPZ, estimated by the applicant, is presented in BLN COL FSAR Table 2.1-209, and the total LPZ population is 344 people. There are no major contributors to the transient population in the LPZ. This LPZ area is serviced by U.S. 72, and the other transportation feature is the Tennessee River. There are no schools, hospitals, prisons, beaches, or parks in the LPZ. The BLN workforce is estimated to be 850 people, which results in total density within the LPZ to be 95 people per square mile. At the projected end of reactor operation (2057), the projected LPZ population is estimated to be 504, giving a total LPZ population of 1354 people with a projected density of approximately 108 people per square mile. The applicant evaluated representative design-basis accidents (DBAs) in Chapter 15 of this SER to demonstrate that the radiological consequences of DBAs at the proposed site are within the dose limits set forth in 10 CFR 50.34(a)(1) as required by 10 CFR 100.21(c).

2.1.3.4.6 Population Center

The nearest population center is the city of Huntsville, Alabama, having a 2005 estimated population of 166,313 and situated 29 miles to the west of the BLN site. Using county projections to the end of the operation (2057), Fort Payne, situated 18 miles southeast of the BLN site, may become the closest population center. However, these distances are greater than one and one-third times the distance from the reactor center point to the outer boundary of the LPZ as required by 10 CFR 100.21(b). The NRC staff did not identify any other population center closer than the identified population center distance. Therefore, the NRC staff concludes that the proposed site meets the required population center distance as defined in 10 CFR Part 100, Subpart B.

2.1.3.4.7 Population Density

The projected resident population of the BLN region is added to the projected transient population in determining the total population. The applicant plotted these values as a function of distance from the center point on BLN COL FSAR Figures 2.1-210 and 2.1-211 for the first year of operation (2017) and about 5 years thereafter (2022), respectively. Illustrated in the same figures is the cumulative population that would result from a uniform population density of 500 people per square mile. The plots show that the total population density for both 2017 and 2022 does not exceed 500 people per square mile within a 50-mile radius.

The NRC staff evaluated the site population density against the criterion in Regulatory Position C.4 of RG 4.7, Revision 2, regarding whether it is necessary to consider alternative sites with lower population densities. The evaluation included the review and verification of whether the population densities at the time of initial site approval (assumed 2012) and 5 years thereafter, would not exceed the criteria of 500 persons per square mile averaged over a radial distance of 20 miles (cumulative population at a distance divided by the area at that distance). The NRC staff has independently determined the population density for the year 2017 based on the NRC staff's confirmatory population projection estimate discussed earlier, and has found that the population density for the BLN site is well below the criterion. Therefore, the NRC staff concludes that the BLN site conforms to Regulatory Position C.4 of RG 4.7, Revision 2.

Based on the applicant's projected population data and population densities, assuming plant approval and start in the year 2017 with 40 years of plant operating life, the NRC finds that the population density is well below the population density criterion of 500 people per square mile averaged out to 20 miles from the BLN site.

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 the information provided and, for the reasons given above, concludes that the population data provided is acceptable to meet 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's provision of an acceptable description and safety assessment of the site, which contains present and projected population densities that are within the guidelines of Regulatory Position C.4 of RG 4.7, and proper specification of 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. The applicant also has calculated the radiological consequences of DBAs at the outer boundary of the LPZ (Chapter 15 in NUREG-0800) and provided reasonable assurance that appropriate protective measures can be taken within the LPZ to protect the population in the event of a radiological emergency.

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. There is no outstanding information expected to be addressed in the BLN COL FSAR related to this subsection.

Section 2.1.1 of Revision 17 of the AP1000 DCD is identical to Section 2.1.1 of Revision 15 of the AP1000 DCD, which is incorporated by reference into 10 CFR Part 52, Appendix D. This subsection is not affected by the changes that Westinghouse proposed in Revision 17 to the AP1000 DCD. Pursuant to 10 CFR 52.63(a)(5) and 10 CFR Part 52, Appendix D, Section VI.B.1, all nuclear safety issues relating to population distribution that were incorporated by reference have been resolved.

In addition, the staff concludes that the relevant information presented within the BLN COL FSAR is acceptable and meets the applicable requirements of 10 CFR Part 50, 10 CFR Part 52, and 10 CFR Part 100. The staff based its conclusion on the following:

- BLN COL 2.1-1, involving the evaluation of population distribution for the site environs, is acceptable to the staff because the applicant provided an acceptable description and safety assessment of the site, which addresses 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.

2.2 Nearby Industrial, Transportation, and Military Facilities

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 Sections 2.2.3, 3.5.1.5, and 3.5.1.6 of NUREG-0800 can be performed. The review covers the following specific areas: (1) the locations of, and separation distances to, transportation facilities and routes, including airports and airways, roadways, railways, pipelines, and navigable bodies of water; (2) the presence of military and industrial facilities, such as fixed manufacturing, processing, and storage facilities; and (3) any additional information requirements prescribed within the "Contents of Application" sections of the applicable subparts to 10 CFR Part 52.

2.2.1.2 <u>Summary of Application</u>

Section 2.2 of the BLN COL FSAR incorporates by reference Section 2.2 of the AP1000 DCD, Revision 17.

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

<u>Tier 2 Departure</u>

- STD DEP 1.1-1

The applicant proposed the following Tier 2 departure from the AP1000 DCD. BLN COL FSAR Section 2.2.1, "Locations and Routes," identifies instances where the FSAR sections are renumbered to include content consistent with RG 1.206, as well as NUREG-0800. Here, Section 2.2.1 of the DCD is renumbered as Section 2.2.4.

<u>AP1000 COL Information Item</u>

- BLN COL 2.2-1

The applicant provided additional information in BLN COL 2.2-1 to address COL Information Item 2.2-1 [COL Action Item 2.2-1]. BLN COL 2.2-1 addresses the provision of information about industrial, military, and transportation facilities and routes to establish the presence and magnitude of potential external hazards.

The applicant identified and addressed the potential hazard facilities and routes within the vicinity (five miles) of BNL 3 and 4, and airports within 10 miles of BLN along with other significant facilities beyond 5 miles, in accordance with RG 1.206 and relevant sections of 10 CFR 50.34(a)(1) and 10 CFR 100.20(b).

This site-specific information was provided in the BLN COL FSAR:

- Maps showing the location and distances from the nuclear units, of all significant manufacturing plants; chemical plants; storage facilities; transportation routes (air, land, and water); transportation facilities; oil and gas pipelines, drilling operations, and extraction wells

- Maps showing the facilities handling toxic, flammable and explosive substances; nearby aircraft flight, holding, and landing patterns that may have potential for adverse effects

- Information on each facility including its primary function, major products, and the number of persons employed

- Description of the products and materials regularly handled, stored, used, or transported in the vicinity of the plant or onsite
- Identification and description of hazardous materials, including toxicity limits
- Statistical data on amounts involved, modes of transportation, frequency of shipment, and maximum quantity of hazard materials likely to be processed, stored, or transported
- Description of pipeline, including indication of pipe size, age, operating pressure, depth of burial, location and type of isolation valves and type of gas or liquid being transported
- Navigable waterway information including location of intake structures in relation to shipping channel, the depth of channel, the location of locks, the types of ships or barges using waterway and any nearby docks and anchorages
- Description of major highways and/or other roadways including the types of hazardous materials, frequency and quantities being transported by truck in the vicinity of the STP site
- Identification of nearby railroads and information on the frequency and quantities of hazardous materials transported in the vicinity of site
- Information on the length and orientation of runways, types of aircraft using the facility, number of operations per year by aircraft type, and the flying patterns associated with the airport
- Identification of all airports within 5 miles of the site
- Identification of airports with projected operations greater than 500d (where “d” is distance in miles from the site) movements per year within 10 miles of the plant
- Identification of airports with projected operations greater than 1000d (where “d” is distance in miles from the site) movements per year outside 10 miles of the plant
- Equivalent information for aviation routes, pilot training areas, and landing and approach paths to airports and military facilities

2.2.1.3 Regulatory Basis

The regulatory basis of the information incorporated by reference is addressed within the FSER related to the DCD.

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

The applicable regulatory requirements for identifying locations and routes are as follows:

- 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 compliance with 10 CFR Part 100.

- In addition, in accordance with Section VIII, "Processes for Changes and Departures," of Appendix D to 10 CFR Part 52—Design Certification Rule for the AP1000 Design, the applicant identified a Tier 2 departure, which does not require prior Commission approval. This departure is subject to the requirements in Section VIII, which are similar to the requirements in 10 CFR 50.59.

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

- Data in the SAR adequately describe the locations and distances from the plant of nearby industrial, military, and transportation facilities and 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 Subsection 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 BLN COL FSAR and checked the referenced DCD to ensure that the combination of the DCD and the information in the COL represent the complete scope of information relating to this review topic.[1] The NRC staff's review confirmed that the information contained in the application and incorporated by reference addresses the required information relating to identifying locations and routes of nearby industrial, transportation, and military facilities. Section 2.2 of the AP100 DCD is being reviewed by the staff under Docket Number 52-006. The NRC staff's technical evaluation of the information incorporated by reference related to identifying locations and routes of nearby industrial, transportation, and military facilities will be documented in the staff SER on the DC application for the AP1000 design.

The staff reviewed the information contained in the BLN COL FSAR:

AP1000 COL Information Item

- BLN COL 2.2-1

The NRC staff reviewed BLN COL 2.2-1 related to the provision of information about industrial, military, and transportation facilities and routes to establish the presence and magnitude of potential external hazards included under Section 2.2 of the BLN COL FSAR. Additional aspects of this information item are addressed in Section 2.2.3 of this SER. The specific text of this COL information item in Section 2.2.1 of the AP1000 DCD, Revision 17, 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 BLN site is located in Jackson County, Alabama. Jackson County is bordered on the west by Madison County, Alabama; on the north by Franklin and Marion counties, Tennessee; on the east by Dade County, Georgia; and DeKalb County, Alabama; and on the south by Marshall County, Alabama, as seen in BLN COL FSAR Figure 2.1-203.

The BLN site is accessible by road, river, and rail. Interstate 59 connects Birmingham, Alabama, with Chattanooga, Tennessee, and its closest point to the BLN site is approximately 18 miles east-southeast. U.S. Highway 72 runs parallel to the Tennessee River through the city of Scottsboro, Alabama, 7 miles southwest, and the town of Hollywood, Alabama, 3 miles west. The Tennessee River borders the site boundary from approximately TRM 390 to 393. Norfolk Southern Railway Company (NSRC) owns and operates a railroad line that runs through the city of Scottsboro, Alabama, and the town of Hollywood, Alabama. The railroad is 2.7 miles northwest of the site center point. A spur line owned and controlled by TVA connects the plant to the mainline.

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

<u>Locations and Routes</u>

The applicant identified and provided information regarding potential external hazard facilities and operations within a 5-mile radius of the BLN site, which include two state highways, one federal highway, one railroad, and one navigable river, four industrial facilities, which include manufacturing sites and a city landfill, and one airport.

The location of these transportation routes and facilities are shown on BLN COL FSAR Figure 2.2-201, and include the following:

- Industrial Facilities within Five Miles

  City of Scottsboro Landfill
  Great Western products
  Maples Industries
  Scottsboro Coca-Cola Enterprises, Inc.

- Transportation Routes within Five Miles

  U.S. 72
  Alabama 40
  Alabama 279
  NSRC Mainline
  Tennessee River
  Scottsboro Municipal Airport – Word Field

In addition, a fuel distribution center, The Fuel Center (Discus Oil Company) is located in Hollywood, Alabama, 3 miles west of the BLN site and has 14 aboveground storage tanks (ASTs) located on-site. These 14 tanks have a storage capacity of 184,500 gallons currently containing unleaded gasoline, supreme gasoline, high-sulfur diesel, low-sulfur diesel, motor oil, and hydraulic oil. Contents of the 14 storage tanks are provided in BLN COL FSAR Table 2.2-201.

There are 11 other locations within a 5-mile radius of the BLN site that have registered underground storage tanks (USTs) and/or ASTs located at local convenience stores, businesses, or municipal facilities. The contents and capacity of the registered storage tanks within a 5-mile radius of the BLN site are listed in BLN COL FSAR Table 2.2-201 and their locations are shown in BLN COL FSAR Figure 2.2-201.

AP1000 standard plants contain liquid hydrogen and compressed hydrogen in the amounts of 1500 gallons and 150 pounds per square inch gauge (psig) and 500 standard cubic feet (scft) at 6000 psig, respectively. The plants do not contain liquid oxygen and propane. Both hydrogen storage tanks are located in the hydrogen storage area adjacent to the cooling towers, in the northeast corner of the site. The BLN site also has quantities of liquid nitrogen and liquid carbon dioxide located in the turbine building.

None of the facilities pertaining to mining and quarrying operations, oil and gas pipelines, and military bases and missile sites are within a 5-mile radius of the BLN site.

On the basis of its review and the information provided by the applicant, the staff concludes that the location of facilities and transporation routes information meets the acceptance criteria of Section 2.2.1-2.2.2 of NUREG-0800.

<u>Descriptions</u>

The industries within the vicinity of the BLN area are mostly located in Scottsboro, Alabama, and Stevenson, Alabama. The locations of the industries within 5 miles of the BLN site center point are shown in BLN COL FSAR Figure 2.2-201. The primary function, major products and number of persons employed at these industries are listed in BLN COL FSAR Table 2.2-202.

Description of Facilities, Products and Materials

Scottsboro Landfill is a 120 acre landfill located 3 miles north of the BLN site, and is operated by the city of Scottsboro, Alabama. The facility is not permitted to accept hazardous waste, and there are currently no plans to expand this facility.

Maples Industries is a large manufacturing plant producing carpet and rug products. This facility is located in Scottsboro, Alabama, 4.9 miles southwest of the BLN site. Hazardous materials stored on site, reported to the Jackson County Emergency Management Agency are listed in BLN COL FSAR Table 2.2-203.

The Scottsboro Coca-Cola Enterprises, Inc., facility is a major distribution center for Coca-Cola products, located 3.8 miles west-southwest of the BLN site. No hazardous materials are being stored at this location.

Great Western Products manufactures snack food processing equipment, supplies, and accessories, and is located 2 miles west of the BLN site. No hazardous materials are being stored at this location.

Widows Creek Fossil Plant is a coal-fired electrical generation plant operated by TVA, and is located 15 river miles upriver of the site center point on the Tennessee River, between the towns of Stevenson and Bridgeport, Alabama. The facility consists of eight units with a winter net dependable generating capacity of 1629 megawatt electric (MWe). The plant consumes approximately 10,000 tons of coal per day and produces about 10 billion kilowatt-hour (kWh) of electricity per year. The hazardous materials and their quantities reported to the Environmental Protection Agency (EPA) are listed in BLN COL FSAR Table 2.2-204.

No mining and quarrying activities are located within 5 miles of the BLN site. Six permitted mines and one permitted non-fuel mine are located in Jackson County, but there are no drilling operations in the county. Since there are no mines or quarrying activities located near the BLN site, there are no explosives stored in the area that would be associated with the mining and quarrying activities.

No military facilities including bombing ranges and jet fuel storage lie within 5 miles of the BLN site. There are no known transportation routes for grade munitions or jet fuel located near the site. However, two military facilities are situated within 50 miles of the site: Arnold Air Force Base (AFB) located 47 miles north of the site, and Redstone Arsenal located approximately 48 miles west of the site. Arnold AFB operates aerodynamic and propulsion wind tunnels, rocket and turbine engine test cells, space environmental chambers, arc heaters, ballistic ranges and other specialized units. The Arnold Engineering Development Center is an U.S. Air Force material command facility. Redstone Arsenal includes the U.S. Army Aviation and Missile Command, the Space and Missile Defense Command, and major components of the Defense Intelligence Agency and the Missile Defense Agency.

On the basis of its review and the information provided by the applicant, the staff concludes that the description of facilities, products and materials meets the acceptance criteria of Section 2.2.1-2.2.2 of NUREG-0800.

Waterways

The nearest navigable waterway to the BLN site is the Guntersville Reservoir/Tennessee River located 3500 ft. south-southeast of the BLN site center point (adjacent to the project boundary). Different types of barges navigate the Tennessee River. Among these are dry covered barges, single-hull tank barges, double-hull tank barges, dry open barges, and deck barges. Tugboats and push boats operate on the Tennessee River, as well as personal watercraft. The mean depth of the Guntersville Reservoir is 15 ft., and the average depth of the Tennessee River is a minimum of 11 ft. The Guntersville Reservoir averages 25.7 ft. deep along the BLN site boundary in the shipping channel. BLN COL FSAR Figure 2.2-201 shows the location of the intake structure in the Guntersville Reservoir/Tennessee River for BLN 3 and 4. This intake structure is located near TRM 392 at the southern end of BLN Island on the western shore of the Tennessee River. The shipping channel generally follows the center of the river and the eastern fork around BLN Island. Water from the Guntersville Reservoir/Tennessee River is withdrawn at this location for use as cooling tower makeup, service water cooling system makeup, and other miscellaneous water uses. The BLN project boundary is situated between TRM 390 and TRM 393. BLN COL FSAR Table 2.2-209 lists the types and amounts of cargo shipped by barge on the Tennessee River for 2004. The types and amounts of commodities shipped past TRM 392 in 2004 are listed in BLN COL FSAR Table 2.2-210.

The nearest major port to the BLN site is located 35 miles south in the town of Guntersville, Alabama, in Guntersville Harbor, between TRM 358 and TRM 359. Major commodities processed at this port are grain, petroleum and wood products. The types and amounts of commodities shipped between TRM 358 and TRM 363 on the Tennessee River in 2004 are listed in BLN COL FSAR Table 2.2-211, and six of these items are considered hazardous cargo.

On the basis of its review and the information provided by the applicant, the staff concludes that the waterway information meets the acceptance criteria of Section 2.2.1-2.2.2 of NUREG-0800.

Highways

The nearest highway with heavy commercial traffic is U.S. 72 passing approximately 1.5 miles to the northwest at its closest point. In addition to U.S. 72, segments of Alabama Highways 40 and 279 are located within a 5-mile radius of the BLN site center point.

Estimated annual average daily traffic counts in 2005 indicate the following:

- 16,720 vehicles travel on U.S. 72 at mile 145.4 (west of the site)
- 5,050 vehicles travel on Alabama 279 at mile 9 (west of the site)
- 6,120 vehicles travel on Alabama 40 at mile 1.7 (south of the site)
- 13,760 vehicles travel past mile 148.2 (north of the site)

On the basis of its review and the information provided by the applicant, the staff concludes that the highway information meets the acceptance criteria of Section 2.2.1-2.2.2 of NUREG-0800.

Railroads

NSRC owns and operates a railroad line that runs through the city of Scottsboro, Alabama, and the town of Hollywood, Alabama. This railroad is the main line in northern Alabama running from Memphis, Tennessee, through Huntsville, Alabama, to Chattanooga, Tennessee. At its closest point, the line runs about three miles northwest of the BLN site center point. On average, 40 trains per day pulling an average of 75 cars use this rail line and travel at speeds up to 50 miles per hour (mph). This line is used for freight service only; no passenger trains use this line. The top 25 commodities shipped through Hollywood, Alabama between September 2005 and September 2006 are listed in BLN COL FSAR Table 2.2-208.

On the basis of its review and the information provided by the applicant, the staff concludes that the railroad information meets the acceptance criteria of Section 2.2.1-2.2.2 of NUREG-0800.

Pipelines

No cross-county pipelines are located in the vicinity of the BLN site. However, there are local residential, commercial, and industrial distribution pipelines near the site.

On the basis of its review and the information provided by the applicant, the staff concludes that the pipeline information meets the acceptance criteria of Section 2.2.1-2.2.2 of NUREG-0800.

Airports

One airport, Scottsboro Municipal Airport- Word Field, is situated within 5 miles of the BLN site center point. The airport is located 4.9 miles west to southwest of the BLN site, has a 5250 ft. asphalt runway oriented in a southwest to northeast direction, and is used primarily by single-engine private aircraft. The average number of operations is 21 per day. There are no designated pilot training areas near the site. Approach and departure paths at Scottsboro Airport are not directly aligned with the BLN site. On a long approach, a plane is expected to get no closer to the plant site than 2 miles, and there are no holding patterns associated with the Scottsboro Municipal Airport.

The closest commercial airport is Chattanooga Metropolitan Airport- Lovell Field, located 47 miles northeast in Chattanooga, Tennessee. Lovell Field averages 252 aircraft operations a day.

The next closest commercial airport is Huntsville International Airport, which is located 49 miles west-southwest of the BLN site center point. The average number of operations is about 283 per day. Historical flight data recorded prior to 2006 provided in BLN COL FSAR Table 2.2-212 shows an average annual increase of 4.1 percent in the number of airline passengers at Huntsville International Airport. Based on this, data projections for air traffic at Huntsville International Airport to fiscal year 2025 are presented in BLN COL FSAR Table 2.2-213.

Approach and departure paths at Huntsville International Airport and Chattanooga Metropolitan Airport are not aligned with the BLN site. All runways at both airports are aligned in a north-south direction, and there are no holding patterns associated with these airports near the BLN site.

On the basis of its review and the information provided by the applicant, the staff concludes that the airport information meets the acceptance criteria of Section 2.2.1-2.2.2 of NUREG-0800.

Airways

Three low-altitude (below 18,000 ft.) federal air routes are located within 35 miles of the BLN site, as shown in BLN COL FSAR Figure 2.2-202. Also known as Victor air routes, these low-altitude routes are flown primarily by general aviation aircraft. They are typically 8 nautical miles wide, and they occupy the airspace between 18,000 ft. mean sea level (msl) and floor of controlled space 700 ft. – 1000 ft. There are no military training routes within 10 miles of the BLN site center point. Due to the distance between these airways and the location of the BLN site, no further hazards analysis due to air traffic along these airways is considered.

Five high-altitude (18,000 ft. – 45,000 ft.) federal air routes are located within 35 miles of the BLN site as shown in BLN COL FSAR Figure 2.2-202. These high-altitude airways are used primarily by commercial air carriers, the military, and high-performance general aviation aircraft. These routes are 8 nautical miles wide and extend from 18,000 ft. to 45,000 ft., the top of controlled airspace. Flights above 18,000 ft. are required to be instrument flight rules flights; therefore, altitudes and routes are assigned by air traffic controllers. Because the centerline of Airway J73 is in close proximity (approximately 3 miles west) of the BLN site, an evaluation of hazards from air traffic along this high-altitude airway is presented in BLN COL FSAR Section 3.5.1.6.

On the basis of its review and the information provided by the applicant, the staff concludes that the airways information meets the acceptance criteria of Section 2.2.1-2.2.2 of NUREG-0800.

Projections of Industrial Growth

Four industrial parks are located in Jackson County, Alabama. As of October 2006, no additional parks were proposed for the county. The Jackson County, Alabama, area is presently experiencing growth and more economic activity. The cities of Jackson County, Alabama; Bridgeport, Stevenson, and Scottsboro, respectively, have approximately 1214, 794, and 526 acres of land available for industrial and agricultural use.

On the basis of its review and the information provided by the applicant, the staff concludes that the projections of industrial growth meet the acceptance criteria of Section 2.2.1-2.2.2 of NUREG-0800.

However, the applicant identified the following Tier 2 departure.

Tier 2 Departure

- STD DEP 1.1-1 in BLN COL FSAR Section 2.2.1, “Locations and Routes,” identifies instances where the FSAR sections are renumbered to include content consistent with RG 1.206, as well as NUREG-0800. Here, Section 2.2.1 of the DCD is renumbered as Section 2.2.4.

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 NRC staff agrees. This departure and a related exemption are also evaluated in Section 1.5.4 of this report.

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 the information provided 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) for compliance evaluation. The nature and extent of activities involving potentially hazardous materials that are conducted at nearby industrial, military, and transportation facilities have been evaluated to identify any such activities that have the potential for adversely affecting plant safety-related structures. Based on an evaluation of information in the FSAR as well as information that the staff independently obtained, the staff concludes 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. This addresses COL Information Item 2.2-1.

In addition, the applicant identified departure, STD DEP 1.1-1. The staff finds that this departure is adequately characterized as not needing prior NRC approval. In conclusion, the applicant has provided sufficient information for satisfying 10 CFR Part 50, 10 CFR Part 52, and 10 CFR Part 100.

2.2.1.5 <u>Post Combined License Activities</u>

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

2.2.1.6 <u>Conclusion</u>

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 identifying locations and routes of nearby industrial, transportation, and military facilities, and there is no outstanding information expected to be addressed in the BLN COL FSAR related to this subsection.

Section 2.2 of Revision 17 of the AP1000 DCD is identical to Section 2.2 of Revision 15 of the AP1000 DCD, which is incorporated by reference into 10 CFR Part 52, Appendix D. This subsection is not affected by the changes that Westinghouse proposed in Revision 17 to the AP1000 DCD. Pursuant to 10 CFR 52.63(a)(5) and 10 CFR Part 52, Appendix D, Section VI.B.1, all nuclear safety issues relating to identifying locations and routes of nearby industrial, transportation, and military facilities that were incorporated by reference have been resolved.

In addition, the staff concludes that the relevant information presented within the BLN COL FSAR is acceptable and meets the applicable requirements of 10 CFR Part 50, 10 CFR Part 52, and 10 CFR Part 100. The staff based its conclusion on the following:

- STD DEP 1.1-1 is acceptable because the staff finds that this departure is adequately characterized as not needing prior NRC approval.

- BLN COL 2.2-1 is acceptable because the staff concludes 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 2.2.3 of the BLN COL FSAR incorporates by reference Section 2.2 of the AP1000 DCD, Revision 17.

In addition, in BLN COL FSAR Section 2.2.3, the applicant provided the following:

AP1000 COL Information Item

- BLN COL 2.2-1

The applicant provided additional information in BLN COL 2.2-1 to address COL Information Item 2.2-1 [COL Action Item 2.2-1]. BLN COL 2.2-1 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.

In addition, BLN COL FSAR Section 2.2.3 addresses Interface Item 2.2, related to external missiles from man-made hazards and accidents and Interface Item 2.3, related to the maximum loads from man-made hazards and accidents.

The applicant identified, evaluated and provided information for potential accidents considered as DBAs that may affect the nuclear plant in terms of design parameters (e.g., overpressure, missile energies) and physical phenomena (e.g., concentration of flammable or toxic vapor clouds outside building structures). DBAs, internal and external to the nuclear plant, are defined as those accidents that have a probability of occurrence on the order of magnitude of 10-7 per year or greater and potential consequences serious enough to affect the safety of the plant to the extent that the guidelines of 10 CFR Part 100 could be exceeded.

This site-specific supplement included in the BLN COL FSAR describes the following:

- Evaluation of hazards associated with nearby industrial activities, such as manufacturing, processing or storage facilities.
- Evaluation of hazards associated with nearby military activities, such as military bases, training areas, or aircraft flights.
- Evaluation of hazards associated with nearby transportation routes (aircraft routes, highways, railways, navigable waters, and pipelines).

The principal types of hazards considered for evaluation, with respect to each of the above areas, include the following:

1. Toxic vapors or gases and their potential for incapacitating nuclear power 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 with 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.
4. Thermal effects attributable to fires.

Based on the information provided in BLN COL FSAR Sections 2.2.3.1-2.2.3.2 pertaining to identification of potential hazards, a determination was made for the potential accidents that were considered as DBAs and identified potential effects of those accidents on the plant in terms of design parameters (e.g., overpressure, missile energies) or physical phenomena (e.g., concentration of flammable or toxic clouds outside building structures). DBAs, internal and external to the nuclear plant, are defined as those accidents that have a probability of occurrence on the order of magnitude of 10-7 per year or greater and potential consequences serious enough to affect the safety of plant to the extent that the guidelines of 10 CFR Part 100 could be exceeded.

Accident categories in selecting design-basis events included explosions, flammable vapor clouds, toxic chemicals, fires, collisions with intake structures, and liquid spills, and covered the following:

1. Accidents involving detonations of high explosives, munitions, chemicals, or liquid and gaseous fuels for facilities and activities in the vicinity of the plant or on site, where materials are processed, stored, used, or transported in quantity.
2. Potential accidental explosions that could produce a blast overpressure of 1 pounds per square inch (psi) or greater, using quantity-distance relationships.
3. Accidental releases of flammable liquids or vapors that result in the formation of unconfined vapor clouds. Assuming no explosion occurs, calculation of extent of cloud

and concentration of gas that could reach the plant under worst-case meteorological conditions was determined.

4. Release of toxic chemicals from onsite storage facilities and nearby mobile and stationary sources were evaluated under worst meteorological conditions. These calculated chemical concentrations were considered in the evaluation of control room habitability in Section 6.4 of the BLN COL FSAR.

5. Accidents leading to high heat fluxes or smoke and nonflammable gas or chemical release as the consequence of fires in the vicinity of the plant. Evaluation of fires in adjacent industrial and chemical plants, storage facilities, oil and gas pipelines, brush and forest fires, and fires from transportation accidents that lead to high heat fluxes or formation of clouds were evaluated under worst meteorological conditions. These calculated concentrations were considered in the evaluation of control room habitability in Section 6.4 of the BLN COL FSAR.

6. For the navigable waterways, the evaluation considered the probability and potential effects of impact on the plant cooling water intake structure and enclosed pumps by the barges or ships that pass, including any explosions incident to the collision.

7. Release of oil or liquids due to spills that could affect the plant's safe operation.

2.2.3.3 Regulatory Basis

The regulatory basis of the information incorporated by reference is addressed within the FSER related to the DCD.

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

The applicable regulatory requirements for identifying evaluation of potential accidents are as follows:

- 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 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 10 CFR 50.34(a)(1) limits as it relates to the requirements of 10 CFR Part 100 is estimated to exceed the NRC staff objective of an order of magnitude of 10-7 per year.

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

2.2.3.4 Technical Evaluation

The NRC staff reviewed Section 2.2.3 of the BLN COL FSAR and checked the referenced DCD to ensure that the combination of the DCD and the information in the COL represent the complete scope of information relating to this review topic.[1] The NRC staff's review confirmed that the information contained in the application and incorporated by reference addresses the required information relating to the evaluation of potential accidents. Section 2.2 of the AP1000 DCD is being reviewed by the staff under Docket Number 52-006. The NRC staff's technical evaluation of the information incorporated by reference related to evaluation of potential accidents will be documented in the staff SER on the DC application for the AP1000 design.

The staff reviewed the information contained in the BLN COL FSAR:

AP1000 COL Information Item

- BLN COL 2.2-1

The NRC staff reviewed BLN COL 2.2-1 related to the provision of 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 under Section 2.2 of the BLN COL FSAR. The specific text of this COL information item in Section 2.2.1 of the AP1000 DCD, Revision 17, 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 applicant analyzed postulated accidents for various types considering the identified sources and locations in BLN COL FSAR Section 2.2.1, which include the following:

- Explosions
- Flammable Vapor Clouds (Delayed Ignition)
- Toxic chemicals
- Fires
- Collision with Intake Structure
- Liquid Spills

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, navigable waterways or facilities using 1 psi overpressure as a criterion for adversely affecting 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 0.52 miles for truck transport, and 1.76 miles for rail transport on the basis of using conservative assumptions and RG 1.91 methodology. These calculated distances are shorter than the respective closest highway distance of 1.13 miles and railroad distance of 2.13 miles from the plant. 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.

The nearest waterway transportation route to the BLN site is the Guntersville Reservoir and is located 0.65 miles from the site. The explosion analysis did not present any details as to what chemicals were screened, or the bases for the selection of two chemicals, styrene and ethanol, as well as amounts and other data for these chemicals. While the methodology was described in some detail, specifics that allow confirmatory calculations were lacking. Therefore, the NRC staff requested additional information in RAI 2.2.3-1, pertaining to the explosion hazard associated with the chemical traffic on the above waterway. The applicant provided its response detailing the bases and the calculation of explosion probability. Based upon the review of additional information provided by the applicant, and also based on similar information available, the NRC staff considers the applicant's response adequate, approach reasonable, and determined probability acceptable.

As part of the response to RAI 2.2.3-1, the applicant provided a proposed revision to FSAR subsection 2.2.3.1.1 that includes a discussion detailing the bases for the waterway analysis and how the calculation of explosion probability was performed. However, the revised information is misplaced in FSAR Revision 1. As this information belongs to the discussion of hazards associated with waterways, it should start at the end of the discussion of railway hazards, where the waterways discussion begins. Placement of the additional waterway hazards discussion identified in the response to RAI 2.2.3-1 in the correct location in the FSAR is **Open Item 2.2.3-1**.

As part of nearby industrial facilities, the applicant evaluated the potential explosion hazard from the Fuel Center located 2.49 miles west of the site, Maples Industries located 3.79 miles southwest of the BLN boundary, and Great Western Products located 1.49 miles west of the BNL boundary. The applicant considered the combined total storage capacity of 184,500 gallons of gasoline for the evaluation purpose. In response to RAI 2.2.3-2, the applicant provided methodology for calculation of confined and unconfined vapor amounts used to estimate safe standoff distance of 0.51 miles and 0.91 miles, respectively. In response to RAI 2.2.3-3 and RAI 2.2.3-4, the applicant provided information for Maples Industries and Great Western Products for chemicals screening and bases for selection of chemicals for evaluation. Based upon review of the additional information provided by the applicant and the NRC staff's independent confirmatory analysis, the staff considers that the applicant's calculations and conclusions are applicable and acceptable.

The applicant referenced the AP1000 DCD, which addressed the onsite chemicals potential for explosion and control room habitability impacts, and concluded that the effects due to potential explosion do not adversely impact the safe operation of the plant. The NRC staff considers the applicant's assumption reasonable and acceptable.

Pending the satisfactory resolution of Open Item 2.2.3-1, based on its review and the information provided by the applicant the staff concludes that the explosion analysis provided in the FSAR meets the acceptance criteria of Section 2.2.3 of NUREG-0800.

Flammable Vapor Clouds (Delayed Ignition)

The applicant addressed the potential detonation and deflagration in a plume from the release of chemicals from a transportation accident as well as from nearby facilities. This evaluation assumed dispersion downwind toward the BLN site, with a delayed ignition. The vapor dispersion assumed a wind speed of 1.8 mph, stability class D, and a 90 °F ambient air temperature. The ALOHA computer model was used to evaluate the dispersion and detonation of the vapor clouds.

For the evaluation of the potential effects of accidents on U.S. 72 and the NSRC railroad, the applicant assumed rupture sizes of 48.4 square (sq.) ft. and 10.7 sq. ft. The applicant analyzed gasoline and propane assuming a conservatively large tanker truck volume. For a rail car tanker, a conservatively large volume is also assumed for chemical transport. Actual volumes for road, rail and barges were not given. Chemicals transported by rail were not identified or quantified. In postulating events involving gasoline releases, the applicant did not provide adequate information regarding assumption used in modeling releases. This information would provide a basis for estimating the release rates that determine spill sizes and cloud formation. The NRC staff requested additional information in RAI 2.2.3-5, pertaining to vapor cloud explosion hazards evaluation associated with these sources. The NRC staff reviewed the applicant's response and concludes that the information provided by the applicant is reasonable and acceptable. The NRC staff also performed an independent flammable vapor cloud analysis and confirmed that all chemical concentrations except styrene due to barge transport remain below the lower explosive limit (LEL) at the BLN site. The NRC staff's analysis resulted in a different LEL concentration for styrene than the applicant addressed in BLN COL FSAR Section 2.2.3.1.2, and requested in RAI 2.2.3-9, that the applicant clarify the assumptions used in the styrene analysis. In response to RAI 2.2.3-9, the applicant provided information stating that even though the concentration levels at the site exceed LEL concentration for styrene, due to consideration of the site as an uncongested area, an overpressure of 1 psi is not obtained at the site. The NRC staff's analysis confirmed the same conclusion; and, therefore, the staff considers that the applicant's approach is reasonable and acceptable.

On the basis of its review and the information provided by the applicant, the staff concludes that the flammable vapor clouds (delayed ignition) information provided in the FSAR meets the acceptance criteria of Section 2.2.3 of NUREG-0800.

Toxic Chemicals

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

Of four major industrial facilities within a five mile radius of the site, the applicant stated that only Maple Industries has the potential for toxic chemical releases and was considered for toxic chemicals evaluation. However, the quantities of these chemicals available for release are not provided in BLN COL FSAR Table 2.2-203. In response to RAI 2.2.1-2.2.2-1 and

RAI 2.2.1-2.2.2-2, the applicant provided the chemical quantities information for BLN COL FSAR Table 2.2-203, and also identified that NSRC transported chlorine in a maximum capacity 90 tons chlorine tanker, which was the basis for control room habitability analysis using 180,000 lbs of chlorine.

In response to the NRC staff's RAI 2.2.3-10, pertaining to the onsite storage of chemicals, the applicant identified site specific chemicals in addition to the standard chemicals addressed in the AP1000 DCD and listed all of the chemicals in BLN COL FSAR Table 6.4-202. The applicant also stated that Standard DCD and Standard COL chemicals identified in BLN COL FSAR Table 6.4-202 were assessed by Westinghouse as part of the main control room habitability hazard analysis. However, the documentation of this analysis is being requested for review and is **Open Item 2.2.3-2** until it is submitted and reviewed. In addition, the applicant's response did not provide enough information to justify screening out sodium hypochlorite. This information is required for conducting the staff's review and to allow the staff to perform confirmatory analysis. This is identified as **Open Item 2.2.3-3**.

In the toxic risk analysis from mobile sources, there was mention of preliminary statistical analysis and other analyses, without sufficient details and results for independent verification. Therefore, the NRC staff requested additional information in RAI 2.2.3-6 and RAI 2.2.3-7. In response to the staff's request, the applicant provided the information, which identified additional chemicals that are being transported by rail. On the basis of review of the applicant's information, and also based on independent analysis, the NRC staff identified, in addition to chlorine, other chemicals (gasoline, ammonia, propylene oxide, styrene, ethanol, sodium hydroxide) that have control room habitability hazard potential and requested in RAI 2.2.3-8, that the applicant evaluate those chemicals. The applicant provided the analyses for all the chemicals except for gasoline and styrene. The styrene was not analyzed because the barge shipments were fewer than 50 per year, which is acceptable based on the guidance given in RG 1.78, "Evaluating the Habitability of a Nuclear Power Plant Control Room During a Postulated Hazardous Chemical Release."

The gasoline, due to road transport, was not analyzed by the applicant based on using the calculated weighted average immediate danger to life and health (IDLH) value of 780 parts per million (ppm) for screening out the gasoline by applying RG 1.78 methodology. Instead of using the conservative value among other standard limiting concentration values such as threshold limiting value (TLV), time weighted average (TWA) value or temporary emergency exposure limits, acute exposure guideline level , Emergency Response Planning Guideline, protective action criteria (PAC), the applicant uniquely determined a weighted average IDLH value and screened out gasoline from the analysis. The applicability of the methodology to determine a weighted average IDLH value and use for screening the gasoline is identified as **Open Item 2.2.3-4**.

As part of the response to RAI 2.2.3-8 dated February 13, 2009, the applicant provided proposed changes to the FSAR regarding toxic chemicals shipped by barge and by rail. The information supplements the information provided in the FSAR regarding the hazards analysis that was performed by the applicant. The proposed FSAR changes include changes to the following FSAR subsections: 2.2.2.2.9, 2.2.2.6, 2.2.3.1.3, 2.2.3.1.3.2.2.1, 2.2.3.1.3.2.2.2, 2.2.3.1.3.2.2.3, 2.2.3.1.3.3, and 6.4.4.2. The proposed changes also include changes to FSAR Table 2.2-208. The staff finds these proposed changes, with the exception of the proposed changes associated with the gasoline IDLH value mentioned above, to be acceptable. The inclusion of this information in the next FSAR revision is Confirmatory Item 2.2.3-1.

Based on the open items above the staff is unable to conclude that the toxic chemical information provided in the FSAR meets the acceptance criteria of Section 2.2.3 of NUREG-0800.

Fires

Fires originating from accidents at any of the facilities or transportation routes will not endanger the safe operation of the plant because of the distances between potential accident locations and the BLN site are at least 0.65 miles.

If a high concentration of smoke is detected in an outside air intake, an alarm is initiated in the main control room and main control room/technical support center heating, ventilation, and an air conditioning (HVAC) subsystem is manually realigned to the recirculation mode by closing the outside air and toilet exhaust duct isolation valves.

Onsite fuel storage facilities are designed in accordance with applicable fire codes and plant safety is not jeopardized by fires or smoke in these areas.

On the basis of its review and the information provided by the applicant, the staff concludes that the fire analysis provided in the FSAR meets the acceptance criteria of Section 2.2.3 of NUREG-0800.

Collision with Intake Structure

There is no safety-related equipment located at the intake structure. Therefore, collisions with the intake structure do not pose a nuclear safety hazard and the acceptance criteria in 2.2.3 of NUREG-0800 are met.

Liquid Spills

There is no safety-related equipment located at the intake structure. Therefore, spills drawn into the intake structure do not pose a nuclear safety hazard and the acceptance criteria in 2.2.3 of NUREG-0800 are met.

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 or plants of the specified type that might be constructed on the proposed site, has appropriately determined those that should be considered as design-basis events, and has demonstrated that the plant is adequately protected and can be operated with an acceptable degree of safety with regard to the design-basis accidents. The staff has reviewed the information provided 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 2.79(a)(1)(vi) for compliance with respect to determining the acceptability of the site. This addresses COL Information Item 2.2-1. In conclusion, the applicant has provided sufficient information for satisfying the applicable requirements of 10 CFR Part 50, 10 CFR Part 52, and 10 CFR Part 100.

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 the evaluation of potential accidents, and there is no outstanding information expected to be addressed in the BLN COL FSAR related to this subsection.

Section 2.2 of Revision 17 of the AP1000 DCD is identical to Section 2.2 of Revision 15 of the AP1000 DCD, which is incorporated by reference into 10 CFR Part 52, Appendix D. This subsection is not affected by the changes that Westinghouse proposed in Revision 17 to the AP1000 DCD. Pursuant to 10 CFR 52.63(a)(5) and 10 CFR Part 52, Appendix D, Section VI.B.1, all nuclear safety issues relating to the evaluation of potential accidents that were incorporated by reference have been resolved.

However, as a result of Open Items 2.2.3-1, 2.2.3-2, 2.2.3-3 and 2.2.3-4, the staff is unable to finalize its conclusions on BLN COL 2.2-1.

2.3 Meteorology

To ensure that a nuclear power plant or plants can be designed, constructed, and operated on an applicant's proposed site in compliance with the Commission's regulations, NRC staff evaluates regional and local climatological information, including climate extremes and severe weather occurrences that may affect the design and siting of a nuclear plant. The staff also reviews information on the atmospheric dispersion characteristics of a nuclear power plant site to determine whether the radioactive effluents from postulated accidental releases, as well as routine operational releases, are within Commission guidelines. The staff has prepared Sections 2.3.1 through 2.3.5 of this SER in accordance with the review procedures described in NUREG-0800, using information presented in Section 2.3 and Appendix 2DD of Revision 1 to the FSAR (which references Revision 17 to the AP1000 DCD), responses to staff RAIs, and generally available reference materials (as cited in applicable sections of NUREG-0800).

2.3.1 Regional Climatology

2.3.1.1 Introduction

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

2.3.1.2 Summary of Application

Section 2.3.1 of the BLN COL FSAR incorporates by reference Section 2.3.1 of the AP1000 DCD, Revision 17.

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

AP1000 COL Information Item

- BLN COL 2.3-1

The applicant provided additional information in BLN COL 2.3-1 to address COL Information Item 2.3-1 [COL Action Item 2.3.1-1]. BLN COL 2.3-1 addresses regional climatology.

Supplemental Information

- BLN SUP 2.3-1

The applicant provided supplemental information in BLN COL FSAR Section 2.3, "Meteorology," describing the use of various sources of meteorological data: (1) onsite data collected from 2006 to 2007; (2) onsite data collected from 1979 to 1982; and (3) offsite data from several decades of collection available from the National Oceanographic and Atmospheric Administration (NOAA) National Climatic Data Center (NCDC).

In addition, BLN COL FSAR Section 2.3.1 addresses Interface Item 2.5, related to tornado and operating basis wind loadings, Interface Item 2.7, related to snow, ice and rain loads, and Interface Item 2.8, related to ambient air temperatures.

2.3.1.3 Regulatory Basis

The regulatory basis of the information incorporated by reference is addressed within the FSER related to the DCD.

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

The applicable regulatory requirements for identifying regional meteorology are as follows:

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

- 10 CFR Part 100, §100.20(c)(2), and §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 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". 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," the 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 where the Ultimate Heat Sink is the atmosphere).

- 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 Environmental Protection Agency (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 RGs.

2.3.1.4 <u>Technical Evaluation</u>

The NRC staff reviewed Section 2.3.1 of the BLN COL FSAR and checked the applicable site parameters in Table 2-1 of the referenced DCD to ensure that the combination of the DCD and the information in the COL represent the complete scope of information relating to this review topic.[1] The NRC staff's review confirmed that the information contained in the application and incorporated by reference (as related to site parameters) addresses the required information relating to regional climatology. Section 2.3.1 of the AP1000 DCD is being reviewed by the staff under Docket Number 52-006. The NRC staff's technical evaluation of the applicable site parameters incorporated by reference related to regional climatology will be documented in the staff SER on the DC application for the AP1000 design.

The staff reviewed the information contained in the BLN COL FSAR:

AP1000 COL Information Item

- BLN COL 2.3-1

The NRC staff reviewed BLN COL 2.3-1 related to the provision of regional climatology included under Section 2.3.1 of the BLN COL FSAR. The specific text of this COL information item in Section 2.3.6.1 of the AP1000 DCD, Revision 17, states:

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

Supplemental Information

- BLN SUP 2.3-1

The NRC staff reviewed supplemental information BLN SUP 2.3-1 in BLN COL FSAR Section 2.3, “Meteorology,” describing the use of various sources of meteorological data: (1) onsite data collected from 2006 to 2007; (2) onsite data collected from 1979 to 1982; and (3) offsite data from several decades of collection available from the NOAA’s NCDC.

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 General Climate

The applicant provided a regional climate description for the BLN site, based primarily on the climatological records of Scottsville and Huntsville, Alabama. The BLN site is located in Alabama state climatic division 2, a temperate latitude in Northeastern Alabama about 250 miles north of the Gulf of Mexico. The region is strongly influenced by the Bermuda-Azores semi-permanent sub-tropical high. Consequently, a marine tropical air mass predominates over the region for most of the year providing a relatively long warm season and a short cold season. The summer climate is dominated by the Bermuda High with southerly winds providing moisture from the Gulf of Mexico. This, coupled with thermal instability, produces frequent afternoon and evening showers and thunderstorms.

Alabama winters are short and characterized by occasional southward movements of continental polar air from Canada. This brings colder and drier air into Alabama and the northern parts of the state receive occasional short-lived snowfalls. Cold spells seldom last more than three or four days. Late winter and early spring thunderstorms associated with polar front activity are more severe than summer storms and can sometimes produce tornadoes.

The applicant provided discussions on snowfall and ice storms (e.g., glaze ice, sleet, freezing rain or drizzle) in northeast Alabama. Scottsboro had measureable snow in 33 of 79 years of record. In the Southeast and Gulf Coast sections of the country, sub-freezing temperatures seldom last more than a few hours after glaze storms.

The applicant stated that the local meteorology was consistent with the regional meteorology with two exceptions. First, was the presence of higher humidity immediately adjacent to the

Tennessee River, and second was the channeling of low level winds along the river valley. Higher humidity adjacent to a water body is an expected phenomenon. Further, the staff confirmed the low level wind channeling with a joint frequency wind distribution and wind rose analysis and concurs with the applicant's assessment.

The staff agrees with the applicant's use of Scottsboro and Huntsville data to describe the general climate of the region. Scottsboro is the closest weather station to the BLN site and is located in the river valley. Huntsville is the closest NWS first order station and is similar in elevation and topography outside the river valley in non-mountainous terrain. The description of the general climate of the region is consistent with the NCDC narrative, "A Local Climatological Data, Annual Summary with Comparative Data for Huntsville, Alabama," and the Scottsboro's climate summaries from "Southeast Regional Climate Center, Historical Climate Summaries for Alabama."

2.3.1.4.2 Regional Meteorological Conditions for Design and Operating Bases

The applicant presented regional meteorological conditions that are relevant to the design and operating bases for the BLN site. Tabular comparisons of the BLN site characteristics with the AP1000 DCD design parameters were provided in BLN COL FSAR Table 2.0-201 and SER Table 2.3.1-1.

2.3.1.4.2.1 Severe Weather Phenomena

The applicant stated that severe synoptic storms are relatively infrequent in the BLN site area. In addition, the applicant stated hurricanes that have penetrated this far inland have dissipated to tropical depressions, and winter storms from snow, freezing rain and ice are uncommon. The staff agrees with these statements. These topics are discussed further in later sections.

2.3.1.4.2.1.1 Hurricanes

The applicant stated that 123 hurricanes affected the Middle Gulf Coast (Alabama, Florida, Louisiana, Mississippi, and Texas) between 1899 and 2002. Monthly hurricane frequency, by Saffir-Simpson Category (i.e., 1 through 5), was presented in BLN COL FSAR Table 2.3-207. Over the same time period, no recorded hurricanes reached Jackson County due to weakening over land. The applicant noted that 16 tropical storms affected Jackson County from 1899 through 2002.

The staff verified the information provided by the applicant and additionally evaluated a 100 nautical mile radius around the BLN site for hurricane tracks. The NOAA Coastal Services Center (CSC) web-site was used to obtain information for this evaluation. The staff found that one Category 1 hurricane reached the 100-mile radius but weakened to tropical storm intensity before reaching Jackson County. As part of the evaluation, the staff used NOAA's CSC database to produce the SER Table 2.3.4.1-2, "Tropical Cyclone Frequencies within 100-Nautical Mile Radius of the BLN Site between 1851 and 2006."

Based on the above information, the staff finds the applicant's description of hurricanes for the BLN site to be acceptable.

2.3.1.4.2.1.2 Tornadoes

The following discussion on tornadoes is intended to provide a general climatic 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.

Section 2.3.1.4.4, Design Basis Tornado Parameters, provides discussion of the generation of site characteristics for use as design or operating bases.

The applicant stated that the probability of a tornado occurring at the BLN site was low. Two methods were used to substantiate this conclusion.

The first method calculated an estimated recurrence interval for a point (P) (Thom, 1963) in Jackson County, the location of the BLN site. The value was then compared to the recurrence frequency value for the 7 counties surrounding the BLN site (Jackson County included). The estimated recurrence interval for a point in Jackson County was 3516 years compared to 1552 years for the 7 counties surrounding the BLN site. The result indicates that the expected frequency of a tornado in the immediate vicinity of the BLN site is less than the expected frequency for the surrounding counties. The staff verified the applicant's references, methods and calculations for determining tornado occurrence probability, and finds this acceptable.

The second method used by the applicant for determining the tornado strike probability at the BLN site was taken from Revision 1 of NUREG/CR-4461. Revision 1 of NUREG/CR-4461 was based on the Fujita Scale wind speeds. A discrepancy was noted with the information presented in this section and in BLN COL FSAR Section 2.3.1.4, Design Basis Tornado. The Design Basis Tornado information had been obtained from Revision 2 of NUREG/CR-4461. The wind speed information in Revision 2 of NUREG/CR-4461 is based on the Enhanced Fujita Scale. RAI 2.3.1-1 was generated to address the inconsistency.

In its response to RAI 2.3.1-1, the applicant revised BLN COL FSAR Subsection 2.3.1.2.1.2 for the tornado expected maximum wind speed values to be consistent with those discussed in Revision 2 of NUREG/CR-4461. The methodology is based on a two degree longitude and latitude box centered on the BLN site. The number of tornadoes was 385 for that two degree box. The corresponding expected maximum tornado wind speed and upper limit (95 percentile) of the expected wind speed was provided with the associated probabilities. Specifically the applicant correctly extracted the tornado climatology information for the BLN site from the referenced NUREG.

The staff reviewed the revised tornado climatology data, and finds it to be acceptable.

2.3.1.4.2.1.3 Thunderstorms

The following discussion on thunderstorms is intended to provide a general climatic 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.

In BLN COL FSAR, Revision 0, the applicant estimated that, locations in northeast Alabama and extreme south central Tennessee experience, on average, approximately 17 thunderstorm events per year. These data were taken from NCDC's climatological database for the 7 counties in Alabama, Tennessee, and Georgia surrounding the BLN site. The majority of thunderstorms recorded (51 percent) occurred between late spring and midsummer

(June-August) indicating warm air-mass thunderstorms. During the period 1950 through 2005, there were 132 thunderstorm or high wind events in Jackson County. The applicant stated that, of these, 86 events had a wind speed of greater than or equal to 50 knots (≥ 57 mph).

The estimated 17 thunderstorm events per year appeared to be low, based on the staff's review of the NCDC Local Climatological Data from the first order NWS station at Huntsville, Alabama. The staff requested in RAI 2.3.1-2 that the applicant justify the estimated value chosen.

The applicant's response to RAI 2.3.1-2, stated that the original thunderstorm estimate was based on data obtained from the NCDC database for the time period 1950 through 2005. Examination of that database indicated that thunderstorm and high wind events may have been under reported prior to 1983. Consequently, the NCDC Local Climatological Data was edited, and the thunderstorm estimate was revised.

The revised RAI response stated that locations in northeast Alabama and extreme south central Tennessee experience approximately 53 thunderstorm events per year. The revised BLN COL FSAR Table 2.3-209 further provided a 49 year average of 57.51 thunderstorm events per year. Local Climatological Data for the Huntsville NWS station were referenced.

The staff verified the applicant's data using NOAA's National Climatic Data Center's Storm Events database, and finds the revised information provided to be acceptable.

2.3.1.4.2.1.4 Lightning

The following discussion of lightning is intended to provide a general climatic 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 provided three methods to estimate annual lightning strike density in the BLN site area. The first two methods used isokeraunic maps of thunderstorm days coupled with estimates of earth flash density (i.e., cloud to ground flashes) in a particular region. These methods produced annual strike densities in the BLN site area of 16-28 strikes per square mile per year. The applicant also presented a more recent study using data measured from the National Lightning Detection Network (NLDN), which indicated a strike density of 8-13 strikes per square mile per year for Northeast Alabama.

The staff verified the applicant's references, methods and calculations and finds the information provided to be acceptable.

2.3.1.4.2.1.5 Hail

The following discussion of hail is intended to provide a general climatic 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 utilized NOAA's NCDC website to gather the hail data for the BLN COL FSAR. Data for the seven counties surrounding the BLN site is shown in BLN COL FSAR Table 2.3-210. Data included the number of events by county, percentage per county and number of events with property damage. The applicant reported that 504 hailstorms occurred in the region annually, with Jackson County receiving approximately 13 percent. The maximum hail size (2.75 inches) reported in Jackson County from 1950 through 2005 was provided.

The staff verified the values presented using the NCDC database and finds the information provided to be acceptable.

2.3.1.4.2.1.6 Regional Air Quality

The applicant identified Jackson County as part of the Tennessee River Valley (Alabama)-Cumberland Mountains (Tennessee) Interstate Air Quality Control Region (AQCR), and provided the attainment designations. Attainment areas are areas where the ambient levels of criteria air pollutants are designated as being "better than," "unclassifiable/attainment," or "cannot be classified or better than," the EPA-promulgated national Ambient Air Quality Standards.

BLN COL FSAR, Revision 0, stated Jackson County was classified as a nonattainment for PM-2.5 (particulate matter with a diameter less than 2.5 microns) as a result of being included in the Alabama-Tennessee-Georgia area, which includes Chattanooga, Tennessee. The staff issued RAI 2.3.1-3, which requested that the applicant describe any impact that the nonattainment area designation had on the design and/or operation of the proposed nuclear power unit.

The response to RAI 2.3.1-3, the applicant provided the following additional information for BLN COL FSAR Subsection 2.3.1.2.1.6. The applicant stated that the nearest nonattainment area was identified to be an area approximately 14 miles north east of the BLN site. The design and/or operation of the BLN units would not be impacted by this nonattainment area due to the distance between the nonattainment area and the site. Likewise, the operation of the proposed nuclear power plants would have no impact on the nonattainment area due to the very low particulate matter release from BLN.

The NRC staff verified the AQCR and nonattainment information presented using the EPA website, and agrees with the applicant's conclusion that safe operation of the plant would not be impacted by the nonattainment due to its distance from the site. The staff finds the information provided by the applicant to be acceptable.

2.3.1.4.2.2 Severe Winter Storm Events

The following discussion on severe winter storm events is intended to provide a general climatic 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 provided data for the recorded ice storms and heavy snowstorms in the vicinity of the BLN site. The frequency of winter storm events (e.g., snow and ice storms) for Jackson County was listed as 1.4 events per year in the BLN COL FSAR. This frequency was confirmed by the staff using NOAA's NCDC database. The period of record was limited to 1993-2007 for accuracy and reliability of the database.

The applicant attempted to address severe winter storm events by estimating the 48-hour PMWP using BLN site data. RAI 2.3.1-4 was issued requesting that the applicant provide an explanation for the difference between SAR Section 2.3.1.2.2, "Severe Winter Storm Events," containing an estimate (7.53 inches liquid) of the 48 hour PMWP derived from 5 years of BLN site data and the 48 hour PMWP value of 24.7 inches (based on Hydrometeorological Report

[HMR]-53) listed in Section 2.3.1.2.2.2, “Estimated Weight of the 48 hour Maximum Winter Precipitation.”

The applicant responded to RAI 2.3.1-4 by stating that the recent drought was prominent in the BLN site data due to a reduction in rainfall during the 2006-2007 period, and that the results from this limited data set cannot be compared with the much longer period of data represented in HMR-53. The HMR-53 data presented in BLN COL FSAR Section 2.3.1.2.2.2 provided a significantly greater 24.7 inch value and was consequently used for establishing the 48-hour PMWP.

The staff finds the applicant’s response to RAI 2.3.1-4 acceptable because the data in this BLN COL FSAR section reflect local climatology information derived from onsite data and not from the probable maximum precipitation estimates found in HMR-53. (Included in BLN COL FSAR Subsection 2.3.1.2.2.2)

2.3.1.4.2.2.1 Estimated Weight of the 100-year Return Snowpack

The methodology for assessing the potential winter precipitation load on the roofs of safety-related structures considers two climate-related components, the weight of the 100-year return period ground-level snowpack, and the weight of the 48-hour PMWP. Consistent with Section 2.3.1 of NUREG-0800, the winter precipitation loads included in the combination of normal live loads considered in the design of a nuclear power plant that might be constructed on a proposed COL site should be based on the weight of the 100-year snowpack or snowfall, whichever is greater, recorded at ground level. Likewise, the winter precipitation loads included in the combination of extreme live loads considered in the design of a nuclear power plant that might be constructed on a proposed COL site should be based on the weight of the 100-year snowpack at ground level plus the weight of the 48-hour PMWP at ground level for the month corresponding to the selected snowpack. A COL applicant may choose to justify an alternative method for defining the extreme winter precipitation load by demonstrating that the 48-hour PMWP could neither fall nor remain on top of the snowpack and/or building roofs.

The applicant used 79 years (1927 to 2005) of snow measurement data from Scottsboro, Alabama to determine the weight of the 100-year snowpack for the BLN site. The maximum 100-year snowpack was reported as 10 inches (February 15, 1958) x 0.2 inches water equivalent/inch snowpack = 2.0 inches of water. The applicant used the conversion factor of 5.2 lbm/sq. ft.-inch x 2.0 = 10.4 pounds per square foot for the weight of the 100-year return snowpack.

The applicant also stated that in the BLN site area, snow melts and/or evaporates quickly, usually within 48 hours, and before additional snow is added; thus, the applicant stated that the water equivalent of the snowpack can be considered equal to the water equivalent of freshly fallen snow.

BLN COL FSAR Section 2.3.1.2.2 reported a 12-inch snowfall (March 13, 1993) but used a 10-inch snowpack value for the winter precipitation load analysis. The applicant was asked in RAI 2.3.1-5 to justify using the 10-inch snowpack value vs. the 12 inch snowfall value.

The applicant responded to RAI 2.3.1-5 with a new last paragraph in BLN COL FSAR Subsection 2.3.1.2.2.1. The applicant justified that the 10-inch snowpack value provided was a conservatively bounded value, due to the higher water density, 0.20 inches of water per inch of snowpack, compared to 0.15 inches of water for freshly fallen snow.

The staff verified the applicant's data and calculations and finds the information provided to be acceptable.

2.3.1.4.2.2.2 Estimated Weight of the 48-hour Maximum Winter Precipitation

Consistent with Section 2.3.1 of NUREG-0800, the applicant identified the 48-hour PMWP for the proposed BLN site as 27.4 inches. Based on an independent analysis, using HMR-53, the staff finds the applicant's estimate acceptable.

2.3.1.4.2.2.3 Weight of Snow and Ice on Safety-Related Structures

In this section the applicant provided an estimate of the weight of snow and ice on safety-related structures. The results of this section are applicable to the structural engineering review in Section 3.8 of this SER.

It should be noted that mid-way through the review of this section, the staff issued Interim Staff Guidance (ISG) DC/COL-ISG-07, "Interim Staff Guidance on Assessment of Normal and Extreme Winter Precipitation Loads on the Roofs of Seismic Category I Structures," (ML081990438), resulting in a supplemental RAI.

In its initial RAI 2.3.1-6, the staff requested that the applicant identify that portion of the 48-hour PMWP that could fall as frozen precipitation. The applicant's response was that the 48-hour PMWP estimated from data in HMR-53 was assumed to be liquid. The applicant considered the rain load separate from the snow and ice roof load. The rationale provided was that water and snow melt buildup on the roofs of the nuclear island are negligible because the roofs of the nuclear island buildings are sloped with no lips. The passive containment cooling system (PCS) tank is flat with no lip and has a central hole that allows water to drain and not accumulate on the roof area. The applicant concluded that as a result of the nuclear island roof design, there was no loading from the PMWP. This information is applicable to the structural engineering review in Section 3.8 of this SER.

RAI 2.3.1-11 was issued requesting a revision to BLN COL FSAR Table 2.0-201 to list the normal winter precipitation event, the extreme frozen winter precipitation event, and extreme liquid winter precipitation event as site characteristics in accordance with proposed ISG DC/COL-ISG-07.

The applicant responded to RAI 2.3.1-11 with a revision to BLN COL FSAR Subsection 2.3.1.2.2.3 to include a discussion of the normal winter precipitation event, the extreme frozen winter precipitation event, and the extreme liquid winter precipitation event. The applicant used the proposed ISG DC/COL-ISG-07 for the assessment provided.

The applicant stated that because the plant site is subjected to a subtropical climate with mild winters, prolonged snowfalls or large accumulations of snow or ice on the ground and structures are not anticipated. Based on the NCDC Snow Climatology database, the applicant stated that the highest observed maximum 2-day snowfall amount was 9.3 inches and the 100-year return 2-day snowfall was 12.9 inches for Scottsboro, Alabama, from 1893 through 2006. The assessment further stated that the 100-year return 2-day snowfall (12.9 inches) was the limiting ground snow event for the BLN site. Using a snow density of 0.15 (volume of snow melt water from a sample of snow), the equivalent ground load was 10.1 lb/ft^2.

The NRC staff independently confirmed both the 2-day snowfall amounts and the 100-year return 2-day estimate provided by the applicant using the Extreme Snowfall Amounts for Scottsboro, Alabama from NOAA's NCDC website. Because the applicant satisfactorily applied the proposed ISG, the staff finds the information provided to be acceptable.

2.3.1.4.2.3 Probable Maximum Annual Frequency and Duration of Dust Storms

The following discussion of the probable maximum annual frequency and duration of dust storms is intended to provide a general climatic 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 the occurrence of dust, blowing dust, or blowing sand is a rare phenomenon in the BLN site area. The staff confirmed this by using NOAA's NCDC database, and considers this information acceptable.

2.3.1.4.3 Meteorological Data Used for Evaluating Heat Removal Capacity

Meteorological data are normally used for evaluating heat removal capacity of safety-related heat removal systems. The applicant, however, has chosen a reactor design (Westinghouse AP1000) that does not use a cooling tower to release heat to the atmosphere following a loss-of-coolant accident (LOCA). Instead the Passive Containment Cooling System (PCS) provides the safety-related UHS for the AP1000. The NRC staff requested in RAI 2.3.1-7 that the applicant provide the meteorological data used to evaluate the PCS and identify all the cooling towers used to support plant operations and state whether they serve a safety-related function. Because the maximum and minimum safety temperature site characteristics should be based on the higher of either historic or 100-year return period values, in RAI 2.3.1-8, the staff requested the applicant to confirm how BLN COL FSAR Table 2.3-203 corresponds with BLN COL FSAR Table 2.0-201 using the higher of either historic or 100-year return period site characteristic values for maximum and minimum safety temperatures.

The applicant responded to RAI 2.3.1-7 and RAI 2.3.1-8 with a revision to BLN COL FSAR Section 2.3.1.3. BLN COL FSAR Subsections 2.3.1.3.1 and 2.3.1.3.2 were deleted, and a supplemental discussion was provided in the RAI response.

In RAI response 2.3.1-7 the applicant stated that: (a) the data used in design and evaluation of the PCS was provided in the DCD and BLN COL FSAR Table 2.0-201 (as revised); and (b) that the circulating water system and the service water system (SWS) cooling towers are used to remove plant heat during normal operations only and serve no safety-related function.

In the revised BLN COL FSAR Section 2.3.1.3 the applicant discussed the maximum dry-bulb temperature with coincident wet-bulb temperature, the maximum wet-bulb temperature (non-coincident), and the maximum and minimum dry-bulb temperatures. The applicant provided a comparison of the BLN site characteristics with the AP1000 DCD design parameters in BLN COL FSAR Table 2.0-201.

In accordance with the AP1000 design specifications, the applicant stated that the maximum dry-bulb temperature and the maximum wet-bulb temperature (non-coincident) were determined as the highest dry-bulb temperature that persisted for at least 2 hours using a 35-year (1973-2007) sequential hourly data set from Huntsville, Alabama. As the NRC staff was not sure a conservative methodology was used to bound the two temperatures follow-up RAI 2.3.1-12 was issued.

The applicant responded to RAI 2.3.1-12 on two separate occasions. In the first response, the applicant revised BLN COL FSAR Section 2.3.1.3.1, Tables 2.0-201 and 2.3-203, but did not include bounding air temperature data for the maximum safety and minimum safety dry bulb and wet bulb entries. In the second response, the applicant updated the maximum safety and minimum safety air temperature entries using 100-year return period values. The maximum normal and minimum normal (1 percent exceedance) values were updated using American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) methodology. BLN COL FSAR Tables 2.0-201 and 2.3-203 were further revised.

***Confirmatory Action*:** The RAI 2.3.1-12 response includes a commitment to revise the FSAR to provide information in Section 2.3.1.3.1, and to revise Tables 2.0-201 and 2.3-203. **This is Confirmatory Item 2.3.1-1**.

The staff performed an independent analysis using Huntsville meteorological data. The staff calculated similar values and the differences are noted in SER Table 2.3.1-1. The maximum and minimum safety values (dry bulb and wet bulb) were within 2°F of the applicant. The maximum and minimum normal air temperature values were within 4°F of the applicant. Despite any differences, both sets of values (applicant and staff) are bounded by the AP1000 DCD Site Parameter values with margin available. The staff finds the BLN site temperature characteristics provided by the applicant to be acceptable. Therefore, the staff also finds TVA responses to RAIs 2.3.1-7, 2.3.1-8, and 2.3.1-12 acceptable.

2.3.1.4.3.1 Meteorological Parameters

Revision 0 of the application included Subsection 2.3.1.3.1, which addressed the meteorological parameters relating to cooling tower performance. The NRC staff issued RAI 2.3.1-7 as discussed in Subsection 2.3.4.3 above. In its response to RAI 2.3.1-7, the applicant removed Subsection 2.3.1.3.1 from the BLN COL FSAR. The staff reviewed BLN COL FSAR Table 2.0-201 and identified a lack of justification for the BLN air temperature site characteristics. The staff issued RAI 2.3.1-10 requesting that the applicant provide the justification.

The applicant did not respond to RAI 2.3.1-10, but chose to provide the requested information in part of its response to RAI 2.3.1-12. The applicant revised in total Subsection 2.3.1.3.1 with a discussion of how the BLN air temperature site characteristics were generated. Further, the applicant stated that the maximum dry-bulb temperature, coincident wet-bulb temperature, maximum wet-bulb temperature (non-coincident), and minimum dry-bulb temperature were determined using 35 years (1973-2007) of sequential hourly meteorological data, from Huntsville, Alabama, to calculate 100-year return period values. The applicant also stated that methodology from the ASHRAE Fundamental Handbook Chapter 27 – Climatic Design Information was used, and provided the equations that were applied.

Based on the BLN COL FSAR revisions to Subsection 2.3.1.3.1 and the detailed calculation methodology provided, the staff finds the justification for the BLN air temperature site characteristics acceptable and consistent with the DCD, and NUREG-0800 guidance. (See discussion for RAI 2.3.1-12).

2.3.1.4.3.2 Worst 1-Day, 5-Day, and 30-Day High Temperature Periods

This subsection was included in Revision 0 of the BLN COL FSAR and dealt with non-passive containment designs. Accordingly, the applicant has deleted this section.

2.3.1.4.4 Design Basis Tornado Parameters

The applicant chose the tornado site characteristics based on the Revision 1 to RG 1.76. This RG 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 BLN site is located in tornado intensity region I. The applicant proposed the following tornado site characteristics:

Maximum Wind speed	230 mi/h
Rotational Speed	184 mi/h
Maximum Translational Speed	46 mi/h
Radius of Maximum Rotational Speed	150 ft.
Pressure Drop	1.2 lbf/in.2
Rate of Pressure Drop	0.5 lbf/in.2/s

Because the applicant has correctly identified those design-basis tornado site characteristics presented in Revision 1 to RG 1.76, the staff concludes that the applicant has chosen acceptable tornado site characteristics.

2.3.1.4.5 100-Year Return Period 3 Second Wind Gust

Consistent with NUREG-0800, Section 2.3.1, the applicant chose the 100-year return period 3 second wind gust site characteristic based on American Society of Civil Engineers (ASCE) 7-05, “Minimum Design Loads for Buildings and Other Structures,” for the proposed BLN site. The applicant states that the 50 year return period 3 second gust is 90 mi/hr. The applicant used an importance conversion factor of 1.07 to determine the 100-year return period 3 second gust of 96 mi/hr.

The BLN site has historically not been impacted by hurricane winds (see Section 2.3.1.4.2.1.1, Hurricanes), the staff, therefore, concludes that the applicant has chosen acceptable 100-year return period 3 second wind gust characteristics.

2.3.1.4.6 Effects of Global Climate Change on Regional Climatology

NUREG-0800, Section 2.3.1, states that historical data used to characterize a site should extend over a significant time interval to capture cyclical extremes. During the course of the technical review the staff made an effort to obtain the longest period of data available to determine the adequacy of the applicant’s proposed site characteristics. For example, snow load was based on a 100-year return period, tornadoes were based on a 10-7 per year return interval, and extreme winds were based on a 100-year return period, including 155 years of historical hurricane data (1851-2006).

The staff issued RAI 2.3.1-9 requesting that the applicant provide a discussion in BLN COL FSAR Section 2.3.1 on the possible changes in the weather in the site region and any potential impact on the proposed site characteristics.

The applicant responded to RAI 2.3.1-9 with a revision to BLN COL FSAR Subsection 2.3.1.3.1, adding two additional paragraphs.

Confirmatory Action: The RAI 2.3.1-09 response includes a commitment to provide two new paragraphs in subsection 2.3.1.3.1 in a future revision of the FSAR. This is **Confirmatory Item 2.3.1-2**.

The applicant stated that the site characteristic temperatures were bounded by the AP1000 DCD site parameters, and that the BLN site characteristic temperatures were developed considering both the 100-year return period temperatures and the 0 percent exceedance temperatures. The applicant further stated, that Huntsville, Alabama, NWS station data was used in the calculation, and the difference between the BLN site characteristics and the DCD site parameters provides additional margin.

The applicant stated that the general predictions on global or U.S. climatic changes expected during the period of reactor operation are uncertain and are only applicable on a macroclimatic scale. The applicant further stated, that since the maximum data span available (that is representative of the microclimate near the BLN site) was used in the severe weather analysis, accurate severe weather phenomena projections have been based on historic data; and projection of future climatological conditions at the BLN site are speculative at best, based on current understanding and modeling of global climate change.

Currently, the staff is unaware of any reliable climate models capable of modeling design-basis climate extremes at a particular location. At this point in time, the staff finds the information presented by the applicant to be acceptable. If it becomes evident that long-term climatic change is influencing the most severe natural phenomena reported at the site, the COL holder has a continuing obligation to ensure the plant remains within its 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 including BLN COL 2.3-1, BLN SUP 2.3-1, and checked the applicable site parameters in 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 BLN COL FSAR related to this subsection.

The Westinghouse application to amend Appendix D to 10 CFR Part 52 includes changes to Table 2-1 of the AP1000 DCD, as stated in Revision 17 of the AP1000 DCD. The staff is reviewing this information on Docket Number 52-006. The results of the NRC staff's technical evaluation of the information incorporated by reference in the BLN COL FSAR will be documented in a supplement to NUREG-1793. The supplement to NUREG-1793 is not yet complete, and this is being tracked as part of Open Item 1-1. The staff will update Section 2.3.1 of this SER to reflect the final disposition of the DC application.

In addition, the staff concludes that the relevant information presented with the COL FSAR is acceptable once Confirmatory Items 2.3.1-1, and 2.3.1-2, are resolved. The staff based its conclusion on the following:

- BLN COL 2.3-1 and BLN SUP 2.3-1, involving the evaluation of regional climatology, and supplemental meterology information, respectively, is acceptable to the staff because the applicant has established the meteorological characteristics at the site and in the surrounding area acceptable to meet the requirements of 100.20(c)(2) and 100.21(d) with respect to determining the acceptability of the site. The applicant has also considered the most severe natural phenomena historically reported for the site and surrounding area in establishing its 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, as documented in safety evaluation reports for previous licensing actions. 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)(iii).

2.3.2 Local Meteorology

2.3.2.1 Introduction

Section 2.3.2, “Local Meteorology,” of the BLN 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 2.3.2 of the BLN COL FSAR incorporates by reference Section 2.3.2 of the AP1000 DCD, Revision 17.

In addition, in BLN COL FSAR Section 2.3.2, the applicant provided the following:

AP1000 COL Information Item

- BLN COL 2.3-2

The applicant provided additional information in BLN COL 2.3-2 to address COL Information Item 2.3-2 [COL Action Item 2.3.2-1]. BLN COL 2.3-2 addresses the provision of local meteorology.

Supplemental Information

- BLN SUP 2.3-1

The applicant provided supplemental information in BLN COL FSAR Section 2.3, “Meteorology,” which describes the use of various sources of meteorological data: (1) onsite data collected from April 2006 to March 2007; (2) onsite data collected from 1979 to 1982; and (3) offsite data from several decades of collection available from the NOAA NCDC.

2.3.2.3 Regulatory Basis

The regulatory basis of the information incorporated by reference is addressed within the FSER related to the DCD.

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

The applicable regulatory requirements for identifying local meteorology are as follows:

- 10 CFR Part 52.79(a)(1)(iii), as it relates to consideration of the most severe local weather 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 100.20(c)(2) and 10 CFR 100.21(d), with respect to the consideration that has been given to the local meteorological and air quality characteristics of the site and other physical characteristics of the site that can influence the local meteorology.

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," and NWS station summaries or other standard installation summaries from appropriate nearby locations (e.g., within 80 kilometers [km] (50 miles)) 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 miles) 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.

2.3.2.4 Technical Evaluation

The NRC staff reviewed Section 2.3.2 of the BLN COL FSAR and checked Section 2.3 of the referenced DCD to ensure that the combination of the DCD and the information in the COL represent the complete scope of information relating to this review topic.[1]

Because only a COL information item is provided in the DCD, the staff only reviewed the BLN COL FSAR to ensure that the information in the COL represents the complete scope of information relating to this review topic. The NRC staff's review confirmed that the information contained in the application addresses the required site characteristics COL information relating to local meteorology.

In addition the staff reviewed BLN SUP 2.3-1 in FSAR 2.3, which provided local meteorological conditions for the proposed site.

The staff reviewed the information contained in the BLN COL FSAR:

AP1000 COL Information Item

- BLN COL 2.3-2

The applicant provided additional information in BLN COL 2.3-2 to resolve COL Information Item 2.3-2 [COL Action Item 2.3.2-1], which addresses the provision of local meteorology.

The NRC staff reviewed BLN COL 2.3-2, related to the provision of local meteorology included under Section 2.3 of the BLN COL FSAR. The specific text of this COL information item in Section 2.3.6.2 of the AP1000 DCD, Revision 17, states:

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

Supplemental Information

- BLN SUP 2.3-1

The NRC staff reviewed supplemental information BLN SUP 2.3-1 within BLN COL FSAR Section 2.3, "Meteorology," describing the use of various sources of meteorological data: (1) onsite data collected from 2006 to 2007; (2) onsite data collected from 1979 to 1982; and (3) offsite data from several decades of collection available from the NOAA NCDC.

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 Normal and Extreme Values of Meteorological Parameters

2.3.2.4.1.1 Winds

2.3.2.4.1.1.1 Site Wind Distribution

The applicant submitted one year of hourly wind data (April 2006 - March 2007) from the permanent meteorological facility at the BLN site. The applicant also presented 2001-2005 joint frequency distributions of wind direction and wind speed from Huntsville, the nearest and most representative first order NWS station. The onsite data collected from 1979 to 1982 were also included.

The BLN site was characterized by the applicant as having mountain-valley topography characteristic of the Appalachian foothills. Additionally, the applicant stated that the BLN site was located on a broad flat Tennessee River flood plain, with mountain ridges to the northeast, east, and southeast.

The applicant stated that the nearest federal weather station (i.e., first order NWS station) with long term data was Huntsville, Alabama, approximately 45 miles west of the site. The Huntsville location was characterized, by the applicant, as Appalachian foothill topography.

The applicant provided joint frequency distributions of wind direction and wind speed for both the BLN site and Huntsville. The applicant stated that the BLN site data show a valley-flow regime, with dominant frequencies of up-valley (south through southwest) and down-valley (north through northeast) wind directions.

The staff verified the applicant's topography characterizations from topographic maps of the BLN site and Huntsville areas. The BLN site data were also independently verified. The Huntsville wind data were verified using the NCDC's Climate Data Online. Both the BLN site and Huntsville exhibit Appalachian foothill topography and dominant north and south wind flows, with the BLN site demonstrating a more northeast to southwest trend as a result of the river valley influence. The staff also noted a secondary flow from the southeast in the Huntsville data, not exhibited at the BLN site. The applicant identified mountain ridges in the sectors east of the BLN site. This topography impacts the secondary (southeast) flow (See SER Section 2.3.4.2.1.1.1.2, BLN Wind Data).

In response to RAI 2.3.3-5, the applicant provided a second year of hourly wind data for the site. The staff used these data to independently develop 2-year wind distributions. These distributions compared favorably with the one-year distributions. Since the data show the valley-flow regime as dominant, the applicant's data are acceptable to the staff.

2.3.2.4.1.1.1.1 Huntsville Wind Distribution

The applicant used Huntsville, Alabama as a nearby representative location for comparison with the BLN site (See SER Section 2.3.4.2.1.1.1.2). The applicant produced 5-year (2001-2005) wind summaries from the Huntsville meteorological data. BLN COL FSAR Tables 2.3-217 through 2.3-229 presented wind-direction and wind-speed percentage frequency in both a monthly and a 5-year format.

The staff used the NCDC Climate Data Online for its analysis, and produced the 5-year joint frequency distribution and wind rose graphic. The staff's analysis agrees with the applicant's wind summaries. The Huntsville wind distribution information submitted by the applicant is acceptable to the staff.

2.3.2.4.1.1.1.2 BLN Wind Data

The applicant provided wind distributions for the BLN site. Based on the first year's data collection, the applicant concluded that, in general, the wind roses for Huntsville show a more north to south trend, and the BLN site demonstrated a more northeast to southwest trend.

The BLN COL FSAR, however, did not include annual joint frequency distributions for the upper measurement level. The staff, therefore, generated RAI 2.3.2-6 requesting the information.

The applicant responded to RAI 2.3.2-6 with a revision to BLN COL FSAR Subsection 2.3.2.1.4 to reference the inclusion, and the addition of new tables that provided the requested annual upper level joint frequency distributions. The upper level wind information provides an additional data set useful in confirmation of the lower level data set and lends credibility for its further use in dispersion analysis.

In response to RAI 2.3.3-5, the applicant provided 2 years of wind data for the site.

The staff independently produced wind distributions for the BLN site. The staff agrees with the airflow trends identified by the applicant. The staff noted the influence of Tennessee River valley topography in the wind distribution. The staff finds the information submitted by the applicant to be acceptable.

2.3.2.4.1.1.1.3 Wind Direction Persistence

A large amount of wind persistence data was presented by the applicant for both the BLN site and Huntsville for multiple wind direction sectors in BLN COL FSAR Tables 2.3.2-256 through 2.3.2-262. Consistent with Section 2.3.2 of NUREG-0800, this amount of data was not considered essential for the staff's review. Thus, the staff reviewed only the 2006-2007 onsite data for the maximum number of consecutive hours of wind persistence for a given sector based on the criteria described in NUREG-0917, "Nuclear Regulatory Commission Staff Computer Programs for Use with Meteorological Data." These results were compared to the applicant's data as presented in BLN COL FSAR Table 2.3.2-259.

The staff performed an independent analysis on the 2006-2007 onsite data using the criteria described in NUREG-0917. Excellent agreement was found among the maximum number of consecutive hours with wind from a single sector when compared to the applicant's data. The longest period of wind persistence occurred in the north sector for 12 hours. Consistent with the criteria described in NUREG-0917, the staff finds the onsite wind persistence statistics presented by the applicant to be acceptable.

2.3.2.4.1.2 Air Temperature

The following discussion on air temperature is intended to provide a general climatic understanding of the local weather phenomena at the site but does not result in the generation of site characteristics for use as design or operating bases.

The applicant provided ambient temperature summaries based on the current onsite meteorological data (2006-2007), the historic onsite data (1979-1982), and NWS data from Scottsboro, Alabama. There appeared to be inconsistencies in the various temperature data presented by the applicant. RAI 2.3.2-1 was generated to clarify the statistics.

As a result of RAI 2.3.2-1, the applicant provided a revision to BLN COL FSAR Subsections 2.3.1.1 and 2.3.2.1.2 to indicate that certain data presented in BLN COL FSAR Table 2.3-263 were "monthly," so as not to be confused with daily extremes. The applicant further clarified their reference as being the Climatology of the United States No. 81, for the Scottsboro data.

In response to the staff's request to add the second year of data where appropriate, the applicant stated that inclusion of an additional year of temperature data would not significantly affect the results currently provided. The applicant further stated that Scottsboro was the preferred data source for this parameter because of its proximity to the BLN site.

The staff independently verified the applicant's Scottsboro climatology reference for the data presented, and found reasonable agreement with the BLN site data. The staff also agrees that the second year of data would not significantly impact the climatological summaries. The staff, therefore, finds the site air temperature information to be acceptable.

2.3.2.4.1.3 Atmospheric Moisture

The applicant stated that Alabama experiences moderately high humidity during much of the year. At Huntsville, during the years 2001-2005, the annual average humidity was greater than 50 percent. Maximum relative humidity values usually occur during the early morning hours, and minimum relative humidity values typically are observed in the mid-afternoon. The applicant summarized the annual and monthly relative humidity based on 4 periods per day (e.g., 12am-6am, 6am-12pm, 12pm-6pm, and 6pm-12am) in BLN COL FSAR Table 2.3.2-205. The staff has independently confirmed the statistics presented using the 2001-2005 NCDC Local Climate Data for Huntsville.

The staff considers atmospheric moisture to be an air mass associated phenomenon, and fairly constant over a localized region. Slight variations might be expected in a river valley (i.e., Tennessee River valley). The staff, therefore, agrees with the applicant's atmospheric moisture assessment.

2.3.2.4.1.3.1 Precipitation

2.3.2.4.1.3.1.1 Rain

The following discussion on rainfall is intended to provide a general climatic understanding of the local weather phenomena at the site but does not result in the generation of site characteristics for use as design or operating bases.

The applicant provided a significant amount of rainfall data and analysis for both the Huntsville and BLN site. The staff used NOAA's National Climatic Data Center Local Climate Data to verify the Huntsville precipitation normals and extremes that were presented for comparison to the BLN site data.

The applicant stated the average monthly precipitation at the BLN site between 1979-1982 followed a seasonal trend, reaching a maximum monthly mean in March (6.7 inches) and a minimum mean in October (2.2 inches). The applicant further stated that the maximum monthly precipitation at the BLN site between 1979-1982 was 14.5 inches.

The applicant provided Huntsville data for the time period from 2001-2005 for comparison to the BLN monthly means and extremes. The applicant stated that similar to the 1979-1982 BLN site data, the maximum mean monthly precipitation for Huntsville was in March (6.7 inches) and the minimum monthly mean was in October (2.1 inches). The applicant further stated that the maximum monthly mean precipitation in Huntsville was 14.5 inches for the period.

The staff noted from its review of the data presented by the applicant, that the Huntsville rain data were about 8 percent greater than those for the BLN site. However, when identical periods (1979-1982 and 2006-2007) were analyzed, the Huntsville rain data were approximately 15 percent greater than those for the BLN site. The seasonal trends and extremes continued to be the same or similar.

The applicant concluded that, in general, the Huntsville data appear to be representative of the BLN site area; and that the variations between the two locations from month to month, particularly during the summer months, are likely reflective of the occurrence of localized heavy shower and thunderstorm activity common in the area.

The staff verified the same or similar results for the precipitation normals and extremes presented by the applicant by using NOAA's NCDC Local Climate Data. The seasonal trends and extremes were also similar between the locations presented. The staff therefore finds the rainfall information presented to be acceptable.

Confirmatory Action: During its review the staff noted that the information presented in FSAR subsection 2.3.2.1.3.1.1 and Table 2.3-307 was not consistent. Specifically, the staff noted that the monthly mean value for October of 5.1 inches reported in Table 2.3-307 was higher than the value provided in FSAR subsection 2.3.2.1.3.1.1. The staff tracked this item as RAI 2.3.3-6. In its response to this issue, TVA commited to revise the FSAR subsection 2.3.2.1.3.1.1 to include the October value in the FSAR subsection 2.3.2.1.3.1.1 discussion. This is **Confirmatory Item 2.3.2-1.**

2.3.2.4.1.3.1.2 Snow

The applicant estimated the BLN site's annual average snowfall and maximum 24-hour snowfall using data reported by Huntsville and Scottsboro, Alabama. Inconsistencies were noted based on the staff's evaluation, and RAI 2.3.2-5 was generated.

The applicant responded to RAI 2.3.2-5 with a revision to BLN COL FSAR Subsection 2.3.2.1.3.1.2.

The applicant's BLN COL FSAR revision stated the annual average snowfall in the BLN area is estimated to be two to four inches. The estimate was based on 47 years of record (1959-2005) at Huntsville and 79 years of record (1927-2005) at Scottsboro. The applicant further stated that Huntsville reported, from the 2005 Local Climate Data, an average total snowfall of 3.8 inches falling from November through March, and a maximum 24-hour snowfall of 15.7 inches (December 31, 1963); and Scottsboro, from the 2005 Local Climate Data, reported an average annual snowfall of 1.7 inches (November through March), and maximum 24-hour snowfall of 12.0 inches (March 13, 1993).

The staff verified the applicant's data using the Southeast Regional Climate Center (SERCC) records and finds the revised snowfall information to be acceptable.

2.3.2.4.1.3.2 Fog

The following discussion on fog is intended to provide a general climatic understanding of the local weather phenomena at the site but does not result in the generation of site characteristics for use as design or operating bases.

The applicant stated that Huntsville averaged 37 hours/year of fog, and that BLN COL FSAR Table 2.3-275 provided the maximum hours of fog per month. The staff was unable to verify the applicant's values from the reference cited and issued RAI 2.3.2-2 requesting clarification.

In response to RAI 2.3.2-2, the applicant clarified that it had used the unedited NCDC local climatological data set for Huntsville for the period 2001-2005, and that no distinction was made in that database relative to fog intensity. From this data set the applicant determined that the number of days with recorded fog was approximately 27 per year, and that a direct comparison to "Heavy" fog (i.e., visibility <= 0.25 mi.) was not provided by this climatological dataset.

The staff notes that based on the 2001-2005 NCDC Local Climate Data Summary for Huntsville, there are on average 19.9 days/year with heavy fog. Within this data set, the actual number of days of heavy fog per year ranged from 12-28 days on an annual basis. Because there is no safety significance associated with the fog assessment, and the reference identified by the applicant is a credible one, the staff finds the fog information presented to be acceptable.

2.3.2.4.1.3.3 Precipitation Wind Roses

The following discussion on precipitation wind roses is intended to provide a general climatic understanding of the local weather phenomena at the site but does not result in the generation of site characteristics for use as design or operating bases. Specifically precipitation wind roses graphically depict the more prevalent wind directions associated with precipitation.

The precipitation figures enumerated in the BLN COL FSAR graphically depict the precipitation data from the frequency distributions presented in BLN COL FSAR Section 2.3.2.1.3.1. The applicant generated precipitation wind rose figures for both the BLN site data and Huntsville tabular data.

The staff generated precipitation wind roses for the BLN site and found similar results. The staff, therefore, finds the precipitation wind rose information presented to be acceptable.

2.3.2.4.1.4 Atmospheric Stability

The applicant generated atmospheric stability data using the vertical temperature difference (ΔT) method for the BLN site from the 1979-1982 and 2006-2007 datasets. Stability class (A-G) summaries were presented in wind direction by wind speed joint frequency distribution tables. These data were summarized and compared in BLN COL FSAR Table 2.3-316 and BLN COL FSAR Figure 2.3-245. The applicant stated that these annual stability class frequency distributions show that the BLN site data gathered over both time periods are relatively similar.

The staff independently generated its own stability class frequency distributions and graph from the BNL onsite hourly database. The staff's results were consistent with those presented by the applicant. The staff finds the applicant's discussion on atmospheric stability to be acceptable. The atmospheric stability data are further utilized for the purposes of dispersion modeling.

2.3.2.4.1.5 Mixing Heights

The applicant presented mixing height data from Nashville, Tennessee. The data were obtained from the EPA Support Center for Regulatory Atmospheric Modeling (SCRAM) Mixing Height Database. Although Nashville is 89 miles north-northwest of the BLN site, it is the closest available station with this type of data. The staff was unable to reproduce the values presented in BLN COL FSAR Tables 2.3-303 and 2.3-211. RAI 2.3.2-3 was issued requesting clarification of those values.

As a result of RAI 2.3.2-3, the applicant recalculated the mixing height and ventilation rate values, and revised the BLN COL FSAR Sections 2.3.1.1, 2.3.1.2.1.6, and 2.3.2.1.5 and BLN COL FSAR Tables 2.3-303 and 2.3-211 to reflect the new values. The applicant's annual average morning mixing height was 492 m. The annual average afternoon mixing height was 1361 m. The applicant's annual average morning ventilation rate was 2560 m^2/s. The annual average afternoon ventilation rate was 7720 m^2/s.

Confirmatory Action: RAI 2.3.2-3 includes a commitment to update section 2.3.1.2.1.6 of the FSAR in a future revision. This is **Confirmatory Items 2.3.2-2.**

The staff independently verified the mixing heights and ventilation rates presented, and found the applicant's data to be acceptable.

2.3.2.4.2 Potential Influence of the Plant and Its Facilities on Local Meteorology

In this section the applicant discussed the operation and construction aspects of the proposed new facility relative to potential influences on the local climatology and impact on the Tennessee River.

The applicant stated that new construction at the site was not expected to impact the climatic situation significantly. The construction aspects considered by the applicant included ground leveling, tree removal, and local hydrologic features. The applicant further stated that impacts of adding more structures, facilities, or activities to a relatively remote, rural area are not expected to be noticeable in terms of local meteorology.

The applicant stated that operation of power generation units can affect local climate in three ways, additional generation of particulates (increased fog and haze), temperature effects on local water sources, and cooling tower plume effects. The applicant further stated that nuclear power is often described as the most environmentally benign source of energy primarily because of the lack of emitted pollutants. The applicant's discussion of these potential influences concluded that impacts would be either small, negligible or limited.

Because of the limited and localized nature of the expected modifications associated with the proposed plant structures and the associated improved surfaces, it is expected that the proposed facility would not have significant impact on local meteorological conditions or air quality conditions. This information is further evaluated in the NRC's Environmental Impact Statement (EIS).

2.3.2.4.2.1 Cooling Tower Plumes

The applicant stated that cooling systems that depend on evaporation of water for a major portion of the heat dissipation may create visible vapor plumes. These plumes cause shadowing of nearby lands, salt deposition, and can cause fogging or icing. The applicant performed an assessment using the Seasonal Annual Cooling Tower Impact (SACTI) plume modeling code. BLN site meteorological data and Nashville mixing height data were used for the model run. Two existing natural draft cooling towers (NDCTs) were analyzed. Both existing NDCTs were analyzed simultaneously so that the two NDCT plumes produced included the assessment of plume interaction. The applicant provided tables that describe expected plume lengths by direction and season. The effects of salt and moisture deposition were not described and RAI 2.3.2-4 was issued requesting a description of those effects.

The applicant responded to RAI 2.3.2-4 with a quantitative analysis from the SACTI model output that determined the deposition rate of salt per area. The SACTI model output determined that the towers do not deposit entrained moisture or salts within the first 6600 ft. (~1.3 miles) due to high elevation of the discharge. The applicant stated that this distance is well beyond the plant's electrical substation and onsite transmission path. Additionally, the applicant also stated that due to channeling of winds by the river valley, most deposition occurs in directions away from electrical equipment.

The applicant also performed a supplemental analysis of the SACTI model output data and provided a White Paper (NUSTART-ER-5.3-BCAL-001 Table Development Discussion) that described the calculation. In addition, the calculation output data such as plume length, plume frequency, salt deposition and water deposition were provided in electronic format.

The staff conducted a confirmatory analysis using the SACTI model and the input assumptions provided. The staff's result was similar to the applicant's, and, therefore, agrees with the applicant's conclusion about salt and moisture deposition. The staff finds the applicant's data and description of the cooling tower plumes to be acceptable.

Confirmatory Action: RAI 2.3.2-4 includes a commitment to revise the FSAR to include a salt and moisture deposition discussion. This is **Confirmatory Item 2.3.2-3.**

2.3.2.4.3 Topographical Description of the Surrounding Area

The applicant stated the terrain surrounding the BLN site is dominated by Sand Mountain across the Tennessee River to the east. Further the applicant stated that the terrain to the north and west is flatter and wooded, and the only significant feature in this direction is the Backbone Ridge. The applicant provided two sets of Topographic Profiles (0-5 miles and 0-50 miles) in 16 compass sectors surrounding the BLN site area. The staff has independently verified the topographical assessment provided from topographic maps and finds the description provided acceptable.

2.3.2.4.4 Local Meteorological Conditions for Design and Operating Bases

Meteorological conditions for design and operating bases are discussed in BLN COL FSAR Section 2.3.1.2.

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 including BLN COL 2.3-2, BLN SUP 2.3-1, and checked the applicable parameters in 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 BLN COL FSAR related to this subsection.

Section 2.3.2 of Revision 17 of the AP1000 DCD is identical to Section 2.3.2 of Revision 15 of the AP1000 DCD, which is incorporated by reference into 10 CFR Part 52, Appendix D. This section is not affected by the changes that Westinghouse propoed in Revision 17 to the AP1000 DCD. Pursuant to 10 CFR 52.63(a)(5) and 10 CFR Part 52, Appendix D, Section VI.B.1, all nuclear safety issues relating to local meteorology that were incorporated by reference have been resolved.

In addition, the staff concludes that the relevevant information presented within the BLN COL FSAR is acceptable once Confirmatory Items 2.3.2-1, 2.3.2-2, and 2.3.2-3, are resolved. The staff based its conclusion on the following:

- BLN COL 2.3-2 and BLN SUP 2.3-1, involving local meterology and supplemental meterology information, respectively, is acceptable to the staff because the applicant has presented and substantiated information relative to the local meteorological, air quality, and topographic characteristics important to the design and siting of this plant. The staff has reviewed the information provided 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 applicant has also considered the appropriate site phenomena in establishing the design bases for structures, systems, and components (SSCs) important to safety. Specifically, the staff has generally accepted the methodologies used to determine the meteorological, air quality, and topographic characteristics reflected in these design bases, as documented in SERs for previous licensing actions. Because the applicant has correctly implemented these methodologies, as described above, the staff has determined that the use of these methodologies results in design basis containing margin sufficient for the limited accuracy, quantity, and period of time in which the data have been accumulated. The staff concludes that the identified design bases meet the requirement of 10 CFR Part 50, Appendix A, General Design Criterion (GDC) 2, "Design Bases for Protection Against Natural Phenomena," with respect to establishing the design basis for SSCs important to safety. This addresses COL Information Item 2.3-2. In conclusion, the applicant has provided sufficient information for satisfying 10 CFR Part 50 and 10 CFR Part 100.

2.3.3 Onsite Meteorological Measurement Programs

2.3.3.1 Introduction

The BLN onsite meteorological measurement 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 (QA) program for sensors and recorders, data acquisition and reduction procedures, and special considerations for complex terrain sites; (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; and (3) any additional information requirements prescribed within the "Contents of Application" sections of the applicable subparts to 10 CFR Part 52.

2.3.3.2 Summary of Application

Section 2.3.3 of the BLN COL FSAR incorporates by reference Section 2.3.3 of the AP1000 DCD, Revision 17.

In addition, in BLN COL FSAR Section 2.3.3, the applicant provided the following:

AP1000 COL Information Item

- BLN COL 2.3-3

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

Supplemental Information

- BLN SUP 2.3-1

The applicant provided supplemental information in BLN COL FSAR Section 2.3, "Meteorology," which describes the use of various sources of meteorological data: (1) onsite data collected from April 2006 to March 2007; (2) onsite data collected from 1979 to 1982; and (3) offsite data from several decades of collection available from the NOAA NCDC.

In addition, BLN COL FSAR Section 2.3.3 addresses Interface Item 2.9, related to the onsite meteorological measurement program.

2.3.3.3 Regulatory Basis

The regulatory basis of the information incorporated by reference is addressed within the FSER related to the DCD.

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

The applicable regulatory requirements for identifying onsite meteorological measurement program are as follows:

- 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, 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 Part 50, Paragraphs 50.47(b)(4), 50.47(b)(8), and 50.47(b)(9), as well as Section IV.E.2 of Appendix E, 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, 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 reasonably achievable.

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

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

- The pre-operational and operational monitoring programs should be described, including: (1) a site map (drawn to scale) that shows meteorological 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 joint frequency distributions 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. 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 FSAR Section 2.3.4; and (2) the long-term atmospheric dispersion estimates for routine releases discussed in FSAR 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 BLN COL FSAR and checked Section 2.3 of the referenced DCD to ensure that the combination of the DCD and the information in the COL represent the complete scope of information relating to this review topic.[1]

Because only a COL information item is provided in the DCD, the staff only reviewed the BLN COL FSAR to ensure that the information in the COL represent the complete scope of information relating to this review topic. The NRC staff's review confirmed that the information contained in the application addresses the required information relating to local meteorology.

The staff reviewed the information contained in the BLN COL FSAR:

AP1000 COL Information Item

- BLN COL 2.3-3

The NRC staff reviewed BLN COL 2.3-3 related to the onsite meteorological measurements program included under Section 2.3 of the BLN COL FSAR. The specific text of this COL information item in Section 2.3.6.3 of the AP1000 DCD, Revision 17, states:

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

Supplemental Information

- BLN SUP 2.3-1

The NRC staff reviewed supplemental information in BLN COL FSAR Section 2.3, "Meteorology," describing the use of various sources of meteorological data: (1) onsite data collected from April 2006 to March 2007; (2) onsite data collected from 1979 to 1982; and (3) offsite data from several decades of collection available from the NOAA NCDC.

BLN COL FSAR Section 2.3.3 stated that the meteorological monitoring program is the same throughout the preconstruction, construction, and operational phases of the project. Further, the applicant stated that the monitoring program is a continuation of the ongoing meteorological monitoring program for operating the BLN facility.

In addition, the applicant stated that the onsite meteorological measurement program has evolved over the years from the temporary meteorological towers installed in 1972 to the current system installed in 2006.

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 Onsite Meteorological Measurements Program - 1975-1983

BLN COL FSAR Section 2.3.3.1 provided a description of the 1975-1983 onsite meteorological measurement program at the BLN site. The applicant's description included a comparison of the historic data to the current (2006-2007) pre-operational monitoring program for the proposed plant. A sensor elevation change was noted in 1979. The applicant stated that the historical (1979-1982) data is comparable to the 2006-2007 data. BLN COL FSAR Table 2.3-317 provided the specifications for the meteorological equipment installed during each time period.

Regarding the data collection portion of the earlier program, the applicant stated that the earlier onsite meteorological data were recorded in both analog and digital form. In addition, the data collection, transfer processes, and permanent storage were described.

The applicant stated that instrument servicing, maintenance, and calibration were performed in accordance with established procedures. The applicant further stated that operational checks of the system were made twice weekly or more frequently as necessary to achieve the required 90 percent annual data recovery. Semi-annual checks for proper instrumentation readings were made at various component points. Each component of the meteorological facility was checked and/or field calibrated and/or removed and replaced with a laboratory calibrated component at least semi-annually. The staff's evaluation was focused on the current program described below.

2.3.3.4.2 Onsite Meteorological Measurements Program - 2006-2007

The applicant stated the new meteorological tower began operation at the permanent monitoring site on April 1, 2006. The permanent meteorological facility consists of a 55 meter instrumented tower for wind and temperature measurements, a separate 10 meter tower for dew point measurements, a ground based instrument for rainfall measurements, and a data collection system in an instrument building (Environmental Data Station [EDS]). The EDS is located west of the tower base and has been evaluated by the applicant as having no adverse influence on the measurements taken at the tower. The data collected include: wind speeds, wind directions, and temperatures at the 10 meter and 55 meter levels; and dew point temperatures at the 10 meter level. Rainfall is monitored by a rain gauge located approximately 45 ft. from the tower. The meteorological sensors are connected to the data collection and recording equipment in the EDS. A system of lightning and surge protection circuitry with proper grounding is included in the facility design.

The applicant provided figures illustrating the Site Plot Plan and the Topographic Plan of the Site Area. The figures, however, did not identify the meteorological tower location with respect to structures and features that could influence meteorological measurements. RAI 2.3.3-2 was generated requesting that information.

The applicant responded to RAI 2.3.3-2 with two updated figures (Figure 2.1-201 and 2.3-288) for inclusion in the BLN COL FSAR. Additionally, as part of the RAI response, the applicant provided three additional figures that depicted in detail: (1) the manmade structures in the immediate proximity of the BLN meteorological tower; (2) an aerial view of the meteorological tower location; and (3) sector views of obstructions (or lack thereof) from the meteorological tower base to the horizon.

The applicant stated that the instrumentation and measurements associated with the updated meteorological facility meet the requirements of both American National Standards Institute (ANSI)/American Nuclear Society (ANS)-3.11 and the guidance provided in RG 1.23.

The staff evaluated the onsite meteorological measurement program during a pre-application site visit and readiness assessment held at the site on April 18-19, 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 monitoring program; and (3) review the prospective applicant's plans for its operational onsite meteorological monitoring program. Based on the above assessment and RAI response, the staff finds the tower siting and associated EDS aspects of the onsite meteorological measurements program acceptable and in compliance with RG 1.23, Revision 1.

2.3.3.4.2.1 Instrument Description

A description of the meteorological sensors is provided by the applicant in BLN COL FSAR Table 2.3-317. A description of both the previously installed meteorological instrumentation (1975-1983) and the current (2006-2007) instrumentation is included. The previous installation used mechanical Climet wind sensors. The current installation uses ultrasonic wind sensors.

The older installation used Climet temperature sensors; while the current installation uses R.M. Young platinum RTD temperature sensors in fan-aspirated solar radiation shields. The older dew point unit was an EG&G Model 440. The current system utilizes a capacitive humidity sensor with a warmed probe head. Rainfall was measured by a Belfort instrument for the previous system, and a heated tipping bucket rain gauge was used for the current system.

The applicant stated that the main tower serves as a representative observation station (i.e., meteorological conditions at its location are representative of the site). The applicant stated that there are no terrain features or structures that would prevent the conditions at the main tower from being representative. The staff visited the BLN site during a pre-application site visit (April 2007) and concurs with the applicant's assessment of the terrain features and the ability of the main tower to collect representative meteorological data at the site.

The applicant provided system performance specifications (e.g., system accuracy, measurement resolution) for the meteorological monitoring instrumentation, which met the criteria specified in RG 1.23. Based on its review, the staff finds that the proposed instrumentation description complies with the appropriate guidance in RG 1.23, Revision 1, and is acceptable.

2.3.3.4.2.2 Meteorological Data Processing

2.3.3.4.2.2.1 Data Acquisition

The applicant stated that it uses the EDS for its meteorological data collection system. The EDS computer scans, scales, and stores the output of each meteorological sensor on a periodic basis. The BLN COL FSAR listed the sample rate for wind speed and wind direction as 5 seconds, while the sample rate for temperature and dew point was 60 seconds. RAI 2.3.3-3 requested justification for the 60 second sample rate, which differs from RG 1.23.

The applicant responded to RAI 2.3.3-3 with a revision to the BLN COL FSAR. Further, the applicant stated that its meteorological monitoring program was based on ANS-3.11 (2005) guidance, and the 60-second sample rate was consistent with that guidance. The applicant also stated that the operational phase of the program would conform to RG 1.23, Revision 1. The applicant also noted that FSAR Table 1-AA would be changed to identify an exception to RG 1.23, Revision 1 regarding the sampling interval for the preoperational phase. Specifically the applicant committed to changing the once per minute sampling rate to a 5-second sampling rate for temperature and dew point. The staff finds this commitment and FSAR change acceptable for the operational phase. The 60-second sampling rate for the preoperational phase that deviates from the 5-second rate guidance in RG 1.23, Revision 1 is acceptable because the 60-second sampling rate generated enough data in the preoperational phase for the applicant to characterize the site. For the operational phase the applicant will conform with RG 1.23, Revision 1 guidance for a 5-second sampling rate. Therefore, the staff finds the exception to RG 1.23, Revision 1 regarding the sampling interval for the preoperational phase to be acceptable. The implementation of this new sampling rate for the operational phase will be confirmed by NRC inspection.

Confirmatory Action: RAI 2.3.3-3 includes a commitment to revise the FSAR to note the exception to RG 1.23, Revision 1 guidance and to include a revision to FSAR subsection 2.3.3.2.2.1 to include a discussion of the sampling rate. This is **Confirmatory Item 2.3.3-1**. The RAI response also includes a commitment that the temperature and dewpoint sampling interval will be changed to a five second sampling rate at least one year before fuel load. This is **Commitment** 2.3.3-1.

2.3.3.4.2.2.2 Data Processing

The applicant stated that the software data processing routines within the EDS computer accumulate output and perform data calculations. Averages are calculated every fifteen minutes and each hour from individual readings. If there are insufficient individual samples to calculate an average (generally 25 percent for most variables, 50 percent for temperatures, and 75 percent for wind direction sigmas), an average is not calculated and the value for the hour (or 15-minute) is classified as missing. The above data processing practices are consistent with RG 1.23 and are, therefore, acceptable to the staff.

2.3.3.4.2.2.3 Data Analysis

The applicant stated the EDS computer sends the data to an offsite computer for validation, reporting and archiving. Meteorological data are generally reviewed on a workday basis, and validated data are archived for permanent storage. These data handling practices are consistent with RG 1.23 and are, therefore, acceptable to the staff.

2.3.3.4.2.3 Meteorological Instrumentation Inspection and Maintenance

The applicant stated that most meteorological equipment is calibrated or replaced at least every six months. The applicant also stated that records documenting calibration and corrective action are maintained with the basic objective to provide at least 90 percent annual joint recoverability and availability of data.

The applicant also stated that the meteorological program has been developed to be consistent with ANSI/ANS-3.11-2005. RAI 2.3.3-4 was issued requesting that the applicant identify and justify any deviations from RG 1.23.

The applicant responded to RAI 2.3.3-4 with a revision to BLN COL FSAR Subsection 2.3.3.2.3. The revision stated that meteorological equipment is calibrated or replaced in conformance with the calibration recommendations set forth in RG 1.23, Revision 1.

The staff noted during the BLN pre-application site visit (April 2007) that a solar radiation sensor was installed at the meteorological tower site. Solar radiation sensors are not specifically required or specified by RG 1.23, Revision 1, but are considered supplemental. This supplemental sensor had an annual replacement or calibration frequency rather than a semi-annual one. Since the solar radiation sensor is not specified by RG 1.23, Revision 1, the staff finds that the annual calibration/replacement frequency for this sensor is acceptable.

The staff finds that the proposed calibration frequency of the appropriate instrumentation specified by RG 1.23, Revision 1, is acceptable.

2.3.3.4.2.4 Meteorological Data Comparison

The applicant stated that the current meteorological data (April 2006 - March 2007) is in good agreement with the historic site data from 1979-1982. Comparisons of wind speed frequency and stability class frequency were provided by the applicant. To independently verify the applicant’s conclusion, the staff reviewed the submitted information and RAI 2.3.3-5 was issued requesting the complete 2-year data and an appendix to the BLN COL FSAR containing the following derived from the second year of BLN hourly meteorological data:

(1) joint frequency distributions of wind speed, wind direction, and atmospheric stability for both the lower and upper levels

(2) atmospheric dispersion and deposition factors presented in FSAR Sections 2.3.4 and 2.3.5.

In response to RAI 2.3.3-5, the applicant submitted: (1) an electronic copy of the complete 2-year meteorological data set; (2) an appendix to the FSAR containing joint frequency distributions of wind speed, wind direction, and atmospheric stability for both the lower and upper levels; and (3) an evaluation of the second year of BLN meteorological data that was used to demonstrate that the first year of data was representative of the long-term conditions at the site. Further, the applicant presented atmospheric dispersion and deposition factors for use with BLN COL FSAR Sections 2.3.4 and 2.3.5. (See Sections 2.3.4 and 2.3.5 of this SER).

Based on the information presented in Appendix 2DD, the applicant stated that the two year meteorological data set was consistent with the first year data set and the historic data set. The applicant further stated that the atmospheric stability percentage frequency, wind speed frequency at both measurement levels, and the wind direction frequency at both measurement levels were consistent for all three data sets.

The applicant further concluded that no anomalous behavior which would indicate that the first year of data was not representative was observed, and that the first year data set and the full two years of data are compatible and do not result in substantial differences in atmospheric dispersion and deposition.

The staff did an independent analysis on the meteorological data provided by the applicant. The quality of the recent 1-year and 2-year data sets were evaluated for use in dispersion modeling for Sections 2.3.4 and 2.3.5 of this SER. An independent meteorological analysis of wind speed, wind direction, atmospheric stability, and temperature performed. Reasonable agreement was found between the 1-year and 2-year data sets. Prevailing winds were the same between the data sets. Wind speed frequencies demonstrated little differences. Atmospheric stability and temperature were consistent between the data sets. No anomalies were indicated between the data sets, and normal variability was observed. The staff finds the 1-year data set to be representative and comparable to the 2-year data and acceptable for use in dispersion modeling.

2.3.3.5 Post Combined License Activities

Part 10 of the COL application contains proposed COL conditions, including inspection, test, analysis, and acceptance criteria (ITAAC). Table 3.8-1 in Part 10 of the BLN COL application contains the emergency planning (EP) ITAAC. The following two EP-ITAAC involve demonstrating that the operational onsite meteorological monitoring program appropriately supports the BLN 3 and 4 emergency plan:

- EP-ITAAC 6.3: The means exist to continuously assess the impact of the release of radioactive materials to the environment, accounting for the relationship between effluent monitor readings, and onsite and offsite exposures and contamination for various meteorological conditions. The acceptance criterion is 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 radiological conditions.

- EP-ITAAC 6.4: The means exist to acquire and evaluate meteorological information. The acceptance criterion is a report exists that confirms the specified meteorological data was {sic} available at the control room, Technical Support Center (TSC), and Central Emergency Control Center (CECC).

Confirmatory Action: BLN COL FSAR Section 2.3 identifies the new BLN meteorological tower's upper monitoring level as 55m; while Part 10 of the application, license conditions and ITAAC identified the upper monitoring level as 54m. The applicant needs to reconcile this throughout the application. The staff tracked this item as RAI 2.3.3-7. In the response associated with this RAI the applicant committed to update the ITAAC (Part 10 of the application) to reflect that the meterological Tower's upper monitoring level is 55 meters in the next revision to the application. This is identified as **Confirmatory Item 2.3.3-2.**

In addition, as discussed above Section 2.3.3. of the FSAR includes the following commitment:

- The temperature and dewpoint sampling interval will be changed to a five second sampling rate at least one year before fuel load. This is Commitment 2.3.3-1.

2.3.3.6 Conclusion

The NRC staff reviewed the application including BLN COL 2.3-3, BLN SUP 2.3-1, and checked Section 2.3 of 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 BLN COL FSAR related to this subsection.

Section 2.3.3 of Revision 17 of the AP1000 DCD is identical to Section 2.3.3 of Revision 15 of the AP1000 DCD, which is incorporated by reference into 10 CFR Part 52, Appendix D. This section is not affected by the changes that Westinghouse proposed in Revision 17 to the AP1000 DCD. Pursuant to 10 CFR 52.63(a)(5) and 10 CFR Part 52, Appendix D, Section VI.B.1, all nuclear safety issues relating to the onsite meteorological measurements program that were incorporated by reference have been resolved.

In addition, the staff concludes that the relevevant information presented within the BLN COL FSAR is acceptable once Confirmatory Items 2.3.3-1, and 2.3.3-2 are resolved. The staff based its conclusion on the following:

- BLN COL 2.3-3 and BLN SUP 2.3-1, involving the onsite meteorological measurements program is acceptable to the staff because the applicant has presented and substantiated information pertaining to the onsite meteorological monitoring program and the resulting database. The staff has reviewed the information provided and, for the reasons given above, concludes that the applicant has established consideration of the onsite meteorological monitoring program and the resulting database are acceptable and meet the requirements of 10 CFR 100.20 and 10 CFR 100.21 with respect to determining the acceptability of the site. Also the onsite data in the application provide an acceptable basis for making estimates of atmospheric dispersion for design basis accident and routine releases from the plant to meet the requirements of GDC 19, 10 CFR 100.20 and10 CFR 100.21, 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 10 CFR 50.47(b) and Appendix E to 10 CFR Part 50.

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

NUREG-0800, Section 2.3.4, states that the NRC staff should review the following related to short-term atmospheric diffusion estimates for accidental releases, as presented by a COL applicant, to ensure the safe design and siting of a nuclear plant:

- Atmospheric dispersion models to calculate atmospheric dispersion factors for postulated accidental radioactive and hazardous airborne releases.
- Meteorological data and other assumptions used as input to atmospheric dispersion models.
- Derivation of diffusion parameters (e.g., σy and σz).
- Cumulative frequency distributions of χ/Q values.
- Determination of conservative χ/Q values used to assess the consequences of: (1) postulated design-basis atmospheric radioactive releases to the EAB, the LPZ, and control room; and (2) onsite and off-site hazardous material releases to the control room.

2.3.4.2 Summary of Application

Section 2.3.4 of the BLN COL FSAR incorporates by reference Section 2.3.4 of the AP1000 DCD, Revision 17.

In addition, in BLN COL FSAR Section 2.3.4, the applicant provided the following:

AP1000 COL Information Item

- BLN COL 2.3-4

The applicant provided additional information in BLN COL 2.3-4 to address COL Information Item 2.3-4 [COL Action Item 2.3.4-1]. BLN COL 2.3-4 addresses the provision of short-term diffusion estimates.

2.3.4.3 Regulatory Basis

The regulatory basis of the information incorporated by reference is addressed within the FSER related to the DCD.

In addition, the relevant requirements of the Commission regulations for the short-term diffusion estimates, and the associated acceptance criteria, 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 off-site 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."

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

- 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. The models should be documented in detail and substantiated within the limits of the model so that the staff can evaluate their appropriateness of use with regard to release characteristics, plant configuration, plume density, meteorological conditions, and site topography.

- 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. Any dispersion estimates should be calculated from the most representative meteorological data available for the site.

- 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. The methodology for establishing these relationships should be appropriate for estimating the consequences of accidents within the range of distances, which are of interest with respect to site characteristics and established regulatory criteria.

- 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. All cumulative frequency distributions of χ/Q values should be presented for appropriate distances (e.g., the EAB distance and the outer boundary of the LPZ) and time periods as specified in Section 2.3.4.2 of RG 1.206.

- Atmospheric dispersion factors used for the assessment of consequences related to atmospheric radioactive releases to the control room for design-basis, other accidents, and for onsite and off-site 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 BLN COL FSAR and checked the applicable site parameters in Table 2-1 of the referenced DCD to ensure that the combination of the DCD and the information in the COL represent the complete scope of information relating to this review topic.[1] The NRC staff's review confirmed that the information contained in the application and incorporated by reference addresses the required information relating to the short-term diffusion estimates. Section 2.3.4 of the AP1000 DCD is being reviewed by the staff under Docket Number 52-006. The NRC staff's technical evaluation of the information incorporated by reference related to short-term diffusion estimates will be documented in the staff SER on the DC application for the AP1000 design.

The staff reviewed the information contained in the BLN COL FSAR:

AP1000 COL Information Item

- BLN COL 2.3-4

The NRC staff reviewed BLN COL 2.3-4 related to the short-term diffusion estimates included under Section 2.3.4 of the BLN COL FSAR. The specific text of this COL information item in Section 2.3.6.4 of the AP1000 DCD, Revision 17, 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).

Supplemental Information

- BLN SUP 2.3-1

The NRC staff reviewed supplemental information BLN SUP 2.3-1 within BLN COL FSAR Section 2.3, "Meteorology," describing the use of various sources of meteorological data: (1) onsite data collected from 2006 to 2007; (2) onsite data collected from 1979 to 1982; and (3) offsite data from several decades of collection available from the NOAA NCDC.

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 (PAVAN Model)

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.

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 joint frequency distribution (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; that 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 (ARCON96 Model)

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 are determined.

2.3.4.4.2 Meteorological Data Input for Dispersion Models

The applicant provided, with the application: (1) a meteorological data set for input into the ARCON96 computer code (Control Dispersion Model); and (2) a JFD for use with the PAVAN computer code (Offsite Dispersion Model). The staff attempted to correlate the meteorological data provided and issued BLN RAI 2.3.4-06 to help resolve data issues.

In its response, the applicant stated that the ARCON96 meteorological data and the JFD used for the PAVAN and XOQDOQ computer codes were derived directly from the original BLN site data. Further, the applicant provided examples of how the meteorological data were processed as input for each of computer code. The process was consistent with regulatory guidance and good scientific practice, and is therefore, acceptable to the staff.

Section 2.3.3 of NUREG-0800, states that for COL applications that do not reference an early site permit (ESP) and for ESP applications, 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. If two years of onsite meteorological data are not available at the time the application is filed, the staff expects that the COL or ESP applicant will provide at least one annual cycle of meteorological data collected onsite 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 Section 2.3.4 of NUREG-0800; and (2) the long-term atmospheric dispersion estimates for routine releases discussed in Section 2.3.5 of NUREG-0800. The applicant should continue to monitor the data and submit the complete 2-year data set when it has collected all the data. This supplemental submittal should also include a reanalysis of the Section 2.3.4 and 2.3.5 atmospheric dispersion estimates based on the complete 2-year data set.

The applicant provided 1-year of meteorological data (April 1, 2006 - March 31, 2007) with its application. The staff requested, in RAI 2.3.3-5, a complete two-year meteorological data set and a reanalysis of atmospheric dispersion estimates, as indicated by Section 2.3.3 of NUREG-0800. The applicant provided a supplemental submittal as Appendix 2DD to the BLN COL FSAR.

In lieu of revising the dispersion estimates of BLN COL FSAR Section 2.3.4, the applicant's Appendix 2DD provided a reanalysis of dispersion estimates using the 2-year meteorological data set, in order to demonstrate that the first year of meteorological data was not anomalous and conservatively represented the long term conditions at the site.

The staff performed an independent analysis that compared the 1-year and the 2-year meteorological data sets (see Section 2.3.3.4.2.4 of this SER), and generated dispersion estimates using the complete 2-year meteorological data set. No anomalies were indicated by the staff's analysis of the 1-year and 2-year data sets. The staff considered the 1-year data set to be conservative and acceptable as representative input for the applicant's dispersion analysis.

2.3.4.4.2.1 Meteorological Inputs for 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 1-year period from April 1, 2006 through March 31, 2007. The wind data were obtained from the 10-meter level of the onsite meteorological tower, and the stability data were derived from the vertical temperature difference (delta-temperature) measurements taken between the 55-meter and 10-meter levels on the onsite meteorological tower. The meteorological inputs used by the applicant are consistent with Section 2.3.4 of NUREG-0800 and RG 1.23 and are, therefore, acceptable to the staff.

2.3.4.4.2.2 Meteorological Inputs for 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 1-year period from April 1, 2006 through March 31, 2007. The wind data were obtained from the 10-meter and 55-meter levels of the onsite meteorological tower, and the stability data were derived from the vertical temperature difference (delta-temperature) measurements taken between the 55-meter and 10-meter levels on the onsite meteorological tower. The meteorological inputs used by the applicant are consistent with Section 2.3.4 of NUREG-0800 and RG 1.23 and are, therefore, acceptable to the staff.

2.3.4.4.3 Diffusion Parameters for Dispersion Models

2.3.4.4.3.1 Diffusion Parameters for Offsite Dispersion Estimates

The applicant chose to implement the diffusion parameter assumptions outlined in RG 1.145, as a function of atmospheric stability, for its PAVAN model runs. RAI 2.3.4-1 was generated requesting the applicant further discuss site characteristics and basis for the selected model inputs and assumptions.

In its response, the applicant stated that a straight-line trajectory was assumed between the point of release and the distances for which χ/Q values were calculated in accordance with NUREG/CR-2858 and RG 1.145. The applicant further stated that NUREG/CR-2858 refers to RG 1.111, "Methods for Estimating Atmospheric Transport and Dispersion of Gaseous Effluents in Routine Releases from Light-Water-Cooled Reactors," for discussion of the effects of spatial and temporal variations in airflow in the region of a site, and that these effects were not described by the constant mean wind direction model; therefore, the effects of hill and valley topography on air flow characteristics near the BLN site were examined by the applicant to identify any variation of atmospheric transport and diffusion conditions. The applicant stated that the wind and stability characteristics of the site were compared with the same parameters at the Huntsville and Chattanooga airports. The representativeness of the observed meteorology in the region of interest (within 2 miles) was assessed. Further, the applicant stated that no long term trends were observed that would bias short term diffusion estimates. Therefore, no adjustments to represent non-straight line trajectories were applied.

The staff disagrees in part with the applicant's response. The staff evaluated the applicability of the PAVAN diffusion parameters and concluded that no unique topographic features preclude the use of the PAVAN model for the BLN site. However, the staff noted that terrain recirculation factors were used in the annual average χ/Q calculations in Section 2.3.5, but not in the PAVAN calculations in Section 2.3.4.

The proposed BLN COL FSAR revision provided in RAI 2.3.4-1 lacks certain information requested by the original RAI, which states:

(1) Were terrain recirculation factors or other adjustments used in the PAVAN calculations?

    The staff noted that terrain recirculation factors were used in the annual average χ/Q calculations in Section 2.3.5, but not in the PAVAN calculations in Section 2.3.4. Evaluate for consistency and provide the basis for the selected assumptions and inputs.

(2) In accordance with RG 1.206, BLN COL FSAR Section 2.3.4 should discuss the effects of topography and nearby bodies of water on short-term dispersion estimates.

    Provide this discussion in the BLN COL FSAR.

This is identified as **Open Item 2.3.4-1**.

2.3.4.4.3.2 Diffusion Parameters for 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 hills and bodies of water. Therefore, the staff finds that 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 (Offsite)

The applicant modeled one ground-level release point and assumed credit for building wake effects by inputting a building cross-sectional area of 2909 square meters. This building area is the above grade, cross-sectional area of the shield building. The applicant also input a building height of 71.3 m, which is the height above plant grade of the containment structure. These inputs are reasonable and acceptable to the NRC staff.

The minimum distances to the EAB and the LPZ distance were used as input to PAVAN. The minimum EAB distances were calculated from a 160-meter radius circle encompassing all site release points to the EAB within a 45° sector centered on each compass direction. With regard to Town Creek on the northwest side of the site, the EAB extends to the opposite shore of the creek as this area is controlled by TVA. The use of the shortest distances from a circle encompassing all site release points to the EAB results in higher (more conservative) χ/Q values and is, therefore, acceptable to the staff. The LPZ is defined as a 3.2-km radius from the site center point. RAI 2.3.4-2 was generated for the applicant to further discuss this issue.

The applicant provided a revision to BLN COL FSAR Subsection 2.3.4.1 to justify the use of the site center point reference for calculating the distance from the postulated release locations to the outer boundary of the LPZ. The applicant stated that the radius of the release boundary, 160m (525 ft.), is not significant in comparison to the LPZ distance for 3219m (10,561 ft.). Further, the applicant stated that this was a reasonable conclusion given the conservative definition of the release boundary described above and the conservative nature of the accident atmospheric dispersion calculations done in accordance with RG 1.145.

The staff did a confirmatory analysis that compared the use of the site center point to the 160-meter radius circle for the distance calculation to the outer boundary LPZ. Results were within 2 percent of the values presented in the BLN COL FSAR. The staff, therefore, accepts the applicant's use of the site center point for this calculation.

SER Table 2.3.4-1 lists the short-term atmospheric dispersion estimates for the EAB and the outer boundary of the LPZ that the applicant derived from its PAVAN modeling run results. In accordance with Section 2.3.6.4 of the AP1000 DCD, Revision 17, BLN COL FSAR Table 2.0-201 compared the site-specific EAB and LPZ χ/Q values to the corresponding site parameters provided in the AP1000 DCD. This comparison showed that the AP1000 DCD LPZ

χ/Q value is conservatively bounded by the site-specific value.[2] This comparison is reproduced in SER Table 2.3.4-1. However, the comparison also showed that the AP1000 DCD EAB χ/Q value is not bounded by the site-specific value. In response to request for additional information (RAI) 15.00.3-1. TVA requested an exemption to this site parameter. The staff's evaluation of this exemption request is addressed in Chapter 6 and Chapter 15 of this SER. As discussed in Section 2.0 of this SER, this exemption request is **Open Item 2.0-1**.

A reassessment of the short-term atmospheric dispersion estimates for the EAB and the outer boundary of the LPZ were done by the staff using the PAVAN model and the 2-year BLN onsite meteorological data set. The staff's results were similar to the applicant's. The applicant's values were slightly more conservative (1 percent to 4 percent) and bounded the staff's values. The staff, therefore, finds the applicant's short-term atmospheric dispersion estimates for EAB and LPZ to be acceptable.

Section 2.3.6.4 of the AP1000 DCD, Revision 17, 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. The applicant provided these values in Table 7.1-11 of the BLN Environmental Report. These χ/Q values will be evaluated as part of the concurrent environmental review and subsequent results presented in the NRC's EIS.

2.3.4.4.4.2 Short-Term Atmospheric Dispersion Estimates for the Control Room (Onsite)

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

- Onsite Hourly Meteorological Data (April 1, 2006 through March 31, 2007)

- Control Room Source/Receptor Data (BLN COL FSAR Table 2.3-320 Source/Receptor Information)

- Plant Layout of the BLN site

In accordance with the AP1000 DCD, Revision 17, two receptor (i.e., air intake) points, the control room HVAC intake and control room door, were modeled for the following eight release points:

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

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[2] 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 those required by the reactor design.

The staff identified inconsistencies in the BLN COL FSAR regarding release points and issued RAI 2.3.4-3 to reconcile the BLN COL FSAR.

The applicant responded to RAI 2.3.4-3, with a revision to BLN COL FSAR Section 2.3.4.3. The applicant stated that the atmospheric dispersion estimates for the BLN control room were calculated based on the guidance provided in RG 1.194, using the ARCON96 computer code. The applicant addressed the containment shell as being the only release point modeled as a diffuse area source. Further, the applicant revised BLN COL FSAR Table 2.3-320, listing the additional control room x/Q input data. The staff finds the proposed BLN COL FSAR revision acceptable, as it provides the inputs necessary to run the ARCON96 computer code.

The staff identified inconsistencies in the BLN COL FSAR regarding map references in BLN COL FSAR Figure 2.1-201 and issued RAI 2.3.4-4 to reconcile the BLN COL FSAR.

The applicant responded to RAI 2.3.4-4 by identifying a combination of four existing information sources that included: (1) Westinghouse AP1000 DCD Figure 15A-1 (as modified by Westinghouse Technical Report (TR)134) that shows the locations of the postulated sources and receptors; (2) a revised BLN COL FSAR Table 2.3-320, (which identifies the distances between sources and receptors as well as the directions with respect to true north from the receptors to each source) was included in the response to RAI 2.3.4-3; (3) a general arrangement site plan drawn to scale shown in BLN COL FSAR Figure 1.1-202 with a scale, state plane coordinate system, and true north orientation arrow; (4) Subsection 1.2.2 of the BLN COL FSAR identified that “plant North” orientation is 219° from true North. This combination of sources provided the information necessary for the control room habitability analyses and is, therefore, acceptable to the staff.

The applicant took a departure in BLN COL FSAR Chapter 18, “Human Factors Engineering,” in that the BLN TSC is not located in the control building as identified in the AP1000 DCD (BLN DEP 18.8-1). BLN COL FSAR Section 2.3.4 does not contain a description of the methodology, inputs, assumptions, and calculated atmospheric dispersion factors (χ/Q values) for releases from the plant vent, PCS air diffuser, fuel building blowout panel, fuel building rail bay door, steam vent, PORV/safety valves, condenser air removal stack, and containment shell to the TSC. RAI 2.3.4-5 was issued requesting information that would be analogous to that provided for releases to the control room and include drawings to show relevant information graphically, including computer input files as part of the response.

In its response to RAI 2.3.4-5, the applicant stated that the atmospheric dispersion estimates for the BLN TSC were calculated using the guidance provided by RG 1.194 and the ARCON96 computer code (NUREG/CR-6331, “Atmospheric Relative Concentrations in Building Wakes,”). The meteorological inputs used were the same as those used for the control room dispersion estimates. The applicant stated it chose the most limiting AP1000 radiological consequences (i.e., LOCA), and the most conservative LOCA release (from containment shell). The staff agrees with these assumptions for the following reasons. The LOCA is identified in NUREG-1793, “Final Safety Evaluation Report Related to Certification of the AP1000 Standard Design,” Table 15.3-1, as the most severe postulated accident, and the containment shell release is the most conservative due to its release height when compared to the plant vent.

The staff’s confirmatory analysis used the full 2-year meteorological data set and produced results similar to the applicant’s results (within ± 2 percent). The staff, therefore finds the BLN site-specific TSC atmospheric dispersion factors (χ/Q values) acceptable. However the applicant did not include these site-specific TSC atmospheric dispersion factors in the FSAR Section 2.3.4. This is identified as **Open Item 2.3.4-2**. (RAI 2.3.4-5)

SER Table 2.3.4-2 lists the control room atmospheric dispersion estimates that the applicant derived from its ARCON96 modeling run results. In accordance with Section 2.3.6.4 of the AP1000 DCD, Revision 17, BLN COL FSAR Table 2.0-202 compared the site-specific control room χ/Q values to the corresponding site parameters provided in the AP1000 DCD. This comparison showed that the AP1000 control χ/Q values conservatively bounded the site-specific values. This comparison is reproduced in SER Table 2.3.4-2.

Confirmatory Action: The staff noted that FSAR Table 2.3-321 values were not consistent with the values presented in FSAR Table 2.0-202. The staff is tracking this item as RAI 2.3.4-7. In its response associated with this RAI the applicant commited to make changes to update the values in FSAR Table 2.3-321 to be consistent with the values in FSAR Table 2.0-202. The staff finds this acceptable. This is confirmatory item 2.3.4-1.

2.3.4.4.5 Onsite and Offsite Hazardous Materials

A review of the identification of onsite and offsite 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 model descriptions are also found in these sections.

Section 2.3.6.4 of the AP1000 DCD, Revision 17, states that a COL applicant shall address the site-specific χ/Q values as specified in DCD Section 2.3.4. The staff finds that the applicant has provided sufficient information to meet the requirements of the DCD.

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 BLN COL 2.3-4, BLN SUP 2.3-1, and checked the applicable parameters in 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 BLN COL FSAR related to this subsection.

The Westinghouse application to amend Appendix D to 10 CFR Part 52 includes changes to Table 2-1 of the AP1000 DCD, as stated in Revision 17 of the AP1000 DCD. The staff is reviewing this information on Docket Number 52-006. The results of the NRC staff's technical evaluation of the information incorporated by reference in the BLN COL FSAR will be documented in a supplement to NUREG-1793. The supplement to NUREG-1793 is not yet complete, and this is being tracked as part of Open Item 1-1. The staff will update Section 2.3.4 of this SER to reflect the final disposition of the DC application.

However, as a result of the confirmatory action 2.3.4-1 and Open Items 2.3.4-1 and 2.3.4-2, concerning terrain recirculation factors and the effects of topography, and concerning the BLN TSC atmospheric dispersion factors respectively, the staff is unable to finalize its conclusions on BLN COL 2.3-4.

2.3.5 Long-Term Diffusion Estimates (Related to RG 1.206, Section C.III.1, Chapter 2, C.I.2.3.5, "Long-Term Atmospheric Dispersion Estimates for Routine Releases")

2.3.5.1 Introduction

NUREG-0800, Section 2.3.5, states that the NRC staff should review the following related to atmospheric dispersion and dry deposition estimates for routine releases of radiological effluents to the atmosphere, as presented by a COL applicant, to ensure the safe design and siting of a nuclear plant:

- 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.
- Meteorological data and other assumptions used as input to the atmospheric dispersion models.
- Derivation of diffusion parameters (e.g., σ_z).
- Atmospheric dispersion factors (χ/Q values) and deposition factors (D/Q values) used for assessment of consequences of routine airborne radioactive releases.
- 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.

2.3.5.2 Summary of Application

Section 2.3.5 of the BLN COL FSAR incorporates by reference Section 2.3.5 of the AP1000 DCD, Revision 17.

In addition, in BLN COL FSAR Section 2.3.5, the applicant provided the following:

AP1000 COL Information Item

- BLN COL 2.3-5

The applicant provided additional information in BLN COL 2.3-5 to address COL Information Item 2.3-5 [COL Action Item 2.3.5-1]. BLN COL 2.3-5 addresses the provision of long-term diffusion estimates.

2.3.5.3 Regulatory Basis

The regulatory basis of the information incorporated by reference is addressed within the FSER related to the DCD.

In addition, the relevant requirements of the Commission regulations for long-term diffusion estimates, and the associated acceptance criteria, 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 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 to 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 off-site.

The following RGs are applicable to this section:

- 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."

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

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

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 to calculate annual average concentrations in air and amount of material deposited as a result of routine releases of radioactive materials to the atmosphere. The models should be sufficiently documented and substantiated to allow a review of their accuracy and validity, source configuration, suitability of input parameters, topography, and appropriateness for the site, plant, and release characteristics.

- A discussion of atmospheric diffusion parameters, such as vertical plume spread (σ_z) as a function of distance, topography, and atmospheric conditions. Use of these parameters should be substantiated as to their appropriateness for use in estimating the consequences of routine releases from the site boundary to a radius of 50 miles (80 km) from the plant.

- Meteorological data summaries (onsite and regional) used as input to the dispersion and deposition models. Data used for this evaluation should represent hourly average values of wind speed, wind direction, and atmospheric stability, which are appropriate for each mode of release and, which are characteristic of annual average atmospheric dispersion and deposition conditions in the vicinity of the plant.

- 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-mile (8-kilometer) radius of the site).

- The χ/Q and D/Q values to be used for assessment of the consequences of routine airborne radiological releases:

    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.

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

2.3.5.4 Technical Evaluation

The NRC staff reviewed Section 2.3.5 of the BLN COL FSAR and checked the applicable site parameters in Table 2-1 of the referenced DCD to ensure that the combination of the DCD and the information in the COL represent the complete scope of information relating to this review topic.[1] The NRC staff's review confirmed that the information contained in the application and incorporated by reference addresses the required information relating to the long-term diffusion estimates. Section 2.3.5 of the AP1000 DCD is being reviewed by the staff under Docket Number 52-006. The NRC staff's technical evaluation of the information incorporated by reference related to long-term diffusion estimates will be documented in the staff SER on the DC application for the AP1000 design.

The staff reviewed the information contained in the BLN COL FSAR:

AP1000 COL Information Item

- BLN COL 2.3-5

The NRC staff reviewed BLN COL 2.3-5 related to long-term diffusion estimates included under Section 2.3.5 of the BLN COL FSAR. The specific text of this COL information item in Section 2.3.6.5 of the AP1000 DCD, Revision 17, 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 miles from the plant.

Supplemental Information

- BLN SUP 2.3-1

The NRC staff reviewed supplemental information BLN SUP 2.3-1 within BLN COL FSAR Section 2.3, "Meteorology," describing the use of various sources of meteorological data: (1) onsite data collected from 2006 to 2007; (2) onsite data collected from 1979 to 1982; and (3) offsite data from several decades of collection available from the NOAA NCDC.

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 (XOQDOQ)

The applicant stated that the XOQDOQ Computer Program, NUREG/CR-2919, "XOQDOQ Computer Program for the Meteorological Evaluation of Routine Effluent Releases at Nuclear Power Stations," which implements the assumptions outlined in RG 1.111, was used to generate the annual average relative concentration, χ/Q and annual average relative deposition D/Q. Further, the applicant stated that the values of χ/Q and D/Q were determined at points of maximum potential concentration outside the site boundary, at points of maximum individual exposure and at points within a radial grid of sixteen 22½° sectors an extending to a distance of 50 miles. Additionally, radioactive decay and dry deposition were considered.

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.

In response to RAI 2.3.5-1, the applicant provided details on the various XOQDOQ model outputs. The staff found the applicant's descriptions acceptable. XOQDOQ is an NRC sponsored computer code that implements the methodology outlined in RG 1.111 and is therefore acceptable to the staff.

RAI 2.3.5-6 questioned the applicability of the no decay depleted output. This output is not identified by Section 2.3.5 of NUREG-0800 and is not needed for the safety finding. The response to this RAI includes a commitment to remove this information from a Table in the FSAR as it is extraneous. The staff finds the removal of this information to be acceptable.

Confirmatory Action: RAI 2.3.5-6 includes a commitment to revise the FSAR to remove a table containing information related to the no decay depleted output. This is **Confirmatory Item 2.3.5-1.**

2.3.5.4.2 Release Characteristics – Points and Receptors

The applicant stated that their analysis assumed a combined vent release point located at the center of the facility. RAI 2.3.5-4 requested clarification of expected release points. The applicant identified several references in the AP1000 DCD and BLN COL FSAR, which were found acceptable to the staff. The applicant further assumed a minimum building cross-sectional area of 2909 square meters and a building height of 71 m taken from the AP1000 DCD in response to RAI 2.3.5-8. The applicant chose to model a mixed mode release, as presented in a revised atmospheric dispersion model analysis in response to RAI 2.3.5-2.

In response to RAIs 2.3.5-2, 2.3.5-3, 2.3.5-5, 2.3.5-7, and 2.3.5-8, the applicant provided new model inputs (including XOQDOQ input files), new release mode characteristics, site-specific terrain features, effective stack height, an updated land census and updated offsite receptor locations. Updated receptors for milk cow, milk goat, garden, meat animal, and house were listed by sector and distance from the center of the site in BLN COL FSAR Table 2.3-322.

The mixed-mode release is defined in RG 1.111 as an elevated release during part of the time and a ground-level release during the remainder of the time. A mixed release mode is considered acceptable to the staff in accordance with RG 1.111. Overall modeling assumptions and inputs were found to be acceptable for release points and receptors.

BLN site-specific terrain values found in the input files provided for XOQDOQ model runs, do not correlate with BLN COL FSAR Figures 2.3-286 and 2.3-287. These inconsistencies, if not adequately addressed, may impact this or other sections of this SER. This is identified as **Open Item 2.3.5-1**.

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 1-year period from April 1, 2006 through March 31, 2007. The wind data were obtained from the 10-meter level of the onsite meteorological tower, and the stability data were derived from the vertical temperature difference (delta-temperature) measurements taken between the 55-meter and 10-meter levels on the onsite meteorological tower.

The applicant provided 1-year of meteorological data (April 1, 2006 - March 31, 2007) with its application. A complete two year meteorological data set is indicated by Section 2.3.3 of NUREG-0800, and was requested by the staff in RAI 2.3.3-5. The applicant provided a supplemental submittal as Appendix 2DD to the BLN COL FSAR. The applicant's appendix discussed the wind speed, wind direction, and atmospheric stability parameters of the two data sets and concluded that the two year meteorological data set was consistent with the first year data set.

The staff's independent meteorological data analysis indicated normal year to year variability, and no anomalies were evidenced between the data sets. The staff considered the 1-year data set to be acceptable and representative as input for the applicant's dispersion analysis. See SER Section 2.3.3.4.2.4.

2.3.5.4.4 Atmospheric Diffusion Parameters

The applicant chose to implement the diffusion parameter assumptions outlined in RG 1.111, 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 BLN site. Therefore, the staff finds that the applicant's use of diffusion parameter assumptions, as outlined in RG 1.111 was acceptable.

2.3.5.4.5 Resulting Relative Concentration and Relative Deposition Factors

SER Table 2.3.5-1 lists the long-term atmospheric dispersion and deposition estimates for the EAB, LPZ, and special receptors of interest that the applicant derived from its XOQDOQ modeling results. SER Table 2.3.5-2 lists the applicant's long-term atmospheric dispersion and deposition estimates for 16 radial sectors from the site boundary, to a distance of 50 miles from the proposed facility. The χ/Q values presented in SER Table 2.3.5-2 reflect several plume radioactive decay and deposition scenarios. Section C.3 of RG 1.111, 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, 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 iodines released to the atmosphere. Definitions for the χ/Q categories listed in the headings of SER Tables 2.3.5-1 and 2.3.5-2 are as follows:

- No Decay/Undepleted 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.

- 2.26-Day Decay/Undepleted 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-133m.

- 8.00-Day Decay/Depleted 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.

Section 2.3.6.5 of the AP1000 DCD, Revision 17, states that a COL applicant will address long-term diffusion estimates and χ/Q values as specified in DCD Section 2.3.5. Using the information provided by the applicant, including the 10-meter level JFDs of wind speed, wind direction, and atmospheric stability for the 1-year and 2-year meteorological data sets, the staff was able to confirm the applicant's χ/Q and D/Q values by using the XOQDOQ computer code. The applicant's JFDs conservatively provided 13 wind speed categories, 2 additional low wind speed categories beyond the 11 wind speed categories specified in RG 1.23, Revision 1. However, the terrain values used by the applicant could not be verified against BLN COL FSAR Figures 2.3-286 and 2.3-287. Resolution of this issue will be tracked by **Open Item 2.3.5-1**.

Section 2.3.6.5 of the AP1000 DCD, Revision 17, also states that with regard to environmental assessment, estimates of annual average χ/Q values for 16 radial sectors to a distance of 50 miles from the plant should be provided. The applicant provided these values in BLN COL FSAR Tables 2.3-323, and 2.3-325 through 2.3-328. These χ/Q values will be evaluated further as part of the concurrent environmental review and subsequent results presented in the NRC's EIS.

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 BLN COL 2.3-5, BLN SUP 2.3-1, and checked the applicable site parameters in 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 BLN COL FSAR related to this subsection.

Section 2.3.5 of Revision 17 of the AP1000 DCD is identical to Section 2.3.5 of Revision 15 of the AP1000 DCD, which is incorporated by reference into 10 CFR Part 52, Appendix D. This section is not affected by the changes that Westinghouse propoed in Revision 17 to the AP1000 DCD. Pursuant to 10 CFR 52.63(a)(5) and 10 CFR Part 52, Appendix D, Section VI.B.1, all nuclear safety issues relating to long-term diffusion estimates that were incorporated by reference have been resolved.

However, as a result of Open Item 2.3.5-1, concerning terrain values noted above, the Site boundary (annual average) maximum χ/Q values were not able to be confirmed. Based on Open Item 2.3.5-1, and Confirmatory Item 2.3.5-1, the staff is unable to finalize its conclusions on BLN COL 2.3-5.

2.4 Hydrologic Engineering

Section 2.4 of this SER contains evaluations associated with: (1) hydrologic description; (2) floods; (3) probable maximum floods; (4) potential dam failures; (5) probable maximum surge and seiche flooding; (6) probable maximum tsunami hazards; (7) ice effects; (8) cooling water canals and reservoirs; (9) channel diversions; (10) flooding protection requirements; (11) low water considerations; (12) groundwater; (13) accidental releases of radioactive liquid effluents in ground and surface waters; and (14) technical specifications and emergency operation requirements. During an inspection conducted from February 19-22, 2008, the NRC staff was unable to verify and validate several computer programs used to determine the probable maximum flood height at the site and a separate flood height analysis associated with postulated dam failures. An inspection report was issued on March 19, 2008, documenting three violations associated with the review of the hydrology computer programs. TVA conceded the violations and documented the actions taken and the actions to be taken related to each violation.

In a letter dated October 22, 2008, TVA requested that the NRC reschedule the review of the hydrology portion of the FSAR because it was having problems meeting the commitments it had made as a result of the NRC inspection. As a result of TVA's October 22, 2008, letter, the staff issued a letter, dated October 29, 2008, stating that it would stop the FSAR hydrology review and restart it after TVA satisfactorily passed an inspection and when reviewer resources were available. The NRC staff does not intend to issue Section 2.4 with the SER with open items for BLN 3 and 4. Instead, the staff intends to provide this section of the SER at a later time. The resolution of hydrologic engineering issues is identified as **Open Item 2.4-1**.

2.5 Geology, Seismology, and Geotechnical Engineering

In Section 2.5, "Geology, Seismology, and Geotechnical Engineering," of the BLN 3 and 4 FSAR, the applicant described geologic, seismic, and geotechnical engineering properties of the proposed COL site. Following NRC guidance in RG 1.206 and RG 1.208, "A Performance-Based Approach to Define Site-Specific Earthquake Ground Motion," the applicant defined the following four zones around the BLN site and conducted investigations in those zones:

Site region – Area within 320 km (200 miles) of the site location
Site vicinity – Area within 40 km (25 miles) of the site location
Site area – Area within 8 km (5 miles) of the site location
Site location – Area within 1 km (0.6 miles) of proposed BLN 3 and 4

Since the COL site is located adjacent to BLN 1 and 2, as well as a later abandoned site southwest of Units 1 and 2, the applicant stated in BLN COL FSAR Section 2.5 that it used the previous site investigations for these facilities as its starting point for the characterization of the geologic, seismic and geotechnical engineering properties of the COL site. As such, the material in Section 2.5 of the COL application focuses on any newly published information since the BLN 1 and 2 FSAR issued in June 1986 and the TVA report prepared in 2006, "TVA, Geotechnical, Geological, and Seismological Evaluations for the Bellefonte Site (GG&S), prepared by CH2M Hill, Inc. and Geomatrix Consultants, Inc., Revision 1, 2006," for the abandoned site. The material in FSAR Section 2.5 of the COL application also focuses on any recent geologic, seismic, geophysical and geotechnical investigations performed for the COL site.

The applicant used seismic source and ground motion models published by the Electric Power Research Institute (EPRI, 1988, 1989) as the starting point for characterizing potential regional seismic sources and the resulting vibratory ground motion. The applicant then updated these EPRI seismic source and ground motion models in light of more recent data and evolving knowledge, in particular in relation to the New Madrid seismic zone and the Charleston seismic source zone. The applicant employed the performance-based approach described in RG 1.208 to develop the Ground Motion Response Spectra (GMRS) for the site.

This SER, written by NRC staff, is divided into five main parts (SER Sections 2.5.1 through 2.5.5), which parallel the five FSAR sections prepared by the applicant for the BLN COL application. The five main SER sections, discussed on the following pages, are "Basic Geologic and Seismic Information" (Section 2.5.1), "Vibratory Ground Motion" (Section 2.5.2), "Surface Faulting" (Section 2.5.3), "Stability of Subsurface Materials and Foundations (Section 2.5.4), and "Stability of Slopes" (Section 2.5.5). Evaluations made in these five sections together contribute to the staff's overall determination (pending resolution of the open items) that the BLN COL site is acceptable based on geologic, seismic and geotechnical information presented in FSAR Sections 2.5.1 through 2.5.5.

2.5.1 Basic Geologic and Seismic Information

2.5.1.1 Introduction

FSAR Section 2.5.1 of the BLN COL application 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 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, to provide the bases for plant design, and to determine whether there is significant new tectonic or ground motion information that could impact seismic design bases as determined by a probabilistic seismic hazard analysis (PSHA). BLN COL FSAR Section 2.5.1.1, “Regional Geology,” describes the geologic and tectonic setting within a 320 km (200 mile) radius of the BLN site, while BLN COL FSAR Section 2.5.1.2, “Site Geology,” describes the geology and tectonic setting within the 40 km (25 mile), 8 km (5 mile), and 1 km (0.6 mile) radius of the site.

2.5.1.2 Summary of Application

Section 2.5.1 of the BLN COL FSAR incorporates by reference Section 2.5.1 of the AP1000 DCD, Revision 17.

In addition, in BLN COL FSAR Section 2.5.1, the applicant provided the following:

AP1000 COL Information Item

- BLN COL 2.5-1

The applicant provided additional information in BLN COL 2.5-1 to address COL Information Item 2.5-1 [COL Action Item 2.5.1-1]. BLN 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 BLN COL FSAR Section 2.5.1 based on information derived from its review of previously prepared reports for BLN 1 and 2, a 2006 TVA report for an abandoned property southwest of BLN 1 and 2, a Final Environmental Impact Statement (FEIS) from the BLN Conversion project, published geologic literature, new borehole data collected for proposed BLN 3 and 4, and unpublished data from communications with TVA personnel who have firsthand knowledge of the studies conducted for BLN 1 and 2. The applicant used recently published literature, reports and maps to supplement and update existing geologic and seismic information and consulted with individual researchers at universities and state agencies.

Based on its investigations for BLN 3 and 4, the applicant concluded in FSAR Section 2.5.1 that no geologic conditions exist at the site that would negatively impact the construction, or the operation of safety-related buildings, or structures. The applicant further concluded that karst- and earthquake-related deformation hazards at BLN 3 and 4 will be mitigated during construction, or designed for appropriately. A summary of the geologic and seismic information provided by the applicant in BLN COL FSAR Section 2.5.1 is presented below.

2.5.1.2.1 Regional Geology

BLN COL FSAR Sections 2.5.1.1.1, 2.5.1.1.2, and 2.5.1.1.3 discuss the regional physiography, topography, geologic history, and stratigraphy within a 320 km (200 mile) radius of the BLN site.

Regional Physiography and Topography

The following is a brief summary describing the physiographic location of the BLN site and related topographic expressions within the site region, or within a 320 km (200 mile) radius of the site. In BLN COL FSAR Section 2.5.1.1.1, the applicant described the BLN site as located within the Appalachian Plateaus province, bordered by the Valley and Ridge, Blue Ridge and Piedmont to the east, the Interior Low Plateaus to the northwest, and the Coastal Plain to the south. SER Figure 2.5.1-1 (reproduced from FSAR Figure 2.5-202) is a regional map showing the BLN site location in relation to these six physiographic provinces.

BLN COL FSAR Subsections 2.5.1.1.1.1 through 2.5.1.1.1.6 describe the six physiographic provinces in the site region. The Appalachian Plateaus province is a broad synclinal fold in late Paleozoic age (350 to 248 million years ago [Ma]) rocks, which extends from New York to Alabama along a northeast to southwest trend. The applicant stated that the width of the province narrows from over 320 km (200 miles) in the northeast to approximately 50 km (30 miles) in the Tennessee area before widening to roughly 80 km (50 miles) in Alabama near the proposed site. The Appalachian Plateaus province is divided into seven sections, including the southwestern most Cumberland Plateau where the BLN site is located.

The Valley and Ridge physiographic province, which follows a northeast to southwest trend, similar to the Appalachian Plateaus, is marked by an abrupt topographic rise that separates the two provinces. The Valley and Ridge is extremely compressed and faulted, a sharp contrast from the broad folds of the Appalachian Plateaus. The Valley and Ridge province is underlain by 9,000 to 12,000 m (30,000 to 40,000 ft.) of Paleozoic (543 to 248 Ma) sedimentary formations.

The Interior Low Plateaus province makes up the northwestern border of the Appalachian Plateaus. The applicant described the Interior Low Plateaus topography as marked by two large shallow basins near the center of the province with moderate karst topography throughout. The Coastal Plain physiographic province borders the Appalachian Plateaus to the southwest, south and east.

The Blue Ridge and Piedmont provinces are located east of the Valley and Ridge and Appalachian Plateaus but within the 320 km (200 mile) site radius. The Blue Ridge province is a deeply dissected mountainous region where the highest peaks in the Appalachian Mountain system are found, while the Piedmont is characterized by gently rolling, well-rounded hills and long, low ridges.

Regional Geologic History

BLN COL FSAR Section 2.5.1.1.2 describes the geologic history of the BLN site region, which is characterized by a series of oceanic openings and closings, and related orogenic (mountain building) events. The applicant stated that the BLN site is situated within the southern portion of the Appalachian-Ouachita orogenic belt, formed as a result of numerous accretionary and collisional events that occurred during the Paleozoic era (543 to 248 Ma). The applicant provided a history of the orogenic events associated with the Appalachian formation, as well as a history of subsequent rifting that led to formation of the present Atlantic Ocean and Gulf of Mexico during early Mesozoic time (248 to 206 Ma). The applicant emphasized that the Alleghanian orogeny, which took place during the late Paleozoic (323 to 248 Ma) was the most expansive and most recent mountain building episode to affect the central and southern Appalachians.

The applicant concluded its summary of the regional geologic history by stating that the present-day Appalachian Mountains result from periods of early Cenozoic (65 to 1.8 Ma) uplift and differential erosion due to crustal isostatic readjustments.

Regional Stratigraphy

BLN COL FSAR Section 2.5.1.1.3 describes the regional stratigraphy for each physiographic province in the BLN site region, which includes a mix of sedimentary rocks of Tertiary to Precambrian age (800 to 50 Ma) as well as igneous and metamorphic rocks of Paleozoic to Proterozoic age (2.5 billion years ago (Ga) to 245 Ma). The applicant stated that the Quaternary (1.8 Ma to present) deposits for the Appalachian Mountains tend to be thin, discontinuous, and difficult to date, and therefore, it did not discuss them in much detail.

BLN COL FSAR Subsection 2.5.1.1.3.1 describes the stratigraphy of the Appalachian Plateaus province in which the BLN site is located. Paleozoic sedimentary limestone, dolomite, siltstone, shale and sandstone associated with the Knox Group and the Chickamauga (including the Sequatchie, Nashville, and Stones River Groups), Red Mountain and Pottsville Formations make up the dominant bedrock in the Alabama portion of the Appalachian Plateaus. The applicant described the sedimentary rocks as nearly horizontal, or gently folded, and slightly deformed but not metamorphosed. The Quaternary (younger than 1.8 million years) deposits of the Appalachian Plateaus province are primarily residual soils or soils modified and derived from local parent material, alluvium, and colluvium.

In BLN COL FSAR Subsection 2.5.1.1.3.2, the applicant described the stratigraphy of the Valley and Ridge province, characterized by folded and faulted sedimentary formations of Paleozoic age (543 to 248 Ma). Quaternary units in the Valley and Ridge are similar to those in the Appalachian Plateaus with thin and discontinuous deposits of alluvium and colluvium. Stream terrace deposits are extensive within the northern Alabama portion of the Valley and Ridge province. The applicant described a number of locations where these alluvial terrace deposits exist south and southeast of the BLN site. The applicant stated that multiple terrace surfaces appear to represent both lower (younger) and higher (older) deposits. The applicant also speculated that the older terrace deposits, based on regional denudation rates and soil development, may be several hundred thousand years old, or older. The applicant described sub-vertical features within terrace deposits located approximately 100 km (65 miles) from the BLN site and concluded that these features represent non-tectonic geologic weathering processes.

BLN COL FSAR Subsection 2.5.1.1.3.3 describes the late Precambrian and Paleozoic age metasedimentary and metavolcanic rocks of the Blue Ridge province and Subsection 2.5.1.1.3.4 describes the metamorphic and plutonic rocks of the Piedmont province. Finally, BLN COL FSAR Subsections 2.5.1.1.3.5 and 2.5.1.1.3.6 briefly describe the mostly sedimentary stratigraphy of the Interior Low Plateaus to the west of the BLN site and of the Coastal Plain provinces to the south, respectively.

Regional Tectonic Description

BLN COL FSAR Section 2.5.1.1.4 describes the regional tectonic setting within a 320 km (200 mile) radius of the BLN site, based on recent information and the current state of knowledge. The applicant divided BLN COL FSAR Section 2.5.1.1.4 into multiple subsections that describe the contemporary tectonic stress environment, regional structures and seismic source zones within a 320 km (200 mile) site radius, and significant seismic sources at distances greater than 320 km (200 miles), respectively.

Contemporary Stress Environment. BLN COL FSAR Subsection 2.5.1.1.4.1 describes the tectonic stresses in the BLN site region based on data from previous investigations of relative plate motions and tectonic stresses in North America. These investigations suggest a far field source contributing to mid plate stress patterns. A near-uniform, compressive mid-plate stress province surrounds the BLN site and has a maximum horizontal shear direction oriented northeast to east-northeast. The regional stress patterns reflect absolute plate motion and ridge push directions for North America. The applicant stated that the analyses of the stress environment, including well-constrained focal mechanisms of North American mid-plate earthquakes, demonstrate that Central and Eastern United States (CEUS) earthquakes occur primarily in response to a transform (strike-slip) stress regime.

Regional Tectonic Structures in the Site Region. BLN COL FSAR Subsection 2.5.1.1.4.2 describes regional tectonic structures within a 320 km (200 mile) radius of the BLN site. The applicant provided a summary of the accretionary history, tectonic evolution and lithotectonic structures associated with the Appalachian orogenic belt. The applicant stated that knowledge of the regional tectonic framework has not changed since the mid 1980's; however, more recent information is available to provide a better understanding of structures within that framework. Therefore, in BLN COL FSAR Sections 2.5.1.1.4.2.1 through 2.5.1.1.4.2.4, as summarized below, the applicant provided additional information regarding regional geologic structures that is based on recent investigations.

Appalachian Foreland Thrust Belt

BLN COL FSAR Subsection 2.5.1.1.4.2.1 describes the Appalachian Foreland thrust belt, a regional tectonic feature, the northwest portion of which underlies the BLN site. This thrust belt consists of large-scale northeast-striking, northwest-verging thrust faults and folds, where it is present in Alabama and Georgia. The applicant stated that broad, flat-bottomed synclines and asymmetric anticlines dominate the northwestern portion of the thrust belt. The belt includes two major structures that are mapped within the BLN site vicinity, or within 40 km (25 miles) of the site. These structures, the Sequatchie Valley and Wills Valley thrust faults, are shallow, imbricate (overlapping) faults that show little displacement relative to more distant regional structures. BLN COL FSAR Sections 2.5.1.2.5 and 2.5.3.2.1 discuss the Sequatchie and Wills Valley faults in more detail relative to the BLN site. The applicant concluded that there is no information available in the published literature to indicate that thrust faults associated with the Appalachian Foreland thrust belt are capable tectonic structures.

Subdetachment Basement Faults

In BLN COL FSAR Subsection 2.5.1.1.4.2.2, the applicant summarized studies conducted since the mid-1980's to better define basement faults located beneath the Appalachian detachment zone. The Appalachian detachment is a mostly horizontal shear zone that separates the overlying Appalachian foreland thrust belt from the underlying Precambrian basement rock. The depth to the Appalachian detachment varies from 2 to 2.5 km (1.2 to 1.5 miles) nearest the BLN site to 6 km (3.7 miles), or greater, further from the site. The applicant stated that known or inferred large normal basement faults, originally formed along the passive margin of the late Proterozoic to early Paleozoic (900 to 490 Ma) Iapetus Ocean, are significant in the southern Appalachians.

Compressional reactivation of these faults may be one possible mechanism for regional seismically active regions east of the BLN site, like those in Giles County, Virginia and eastern Tennessee (both discussed in BLN COL FSAR Subsection 2.5.1.1.4.2.4). However, no capable tectonic sources are known to coincide with the regional seismicity.

The applicant described a series of northeast striking basement faults that are offset by other northwest striking faults. The system of offset faults and graben structures reflect a more complex basement structure, including depth to basement and detachment thickness, both of which tend to increase along a northwest to southeast trend. Bayona et al., (2003) interpreted a basement fault from seismic reflection data that is located within a few miles of the BLN site. The applicant stated that seismic data and borehole data near the site have not confirmed the location of this basement fault. Furthermore, the applicant stated that there is no evidence for surface deformation, no seismicity data to suggest the presence of this fault, and no information to indicate that it is a capable tectonic structure. Finally, the applicant stated that no geologic or seismicity evidence exists to suggest that any of the subdetachment basement faults are active, or capable tectonic structures.

Other Major Regional Structures

In BLN COL FSAR Subsection 2.5.1.1.4.2.3, the applicant described major mapped faults and tectonic structures that represent deformational episodes no younger than Paleozoic (543 to 248 Ma) in age. The applicant highlighted these faults and structures with respect to physiographic provinces. In its description of the Appalachian Plateaus province, where the site is located, the applicant briefly described the Sequatchie anticline and the Wills Valley fault. BLN COL FSAR Sections 2.5.1.2.5 and 2.5.3 discuss these two structures in detail as they are located within 40 km (25 miles) of the BLN site.

The applicant described the major structures associated with the Blue Ridge, Piedmont, Interior Low Plateaus and Gulf Coastal Plain physiographic provinces. While these structures are located within the 320 km (200 mile) radius of the COL site, there is no evidence that they have been active since the Paleozoic era (543 to 248 Ma). Therefore, because these structures do not exhibit geologically recent (less than 1.8 Ma) deformation, the applicant concluded that they are not capable tectonic features.

Seismic Sources within the Site Region. BLN COL FSAR Subsection 2.5.1.1.4.2.4 describes the two major seismic source zones in the site region, the Giles County, Virginia, and the Eastern Tennessee seismic zones. The applicant stated that several of the six teams in the late 1980's Electric Power Research Institute – Seismicity Owners Group (EPRI-SOG) study (EPRI, 1988) identified these two zones as distinct seismic source zones.

Giles County, Virginia, Seismic Zone (GCVSZ)

BLN COL FSAR Subsection 2.5.1.1.4.2.4.1 describes the GCVSZ as a steeply dipping 40 km (25 miles) long, 10 km (6 miles) wide tabular zone that ranges in depth from 5 to 25 km (3 to 16 miles). The GCVSZ involves the Precambrian basement beneath the Appalachian detachment. In 1897, the largest earthquake in the state of Virginia, with an estimated moment magnitude (**M**) 5.9, occurred in Giles County, Virginia near the West Virginia border. The applicant stated that strike slip faulting was the mechanism for this earthquake, as well as for more recent earthquakes in the GCVSZ. The applicant concluded that, based on several complimentary published interpretations, reactivation of Precambrian/Iapetan normal faults is most likely responsible for the modern seismicity within the GCVSZ. Focal mechanisms for recent earthquakes are consistent with this interpretation.

The applicant explained that while there is no known capable tectonic source in the region, some Quaternary terraces do exhibit evidence of possible deformation and there is a zone of small faults in Southwestern Virginia that exhibits late Pliocene to early Quaternary age deformation, or deformation younger than 5 Ma. Explanations for such geologically recent deformation include a tectonic origin, land sliding, and a response to solution activity in basement limestone. The applicant discussed several studies conducted to investigate these interpretations, however none provided definitive evidence of either the tectonic or the solution explanations, and the applicant did not further discuss the landslide explanation. The applicant concluded that, based on field investigations, there is not sufficient evidence to support Quaternary displacement along these terrace structures or small faults, or in the GCVSZ as a whole.

Eastern Tennessee Seismic Zone (ETSZ)

BLN COL FSAR Subsection 2.5.1.1.4.2.4.2 describes the ETSZ, which is located almost entirely within the 320 km (200 mile) BLN site region and is one of the most active seismic regions in the eastern United States. The applicant stated that the ETSZ is a well-defined, northeasterly trending seismicity belt that stretches 300 km (187 miles) through the Blue Ridge and Valley and Ridge physiographic provinces in eastern Tennessee and parts of Alabama, Georgia, and North Carolina. The **M** 4.6 1973 Maryville, Tennessee and the April 2003 Fort Payne, Alabama earthquakes are the largest recorded earthquakes in the ETSZ. The majority of ETSZ earthquakes have focal depths that range from 4.8 to 22.5 km (3 to 14 miles) and occur in the basement rock, beneath the Alleghanian detachment zone. The applicant stated that most earthquake focal mechanisms indicate left lateral faulting on east-west trending structures, while others suggest right lateral movement on north-northeast trending structures.

The applicant discussed the ETSZ with respect to the New York – Alabama (NY-AL) lineament, a prominent northwest – southeast trending magnetic gradient that extends along much of the eastern United States. The western edge of seismicity within the ETSZ coincides with the magnetic anomalies of the NY-AL lineament. These anomalies likely represent a sharp contrast in crustal strength, with stronger stable continental crust to the northwest separated by weaker crust to the southeast. The applicant described alternative models that attempt to explain ETSZ seismicity without relying on the NY-AL lineament. These models suggest reactivation of basement faults along weak lower crust in possible combination with higher fluid pressures in the upper to middle crust.

The applicant briefly described the limited paleoseismic investigations conducted in the ETSZ to search for evidence of prehistoric earthquakes. The applicant stated that these investigations found no clear evidence for prehistoric earthquakes; however, soft sediment deformation did exist at two locations within the 302 square km (117 square miles) study area in eastern Tennessee. The applicant stated that the mechanism for the soft sediment deformation is not clear but suggested that land sliding, dissolution, or earthquake-induced ground shaking is possible.

Significant Seismic Sources at Distances Greater than 320 km (200 miles). BLN COL FSAR Subsection 2.5.1.1.4.3 describes the New Madrid, Missouri and Charleston, South Carolina seismic sources that, while outside of the 320 km (200 mile) site radius, may contribute to the seismic hazard at the BLN site.

New Madrid Seismic Source

In BLN COL FSAR Subsection 2.5.1.1.4.3.1, the applicant provided a brief overview of the New Madrid seismic zone (NMSZ). In 1811-1812, the NMSZ produced the three largest historical earthquakes to have occurred in the CEUS. The applicant stated that even though the New Madrid region was a known seismic source at the time of the EPRI-SOG study in the late 1980's, numerous seismic and geologic investigations took place after 1989 that helped to better characterize the NMSZ. The applicant stated that the majority of these investigations are summarized in the Clinton ESP and the Grand Gulf ESP applications, approved by the NRC. The applicant referred to these applications and to FSAR Section 2.5.2.4.4.1 of this COL application for more descriptions of the New Madrid seismic source.

Charleston Seismic Source

BLN COL FSAR Subsection 2.5.1.1.4.3.2 discusses the Charleston, South Carolina seismic source with an emphasis on the 1886 Charleston earthquake and the relationship of the seismic source in terms of the areal source characterization, the repeat times of large earthquakes in the Charleston area, and estimates of associated maximum magnitudes for large, repeating earthquakes. The 1886 Charleston earthquake provides a significant point of reference as it was the largest historical earthquake in the eastern United States. The meizoseismal area (area with the most significant earthquake damage) associated with the 1886 Charleston earthquake, forms an elliptical zone approximately 32 km (20 miles) wide and 48 km (30 miles) long and is centered near Middleton Place, South Carolina, northwest of Charleston. The Middleton Place-Summerville seismic zone, as it is called, is a site of continuing seismicity, and it encompasses the juncture of two main faults, the Woodstock and Ashley River faults, both suggested source faults for the 1886 earthquake.

The applicant considered the relationship of the Charleston seismic source zone to other features in the vicinity that may be potential sources for large-magnitude earthquakes, such as strike-slip faults that bound Mesozoic rift basins, and, inferred or mapped faults associated with regions of tectonic warping (a slight bending, or flexing, of the earth's crust). The applicant concluded that there is some evidence to suggest a relationship between the regions of tectonic warping and the 1886 earthquake.

The applicant discussed historic and prehistoric earthquake-induced liquefaction features, or paleoseismic features, documented in the Charleston seismic source area and their use in determining an earthquake chronology for large 1886-type earthquakes. The applicant identified six prehistoric earthquakes that, based on paleoseismic evidence, may be similar in location, magnitude and intensity to the 1886 Charleston event. The applicant stated that earthquake intensity data associated with the 1886 earthquake, and to a lesser extent the paleoseismic evidence, contribute to determining potential maximum magnitudes for the 1886 and earlier earthquakes. The maximum moment magnitude estimates for the 1886 Charleston earthquake range from **M** 6.8 to 7.8.

2.5.1.2.2 Site Geology

In BLN COL FSAR Section 2.5.1.2, the applicant discussed geologic conditions of the site vicinity, site area, and site location, including site physiography and topography, site geologic history, site stratigraphy, site structural geology, and site engineering geology.

Site Physiography and Topography

The applicant discussed the physiography and topography of the BLN site in a regional context in BLN COL FSAR Section 2.5.1.1.1. BLN COL FSAR Section 2.5.1.2.1 provides a more detailed discussion of both the physiography and topography within a 40 km (25 mile) radius of the site. The BLN site is situated in the southeastern portion of the Browns Valley-Sequatchie Valley, a segment of the Cumberland Plateau and part of the Appalachian Plateaus Physiographic Province. The valley is an erosional remnant of the Sequatchie anticline that extends northeast-southwest for approximately 225 km (140 miles). The valley, referred to as the Browns Valley in Alabama, is approximately 8 km (5 miles) wide at the BLN site. The Browns Valley is bounded by Sand Mountain to the Southeast and the Cumberland Plateau to the Northwest.

The applicant described the BLN site as situated on the right bank of the Guntersville Reservoir, a part of the Tennessee River. BLN 3 and 4 are within the Tennessee River valley and situated at 190 m (620 ft.) above mean sea level (amsl), 8 m (25 ft.) above the normal pool level for the reservoir. The site is located just less than one kilometer (0.6 mile) from the reservoir, separated by River Ridge, which reaches an elevation of approximately 245 m (800 ft.). The BLN site slopes down to the north, has an overall elevation of approximately 10 m (34 ft.), and drains into the Town Creek Embayment located to the north-northwest.

Site Geologic History

BLN COL FSAR Section 2.5.1.2.2 provides a description of the geologic history within a 40 km (25 mile) radius of the site. The applicant suggested that the oldest rocks in the site vicinity are late-Proterozoic in age, approximately 1000-750 Ma, and lie at depths greater than 2.4 km (1.5 miles) beneath the ground surface. These metamorphic basement rocks are not exposed at the surface anywhere in the site vicinity. The applicant stated that there was a gap between the metamorphosed, Proterozoic basement rocks and deposition of the Paleozoic sedimentary rocks underlying the BLN site.

The applicant identified two primary geologic episodes that occurred in the site vicinity over the last 500 million years. The first episode was a marine and near-shore depositional period during the Paleozoic era. During this period, limestone, shale and sandstone were deposited over the existing basement rocks. The Pottsville Formation is the youngest of these sedimentary rocks and is of Pennsylvanian age (323-290 Ma). Paleozoic rocks were thrust upward and westward following Pennsylvanian deposition and continuing through the early Mesozoic as part of the Alleghanian orogeny. The second and most recent geologic episode, described by the applicant, reflects a period of erosion during Mesozoic and Cenozoic time.

Another gap in the geologic record for north Alabama, between deposition of the Pottsville Formation and the present time, reflects the long erosional episode following the Alleghanian thrust faulting period.

The applicant stated that there is no evidence of geologic deposition over the last 300 million years within the site vicinity and in most places no geologic record even exists for the past 135-150 million years due to erosional processes. The applicant stated that small-scale karst features, due to dissolution in limestones and other carbonate rock formations, are present within the BLN site. The applicant discussed these features in FSAR Section 2.5.4.1.

Site Stratigraphy

BLN COL FSAR Section 2.5.1.2.3 describes the stratigraphic units mapped within a 1 km (0.6 mile) radius of the site, including several thousand feet of Paleozoic bedrock overlain by thin layers of unconsolidated Quaternary sediments. As mentioned in the previous SER section, there is a gap in the depositional record between the Pennsylvanian period (290 Ma) and the Quaternary period (present). Thin layers of Quaternary sediments that do exist are limited and may be found along larger streams and on hill slopes and hollows.

Paleozoic Units. Weathered dolomite and limestone associated with the Knox Group are the oldest of the Paleozoic rocks underlying the BLN site and are Cambrian to Lower Ordovician (540-470 Ma) in age. Outcrops of the Knox Group are present to the northwest of the BLN site, along the Sequatchie anticline axis, and consist mostly of deeply weathered residual material. Karst features, including sinkholes, are common within the Knox group. The applicant observed a presumably active sinkhole, or collapse structure, southwest of the BLN site. BLN COL FSAR Section 2.5.4.1 provides a more detailed examination of the karst features.

The applicant described the sedimentary unit immediately underlying the BLN site, the Stones River Group. The Stones River Group is undifferentiated in northern Alabama and is characterized by thick bedded limestone with locally interbedded silty, clay-rich (argillaceous) layers. A zone of bentonite and bentonitic shale is present near the top. The Stones River Group lies unconformably over the Knox Group and is Middle Ordovician (480-450 Ma) in age. The applicant stated that the thickness of the Stones River Group beneath the BLN site is approximately 320 m (1050 ft.) as measured northeast to southwest across the site from the Town Creek Embayment to the Guntersville Reservoir.

In FSAR Section 2.5.1.2.4, the applicant described six distinct lithologic units within the Stones River Group present beneath the proposed BLN 3 and 4. The applicant identified these units during the exploratory drilling program that it conducted for this COL application. The units are approximately 140 m (453 ft.) thick and make up the Middle Stones River Group. The applicant designated these six units as units A through F. The units contain alternating beds of limestone and dolomitic limestone, silty and argillaceous limestone, as well as some cherty limestone. The carbonate component in the purer limestone and dolomite averages 83 percent, whereas carbonate content in the argillaceous-silty limestone only averages about 50 percent. The applicant stated that approximately thirty percent of the purer carbonate rock is dolomite.

The applicant described the Nashville Group as a fossiliferous, silty and argillaceous limestone that conformably overlies the Stones River Group. The base of the Nashville group contains bentonite beds, similar to those in the upper Stone River Group. The Nashville Group is 82 m (270 ft.) thick and underlies some of the existing service buildings constructed for BLN 1 and 2.

The Nashville group is higher in the sedimentary section than the BLN 3 and 4 power block construction zone and therefore does not underlie the proposed BLN 3 and 4 Units.

The applicant described the Upper Ordovician (460-440 Ma) Sequatchie Formation as conformably overlying the Nashville Group. The Sequatchie Formation, characterized by interbedded limestone, shale and mudstone, forms the core and the crest of River Ridge, located just east of the BLN site. The Red Mountain Formation lies unconformably over the Sequatchie Formation, is a shallow-marine sequence of Silurian (443-417 Ma) age, and is composed of interbedded sandstone, siltstone, shale and limestone as well as thin interbedded layers of hematite.

Quaternary Units. In FSAR Subsection 2.5.1.2.3.2.2, the applicant described the Quaternary units in the vicinity of the BLN site including alluvial and colluvial sediments and residual soils. Thin layers of Quaternary alluvium exist in limited areas throughout Northern Alabama, specifically along major and minor streams. Quaternary alluvium exists near the site as remnant fluvial terrace deposits of the Tennessee River, which are mapped along the margins of the Guntersville Reservoir. Quaternary alluvium also exists near the site as valley fill, deposited by streams draining from higher elevations. Similar to the alluvial deposits, Quaternary age colluvium exists in limited quantities near the site, characterized by thin deposits that have accumulated at the bases of hill slopes or along the slopes within hollows, or depressions.

The applicant described residual soils that average 3 to 5 m (10 to 15 ft.) in thickness within an 8 km (5 mile) radius of the BLN site. These soils blanket the bedrock and are grouped according to their topographic position. The majority of soils nearest to the BLN site consist of a thin veneer of residual soils that formed from the in-situ weathering of the existing bedrock.

Site Structural Geology

BLN COL FSAR Section 2.5.1.2.5 provides a review of the structural geology surrounding the BLN site. The applicant based its descriptions on existing literature reviews, including the FSAR for BLN 1 and 2, and on new data obtained for BLN 3 and 4, including geologic mapping and borehole data. The BLN site is situated on the gently dipping southeast limb of the Sequatchie anticline, within the Appalachian fold-thrust belt. Borehole data indicates that the strata beneath the BLN 3 and 4 power block construction zone dip gently to the southeast approximately 15-17 degrees.

Faults. The applicant stated that there are two bedrock faults within the 40 km (25 mile) site vicinity but considers neither of these faults to be a capable tectonic source. One of these faults, the Sequatchie Valley thrust fault, lies within the site area, or within the 8 km (5 mile) site radius. BLN COL FSAR Section 2.5.3 discusses the two faults in greater detail. The applicant identified no intense folding or major faulting within the foundation bedrock for BLN 1 and 2, based on previous investigations.

Sequatchie Valley Fault

SER Figure 2.5-2 (reproduced from FSAR Figure 2.5-228) shows the Sequatchie Valley thrust fault, which cuts the Sequatchie anticline 3.5 km (2.2 miles) west-northwest of the BLN site. This fault dips to the southeast and projects to a depth of approximately 1.5 km (5000 ft.) beneath the BLN site. The Sequatchie Valley thrust fault appears to have numerous small faults associated with it and these are visible in an excavation approximately 6 km (3.8 miles) from the BLN site. The applicant attributes these small faults to being splay or backthrust faults in the hanging wall of the primary thrust fault. The applicant stated that the Sequatchie Valley fault offsets units of Ordovician and Mississippian age in the site area but no features or deformation are present that indicate potential Quaternary activity. Therefore, the applicant does not consider the Sequatchie Valley thrust fault to be a capable tectonic source.

Joints. Excavations for BLN 1 and 2 identified a single minor displacement with 7.6 centimeter (cm) (3 inch [in.]) of vertical offset beneath the northwest corner of the BLN Unit 1 QA Records Storage Vault. Additional investigations to observe the offset relied on core drilling and surface mapping. The applicant stated that TVA concluded, at the time of the investigation, that the offset was a result of joint formation processes within a single joint, and not a significant fault. The applicant stated that those excavations identified no other evidence for faulting or displacement.

BLN COL FSAR Section 2.5.1.2.5 describes at least three high angle joint sets that were identified in the BLN 1 and 2 FSAR. The applicant observed one of those prominent joint sets in core fractures and borehole televiewer data collected for BLN 3 and 4. The applicant stated that primary compressive forces and northwest-southeast shortening associated with late Paleozoic (354-248 Ma) thrusting and mountain building likely created these high angle joint sets. The applicant further stated that the joint sets identified during the BLN 1 and 2, and the BLN 3 and 4 investigations reflect regional trends observed throughout the Appalachian Plateau.

Lineaments. The applicant conducted a lineament analysis for the BLN site as a response to linear features identified on topographic maps and in aerial photographs of the site. BLN COL FSAR Section 2.5.3.1 discusses the applicant's investigation in detail and Section 2.5.3.4 of this SER provides the staff's review of the investigation. The applicant found no geomorphic, structural or stratigraphic evidence to suggest differential uplift or lateral displacement across any of the lineaments that intersect the site and no evidence to indicate that any of the identified lineaments are associated with capable tectonic sources.

Site Engineering Geology

BLN COL FSAR Section 2.5.1.2.6 describes the site engineering geology evaluation that the applicant performed. The applicant reviewed published maps and reports, performed a visual reconnaissance of the area and reviewed data from the TVA 2006 geotechnical evaluation for the abandoned site in order to evaluate the engineering geology at the site, which included geologic hazards. The applicant identified two potential geologic hazards at the BLN site; karst-related ground failure, or subsidence due to underground dissolution, and earthquake activity with resulting ground motion effects. The applicant investigated the potential for other geologic hazards at the site, including landslides, but concluded that no others exist. Finally, the applicant investigated the potential for ground subsidence or deformation due to human-induced activities and concluded that there are no human activities such as mining or fluid withdrawal near the BLN site.

The applicant anticipated potential hazards due to karst related ground failure to be minor at the site. The applicant compared exploration data for BLN 3 and 4 with conditions encountered at BLN 1 and 2 as a basis for its conclusion that any potential karst-related ground failures can be mitigated with proper excavation methods. BLN COL FSAR Section 2.5.4.1 further develops the applicant's discussion of karst, its potential for causing ground failure at the site, and related excavation and construction activities.

The applicant concluded that there is negligible potential for tectonic surface deformation at the BLN site and presented a more detailed review of surface faulting in BLN COL FSAR Section 2.5.3. The applicant accounted for potential large earthquakes that could affect the site in its development of the site GMRS. BLN COL FSAR Section 2.5.2 discusses vibratory ground motion and the applicant's establishment of the site GMRS.

Steep slopes that characterize River Ridge to the east of the site exhibit small landslides. These landslides are directed eastward away from the site. The applicant assessed the stability of these slopes in BLN COL FSAR Section 2.5.5. The applicant stated that no other slopes are considered to be a hazard to the site.

The applicant stated that there are no groundwater withdrawal activities, petroleum production or subsurface mining operations (past or present) that could lead to subsidence and create a hazard due to human-induced activities at the BLN site. Limestone and chert quarries along the Sequatchie Valley are a minimum of 3 to 8 km (2 to 5 miles) from the BLN site and the applicant stated that human activities related to these quarries do not pose a hazard at the site.

The applicant evaluated rock strength, zones of alteration, zones of structural weakness, liquefaction potential, dissolution, and residual stress related to the BLN site in BLN COL FSAR Sections 2.5.4 and 2.5.5. BLN COL FSAR Sections 2.4.12 and 2.5.4.6 provide a detailed evaluation of the groundwater conditions for the site.

2.5.1.3 Regulatory Basis

The regulatory basis of the information incorporated by reference is addressed within the FSER related to the DCD.

In addition, the relevant requirements of the Commission regulations for geologic and seismic information, and the associated acceptance criteria, are given in Section 2.5.1 of NUREG-0800.

The applicable regulatory requirements for reviewing geologic and seismic information 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 Section 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 must satisfy the requirements of 10 CFR 100.23 with respect to the development of the SSE.

The related acceptance criteria from Section 2.5.1 of NUREG-0800 are as follows:

- Regional Geology: In meeting requirements of 10 CFR 52.79 and 10 CFR 100.23, 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.

- Site Geology: In meeting requirements of 10 CFR 52.79 and 10 CFR 100.23, and regulatory positions presented in RG 1.165, "Materials and Inspections for Reactor Vessel Closure Studs," RG 1.208, RG 1.132, "Site Investigations for Foundations of Nuclear Power Plants," RG 1.138, "Laboratory Investigations of Soils and Rocks for Engineering Analysis and Design of Nuclear Power Plants," RG 1.198, "Procedures and Criteria for Assessing Seismic Soil Liquefaction at Nuclear Power Plant Sites," RG 1.206, and RG 4.7, FSAR Section 2.5.1.2 will be considered acceptable if it contains a description and evaluation of geologic (including tectonic and non- tectonic) features, geotechnical characteristics, seismic conditions, and conditions caused by human activities at appropriate levels of detail within areas defined by circles drawn around the site using radii of 40 km (25 miles) for site vicinity, 8 km (5 miles) for site area, and 1 km (0.6 mile) for site location.

2.5.1.4 Technical Evaluation

The NRC staff reviewed Section 2.5.1 of the BLN COL FSAR and checked the referenced DCD to ensure that the combination of the DCD and the information in the COL represent the complete scope of information relating to this review topic.[1] The NRC staff's review confirmed that the information contained in the application and incorporated by reference addresses the required information relating to the basic geologic and seismic information. Section 2.5.1 of Revision 17 to the AP1000 DCD is being reviewed by the staff under Docket Number 52-006. The NRC staff's technical evaluation of the information incorporated by reference related to the basic geologic and seismic information will be documented in the staff SER on the DC application for the AP1000 design.

The staff reviewed the following information contained in the BLN COL FSAR:

AP1000 COL Information Item

- BLN COL 2.5-1

The NRC staff reviewed BLN COL 2.5-1 related to the evaluation of the geologic, seismic and geophysical information included under Section 2.5.1 of the BLN COL FSAR. The technical information presented in BLN COL FSAR Section 2.5.1 resulted from the applicant's surface and subsurface geologic, seismic, and geotechnical investigations, which were undertaken at increasing levels of detail moving closer to the site. Through its review of BLN COL FSAR Section 2.5.1, the staff determined whether the applicant had complied with the applicable NRC regulations and conducted its investigations at the appropriate levels of detail within the four circumscribed areas designated in RG 1.208, which are defined based on various distances from the site (320 km (200 miles), 40 km (25 miles), 8 km (5 miles), and 1 km (0.6 mile)).

BLN COL FSAR Section 2.5.1 contains geologic and seismic information collected by the applicant in support of the vibratory ground motion analysis and the site GMRS provided in BLN COL FSAR Section 2.5.2. RG 1.208 recommends that applicants update the geologic, seismic, and geophysical database and evaluate any new data to determine whether revisions to the existing seismic source models are necessary. Consequently, the staff focused its review on geologic and seismic data published since the mid to late 1980s to assess whether these data indicate a need to update the existing seismic source models.

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 BLN 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 BLN site in October 2008, 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 BLN COL FSAR Section 2.5.1 and of the applicant's responses to RAIs is presented below.

The NRC staff reviewed the resolution to BLN COL 2.5-1 that addresses the provision of regional and site-specific geologic, seismic, and geophysical information, as well as conditions caused by human activities included under Section 2.5.1 of the BLN COL. Additional aspects of this information item are addressed in Sections 2.5.2 and 2.5.4 of this SER. Based on the applicant's regional and site geologic descriptions in BLN COL FSAR Section 2.5.1, the staff concludes that the applicant provided the information required to satisfy BLN COL 2.5-1.

2.5.1.4.1 Regional Geology

The staff focused its review of BLN COL FSAR Section 2.5.1.1 on the applicant's description of the regional physiography, geomorphology, geologic history, stratigraphy and tectonic history, within a 320 km (200 mile) radius of the BLN site.

Regional Physiography and Topography

BLN COL FSAR Section 2.5.1.1.1 describes portions of six different physiographic provinces found within the BLN site region. The applicant stated that the BLN site is located within the Appalachian Plateaus province and is bordered by the Valley and Ridge, Blue Ridge and Piedmont provinces to the east, the Interior Low Plateaus to the northwest, and the Coastal Plain to the southwest, south and east. Based on its review of BLN COL FSAR Section 2.5.1.1.1, the staff concludes that the applicant provided a thorough and accurate description of physiographic and topographic features within the site region in support of the BLN COL application.

Regional Geologic History

BLN COL FSAR Section 2.5.1.1.2 describes the orogenic, or mountain building, history of the region, with particular emphasis on the Appalachian orogen, where the BLN site is located. Proterozoic (1.1 to 1.0 Ga) rocks formed the basement beneath the BLN site upon which younger stratigraphic packages were deposited. Subsequent orogenies, including the Appalachian orogeny, involved a series of ocean basin openings and closings along what would become the Atlantic coast. Based on its review of BLN COL FSAR Section 2.5.1.1.2, the staff concludes that the applicant provided a thorough and accurate description of the regional geologic history, including key mountain building (orogenic) processes within the BLN site region in support of the BLN COL application.

Regional Stratigraphy

BLN COL FSAR Section 2.5.1.1.3 describes the regional stratigraphy for each physiographic province in the region, which includes a mix of sedimentary rocks of Precambrian to Tertiary age (800 to 50 Ma) as well as igneous and metamorphic rocks of Proterozoic to Paleozoic age (2.5 Ga to 245 Ma). The applicant stated that the Quaternary (1.8 Ma to present) deposits for the region tend to be thin, discontinuous, and difficult to date, and therefore, these deposits were not discussed in great detail.

The staff focused its review of BLN COL FSAR Section 2.5.1.1.3 on the applicant's descriptions of the stratigraphy within the site region. The staff concentrated on surfaces and deposits of Quaternary age (less than 1.8 Ma) that, while limited in the region, are preserved as fluvial deposits along major rivers and streams and provide useful markers for the presence, or absence, of geologically recent tectonic activity.

BLN COL FSAR Section 2.5.1.1.3.2 describes sub-vertical, upward-widening soil features that are present in an alluvial terrace deposit exposed in Gadsden, Alabama, approximately 80 km (50 miles) from the BLN site. Figure 2.5.1-3 (reproduced from FSAR Figure 2.5-208a) shows the location of the soil features in relation to the BLN site. The applicant stated that these features are not associated with any vertical offset, or deformation, and that they are similar in appearance to non-tectonic soil weathering features present in other areas within the Coastal Plain of the southeastern United States. In RAI 2.5.1-1, the staff asked the applicant to provide observations, measurements, or analyses, as well as any additional documentation to demonstrate whether or not these features could be seismically induced. This clarification is important because seismicity is known to occur in the site region, and the staff must ensure that none of the features described by the applicant in BLN COL FSAR Section 2.5.1.1.3.2 are related to Quaternary tectonic deformation not accounted for in the applicant's PSHA.

In response to RAI 2.5.1-1, the applicant stated that, based on its field evaluation of the exposures at Gadsden, Alabama, and its review of the pedologic (soil science) literature, soil weathering processes are responsible for the formation of these subvertical features. The features are exposed in an iron-rich soil horizon composed of mottled, silty-clay loam. Figure 2.5.1-4 (reproduced from BLN COL FSAR Figure 2.5-209) shows the exposed soil features and their characteristics. The applicant stated that while the exact age of the soil deposits is not known, it interpreted the soils to be early to middle Pleistocene, or at least hundreds of thousands of years old.

The applicant referred to the features as veins that typically: (1) vary from 0.5 to 2 inches in width; (2) do not vary in thickness at depth; (3) contain reddish iron-cementation along the edges; and (4) do not offset, or displace, surrounding host sediments, often retaining the surrounding soil texture and fabric. The applicant stated that the soil science literature refers to these features, or veins, as bleached fractures and provided the following technical rationale for their genesis:

> They form from the cracking of a partially cemented or brittle soil horizon during seasonal drying, followed by infiltration of fresh rainwater along the crack, mobilizing free iron and translocating silt and clay into the crack from the upper soil horizons. Water is drawn into the partially cemented block on the margins of the fracture; iron is then precipitated from the water in the walls of the fractures as the soil dries again, forming the red borders adjacent to the fracture. The

fracture becomes a preferred pathway for the infiltration of water and for root penetration, and over time takes on a bleached appearance.

Regarding the potential for these subvertical veins to be tectonic, or seismic in origin, the applicant stated that the veins are not characteristic of earthquake-induced liquefaction features because the veins: (1) are not made up of liquefiable sediments; (2) "do not appear to originate from a layer of liquefiable material at depth;" (3) do not widen upward "into a surficial deposit of erupted silt and sand;" (4) retain the characteristics of the surrounding soil horizon; and (5) do not offset, or displace, the stratigraphic units across the veins. Based on the above lines of evidence, the applicant concluded that the subvertical features, or veins, investigated in the exposed soil horizons at Gadsden, Alabama, are soil weathering features and not earthquake-induce liquefaction features.

Based on its review of the applicant's response to RAI 2.5.1-1, the staff concludes that the applicant provided adequate information to justify its conclusion that the observed subvertical features are related to soil weathering processes. In addition, the staff concludes that the applicant provided sufficient documentation to assist in ruling out a tectonic, or seismic, origin for the features. However, to make further verification of the characteristics of the features described by the applicant, the staff and its USGS counterparts visited the soil exposures in Gadsden, Alabama and investigated more than 20 subvertical veins within the soils.

The following critical observations were made to strengthen the conclusion that the features, or veins, described by the applicant are non-seismic in origin: (1) none of the investigated veins exhibited evidence of flow in an upward direction that is typical of earthquake-induced liquefaction features; (2) multiple veins appeared to crosscut gravel lenses, however, the material within the veins included gravels, most likely from the lenses, as well as the same apparent matrix material, all of which was undisturbed by the veins crossing through it; (3) none of the aforementioned gravel clasts was observed in the veins above the gravel lenses, yet a few clasts were observed below the lenses that were cut by the veins; (4) with the exception of the gravel clasts, no vein filling was observed to be coarser-grained than the adjacent host material, regardless of the host grain size (in some cases the grain size within the veins was finer than the host and in other cases it was the same); (5) abundant soil mottles (irregularly shaped elliptical features) that were observed on sloping and sub-horizontal surfaces within the same soil horizons as the veins in question, suggest that they extend three-dimensionally through the soil horizons, are potentially tubular and exhibit sedimentary structure and grain size variation similar to that of the veins; and (6) soil mottling is more prevalent in the shallower soil horizons and appears to represent root casts or burrows that served as conduits for water flowing downward and for infiltration of materials from above.

Liquefaction typically involves the upward movement of sandy, loosely consolidated sediments that are injected upward into and through a finer-grained sediment cap. If the veins in question were liquefaction features, then the vein fillings would most likely be coarser than that of the surrounding host material. In the observed veins, however, the vein fillings were finer-grained or the same as the adjacent host material, with noted exceptions. Furthermore, the veins did not exhibit a sense of upward movement of material and in some cases exhibited downward movement of material within the veins. The mottles representing root casts and burrows in shallower soils exhibited an appearance similar to that of the subvertical veins, suggesting that the same chemical and physical soil formation processes were present.

Based on the applicant's response to RAI 2.5.1-1 and the staff's confirmatory observations, the staff concludes that sufficient evidence exists to rule out an earthquake-induced origin for the subvertical features, or veins, located in the soil exposures at Gadsden, Alabama. Furthermore, the staff concludes that the veins were most likely formed by physical and chemical soil weathering processes, based on information presented by the applicant and evidence that the staff observed in the field, as described above. As part of its response to RAI 2.5.1-1 the applicant stated that it would make a future revision to the FSAR to provide more description of the subvertical features and discussion of the evidence that supports the applicant's conclusion that the features are non-seismically induced. This is **Confirmatory Item 2.5.1-1**.

Based on its review of BLN COL FSAR Section 2.5.1.1.3 and resolution of RAI 2.5.1-1, the staff concludes that the applicant provided an accurate description of the regional stratigraphy in support of the BLN COL application.

Regional Tectonic Description

BLN COL FSAR Section 2.5.1.1.4 describes the regional tectonic setting within a 320 km (200 mile) radius of the proposed site of BLN 3 and 4. The applicant divided this section into multiple subsections that describe the contemporary stress environment, structural features and seismicity zones within the 320 km (200 mile) site radius, and significant seismic sources at distances greater than 320 km (200 miles).

<u>Contemporary Stress Environment.</u> In BLN COL FSAR Subsection 2.5.1.1.4.1, the applicant stated that the site is encompassed by a compressive mid-plate stress province that is characterized by a near uniform compressive stress field with a maximum horizontal shear direction oriented northeast to east-northeast. The applicant concluded that the analyses of the stress environment demonstrated that CEUS earthquakes occur primarily in response to a transform (strike-slip) stress regime.

<u>Tectonic Structures in the Site Region.</u> BLN COL FSAR Subsection 2.5.1.1.4.2 describes the regional tectonic structures within the 320 km (200 mile) radius from the site. The applicant identified several lithotectonic subdivisions in the region, including the Appalachian Foreland Thrust Belt and Subdetachment Basement Faults nearest to the BLN site. The applicant also described other major faults that are mapped farther from the site yet within the 320 km (200 mile) radius of the site. The applicant concluded that all of the identified "major" faults within the site region (320 km, or 200 mile radius) exhibit Paleozoic (543 to 248 Ma) and older deformation and that based on the most recent literature, none is considered a capable fault, as defined by RG 1.208.

<u>Appalachian Foreland Thrust Belt and Subdetachment Basement Faults</u>

BLN COL FSAR Subsection 2.5.1.1.4.2.1 describes the regional tectonic feature on which the BLN 3 and 4 site is located, the Appalachian foreland thrust belt. The belt consists of a stack of mostly thin-skinned thrusts (meaning that the thrust faults occur above a subhorizontal detachment surface) in an unconfined wedge configuration. The applicant concluded that none of the thrust faults in the Appalachian Foreland thrust belt is a capable tectonic structure based on information available in the published literature and on historical seismicity records that suggest that the most recent earthquakes occurred at depths coincident with basement rock beneath the Appalachian detachment zone.

BLN COL FSAR Subsection 2.5.1.1.4.2.2 describes basement faults that lie beneath the Appalachian detachment and briefly discusses the seismic potential of these basement faults. The applicant concluded that there is no indication that the mapped basement faults have been reactivated in the current tectonic stress field based on a lack of surficial geologic evidence and a lack of current seismicity associated with any known basement fault.

BLN COL FSAR Section 2.5.1.1.4.2 describes the Appalachian foreland thrust belt and Subdetachment basement faults as independent structural zones. SER Figure 2.5.1-5 (based on BLN COL FSAR Figure 2.5-220) identifies subdetachment basement faults, most of which exhibit a northeast strike. SER Figure 2.5.1-6 (based on BLN COL FSAR Figure 2.5-294) shows Appalachian thrust faults that overlie the basement faults and suggests that these thrust faults are similar in trend to the basement faults. Furthermore, some of the Appalachian thrust faults and the underlying subdetachment basement faults appear to be mapped in close proximity to one another. In RAI 2.5.1-4, the staff asked the applicant to explain this coincidence and to discuss, given the uncertainty in determining exact fault location at depth, whether or not the thrust faults could actually penetrate the detachment surface rather than soling (flattening) into it, making the thrust faults shallower extensions of the basement faults mapped at depth.

In response to RAI 2.5.1-4, the applicant stated that the geometry of the Appalachian thrust faults, described in BLN COL FSAR Sections 2.5.1.1.4.2 and 2.5.3 and shown in BLN COL FSAR Figure 2.5-294, is based on geologic mapping, seismic reflection profile interpretation, as well as paleomagnetic and deep well data. The applicant provided numerous publications that referenced the Appalachian thrust system and provided a basis for its characterization of the thrust faults and the structural model that it presented in the BLN COL FSAR. In its response to RAI 2.5.1-4, the applicant provided a map, based on Thomas and Bayona (2005), which shows 18 northwest to southeast structural cross sections that were created to constrain the structure of the Appalachian thrust belt. These structural cross sections and the data compiled by Thomas and Bayona, recognized experts in southern Appalachian structural geology, helped to determine the depth to basement interpretations presented in SER Figure 2.5.1-5, as well as the locations and orientations of the basement faults and the overlying thrust faults and detachment surface.

All of the published literature presented by the applicant suggests that the Precambrian (greater than 543 Ma) basement faults are northeast striking normal faults offset by other northwest striking normal and transverse faults. An uneven topographic basement surface reflects the Precambrian faulting. Paleozoic sedimentary units overlie the uneven basement surface. Alleghanian compression during the Late Paleozoic (354 to 290 Ma) was responsible for the formation of the Appalachian thrust faults, including the Sequatchie Valley and Big Wills Valley thrust faults described in BLN COL FSAR Sections 2.5.1.1.4.2 and 2.5.3 and shown in SER Figure 2.5.1-6. These thrust faults flatten, or sole, into a decollement (or detachment surface) within a weak, Cambrian age (543 to 490 Ma) sedimentary shale unit.

In response to RAI 2.5.1-4, the applicant stated that the uneven basement surface influenced the overlying thrust faulting as seen in the ramp-like structure presented in BLN COL FSAR Figure 2.5-217. SER Figure 2.5.1-7 (provided by the applicant in response to RAI 2.5.1-4), shows a more detailed example of the relationship between the Precambrian basement faults, the overlying ramp-like structure above the detachment surface, and the late Paleozoic thrust faults. SER Figure 2.5.1-7 is based on an enlarged structural cross section from Thomas and Bayona (2005) and clearly shows that while the basement faults influence the overlying structure, the overlying thrust faults do not appear to represent extensions of the basement faults. The applicant indicated that due to the influence of the basement faults at depth on the overlying structure, it is not unusual for these basement faults to be in similar alignment and close proximity with the overlying thrust faults.

In its conclusion to RAI 2.5.1-4, the applicant provided the following statement:

> These two types of faults- the Precambrian basement normal faults and the Paleozoic thrust faults- are different in age, in sense of motion, and in the rocks they displace. Their apparent spatial coincidence is a reflection of the influence that fault-related topography on the basement surface has had on the initiation of the thrust ramps.

In addition, the applicant stated that the location of the basement fault associated with the Sequatchie Valley thrust fault near the BLN site, as shown in BLN COL FSAR Figure 2.5-217 and SER Figure 2.5.1-7, is an inferred location and is not well constrained. With respect to this basement fault, the applicant stated the following:

> The two seismic reflection profiles that image this fault nearest the BLN site are located 33 mi. southwest and 23 mi. northeast of the site (Figure 1 of Attachment 02.05.01-04A). However, the occurrence of a basement fault associated with the Sequatchie Valley fault is inferred by the association of vertical basement faults with thrust faults in areas where direct data do exist, such as along the Wills Valley fault. Geologic reasoning leads to the conclusion that a vertical basement fault is likely to be present near the BLN site, its location bounded by the surface trace of the Sequatchie Valley fault on the northwest, and the eastern edge of the Sequatchie anticline (approximately the western edge of Sand Mountain) on the southeast. Neither the Sequatchie Valley fault nor the underlying basement fault are active, and no seismicity has been directly associated with these structures.

To fully evaluate the applicant's response to RAI 2.5.1-4, the staff reviewed the evidence presented by Thomas and Bayona (2002, 2005), Thomas (2001), and Bayona et al. (2003) as well as the evidence provided by the applicant to support its conclusion that the Appalachian thrust faults sole, or flatten, into a regional detachment surface and are not extensions of the underlying basement faults. With respect to the proximity of the thrust faults and basement faults, the staff concurs with the applicant's conclusion that the underlying basement fault structure influences the overlying thrust faults but that the two fault types are not joined and the thrust faults do not project beneath the basement surface. In summary, the staff concludes that the applicant has adequately evaluated the relationship between the basement normal faults and the overlying thrust faults and made a reasonable conclusion that shallower thrust faults do not represent extensions of the deeper basement faults.

<u>Seismic Sources within the Site Region.</u> BLN COL FSAR Subsection 2.5.1.1.4.2.4 describes the two major seismic zones that the applicant identified in the site region, the Giles County, Virginia, and East Tennessee seismic zones.

BLN COL FSAR Subsection 2.5.1.1.4.2.4.2 describes the ETSZ, a northeasterly trending seismicity belt stretching 187 miles through the Blue Ridge and Valley and Ridge physiographic provinces. The applicant stated that focal mechanisms associated with historical seismicity in the ETSZ indicate strike-slip faulting on steeply dipping planes resulting form a uniform regional, compressive stress field. The largest recorded earthquakes reported in the ETSZ are the M 4.6 1973 Maryville, Tennessee and the April 2003 Fort Payne, Alabama earthquakes. The applicant noted that the seismicity is not uniformly distributed throughout the ETSZ. In RAI 2.5.1-3, the staff asked the applicant to discuss the likelihood that some of the recorded earthquakes in the BLN site vicinity are associated with one or more of the mapped faults shown in SER Figures 2.5.1-5 and 2.5.1-6, given the uncertainty in locating earthquakes in most seismic network data.

In its response to RAI 2.5.1-3, the applicant acknowledged that there is an element of uncertainty associated with locating earthquakes in the ETSZ due to the sparse seismic network in Alabama and the surrounding states. However, the applicant added that there are models that were developed specifically for the southeastern area encompassing the BLN site, and that the use of these models provides an added level of confidence in the results.

The applicant provided a modified version of BLN COL FSAR Figure 2.5-294, showing the 68 percent confidence error ellipsoids used in estimating hypocentral earthquake locations in the horizontal plane, based on instrumentally located earthquakes. This modified figure, as part of the applicant's response to RAI 2.5.1-3, shows all of the estimated earthquake locations within the 40 km (25 mile) site radius, and just beyond. The applicant stated in its response that the uncertainty associated with a majority of the error ellipsoids is less than 2 km (1.2 miles) in the horizontal plane, supporting its assumption that a majority of the earthquakes located within the 40 km (25 mile) site radius lie to the northwest of the Sequatchie Valley thrust fault and are not likely related to the Sequatchie Valley fault.

As part of its response to RAI 2.5.1-3, the applicant provided a histogram that shows earthquake focal depths for 19 of the earthquakes shown in BLN COL FSAR Figure 2.5-294. The applicant stated that these 19 earthquakes "represent the best-constrained hypocenter locations, and should have minimum bias in the focal depth estimates due to uncertainty in the assumed velocity model." The applicant noted that only one of the 19 "best-constrained" earthquakes has an estimated focal depth that is less than 4 km (2.4 miles). Estimated focal depths for the remaining 18 earthquakes range from 5 to 22 km (3.1 to 13.7 miles). The applicant made the following conclusion:

> This distribution derived for events in the vicinity of the Bellefonte site is consistent with results for the Eastern Tennessee seismic zone as a whole (FSAR Reference 292), showing 90% of the focal depth estimates below 5 km, with a median depth of 16.8 km, in the mid-crust. The crystalline basement within 25 miles of the site is at a depth of approximately 2 to 2.5 km (see SER Figure 2.5.1-5), so the earthquake hypocenters demonstrate that the seismicity shown in FSAR Figure 2.5-294 is almost exclusively within the crystalline basement, thus supporting the conclusion that faults shown in FSAR Figure 2.5-294 are not capable faults.

Based on its review of the applicant's response to RAI 2.5.1-3, the staff notes that the applicant acknowledged the uncertainties associated with estimating earthquake focal depths, given the sparse network of seismographs in the southeastern United States. The staff concludes that the applicant reasonably demonstrated that the majority of the seismicity within the 40 km (25 mile) BLN site radius (and beyond) occurs at depths greater than that of the inferred Appalachian detachment zone, thus making it unlikely that the Appalachian thrust faults are the source of ongoing seismicity. With respect to subdetachment basement faults, the only basement fault that is mapped within the 40 km (25 mile) BLN site radius is an inferred fault, as noted by the applicant in its responses to RAI 2.5.1-3 and RAI 2.5.1-4 . The staff concludes that the applicant did not clearly address the likelihood of correlating earthquakes in the site vicinity with mapped basement faults. However, the staff concurs with the applicant's conclusion that based on the available data, no direct correlations can be made between individually located earthquakes and known basement faults. Furthermore, the staff finds the applicant's conclusion adequate, given the lack of data points to precisely constrain the location of some basement faults in addition to the added uncertainty of estimating earthquake hypocenters.

Based on its review of BLN COL FSAR Section 2.5.1.1.4.2.4, the staff concludes that the applicant adequately characterized the zones of seismicity within the BLN site region in support of the BLN COL application. The staff provides a more detailed evaluation of the potential seismic hazard associated with the Eastern Tennessee seismic zone in SER Section 2.5.2.4, based on the applicant's additional descriptions in BLN COL FSAR Section 2.5.2.

Significant Seismic Sources at Distances Greater than 320 km (200 miles). In BLN COL FSAR Subsection 2.5.1.1.4.3.1, the applicant provided a brief overview of the seismic sources in the New Madrid region. This is the source region for the three largest earthquakes recorded in the CEUS during historical time, the 1811-1812 New Madrid earthquakes. The applicant referred to FSAR Subsection 2.5.2.4.4.1 for additional details, due to the influence of the New Madrid seismic source on vibratory ground motion at the BLN site. FSAR Subsection 2.5.1.1.4.3.2 describes the Charleston, South Carolina seismic source. The applicant discussed this source with emphasis on the repeat times for large, 1886-type earthquakes and their associated maximum magnitudes. FSAR Subsection 2.5.2.4.4.2 provides additional discussion of the Charleston seismic source as it relates to the BLN updated PSHA.

Based upon its review of BLN COL FSAR Section 2.5.1.1.4.3, the staff concludes that the applicant provided a thorough and accurate description of the significant seismic sources at distances greater than 320 km (200 miles) from the BLN site in support of its COL application. SER Section 2.5.2 evaluates the models for each of these seismic sources.

Staff Conclusions of the Regional Tectonic Description

Based upon its review of BLN COL FSAR Section 2.5.1.1.4, the staff concludes that the applicant provided a complete and accurate description of the regional tectonics surrounding the BLN site, including the tectonic stresses in the region, major regional structures within a 320 km (200 mile) radius of the site, zones of seismicity within the site region, and significant seismic sources at distances greater than 320 km (200 miles) from the BLN site. The staff concludes that the regional tectonic description provided in BLN COL FSAR Section 2.5.1.1.4 reflects the current literature and state of knowledge and meets the requirements of 10 CFR 52.79 and 10 CFR 100.23.

2.5.1.4.2 Site Geology

In BLN COL FSAR Section 2.5.1.2, the applicant discussed geologic conditions of the site vicinity (40-km [25-mi] radius), site area (8-km [5-mi] radius) and site location (1-km [0.6-mi] radius). The staff focused its review of BLN COL FSAR Section 2.5.1.2 on the applicant's description of the site-related geologic features and structures, as well as conditions caused by human activities. Based on its review of BLN COL FSAR Section 2.5.1.2, described below, the staff concludes that the applicant has provided a thorough and accurate description of the local geology in support of the BLN COL application.

Site Physiography and Topography

In BLN COL FSAR Section 2.5.1.2.1, the applicant stated that the BLN site is situated in the southeastern portion of the Browns Valley-Sequatchie Valley, a segment of the Cumberland Plateau, which is part of the Appalachian Plateaus Physiographic Province. The Browns

Valley-Sequatchie Valley is an erosional remnant of the Sequatchie anticline and extends northeast-southwest for approximately 225-km (140-mi). Based on its review of BLN COL FSAR Section 2.5.1.2.1, the staff concludes that the applicant provided a complete and accurate description of the site physiography and topography in support of the BLN COL application.

Site Geologic History

BLN COL FSAR Section 2.5.1.2.2 provides a description of the geologic history within a 40 km (25 mile) radius of the site. The oldest rocks in the site vicinity are believed to be late-Proterozoic in age, approximately 1000 to 750 Ma, and lie at depths greater than 2400 m (1.5 miles) beneath the ground surface. The applicant stated that there is a gap between the Proterozoic basement rocks and the deposition of the sedimentary rocks that lie beneath the site. Based upon its review of BLN COL FSAR Section 2.5.1.2.2, the staff concludes that the applicant provided a complete and accurate description of the site geologic history in support of the BLN COL application.

Site Stratigraphy

BLN COL FSAR Section 2.5.1.2.3 describes the stratigraphic units that the applicant mapped within a 1 km (0.6 mile) radius of the site, including several thousand feet of Paleozoic bedrock overlain by thin layers of unconsolidated Quaternary sediments. As mentioned in the previous SER section, there is a gap in the depositional record between the oldest rocks and the youngest sediments in the BLN site vicinity. Thin layers of Quaternary sediments that do exist are limited and may be found along larger streams and on hill slopes and hollows. Based upon its review of BLN COL FSAR Section 2.5.1.2.3, the staff concludes that the applicant provided a complete and accurate description of the BLN site stratigraphy in support of the BLN COL application.

Site Structural Geology

BLN COL FSAR Section 2.5.1.2.5 provides a review of the structural geology surrounding the BLN site. The applicant based its descriptions on existing literature reviews, including the FSAR for BLN 1 and 2, and on new data obtained for BLN 3 and 4, including geologic mapping and borehole data. The BLN site is situated on the southeast limb of the Sequatchie anticline. The applicant stated that there are two bedrock faults within the 40 km (25 mile) site vicinity, the Sequatchie Valley and Wills Valley faults, but considers neither of these faults to be a capable tectonic source. The applicant discussed both of these faults in more detail in BLN COL FSAR Section 2.5.3 and SER Section 2.5.3.4 provides the staff's detailed evaluation of faults within the BLN site vicinity.

In BLN COL FSAR Section 2.5.1.2.5, the applicant stated that a single minor displacement with 7.6 cm (3 in.) vertical offset was observed beneath the northwest corner of the BLN Unit 1 QA Records Storage Vault, during excavations for BLN 1 and 2. No other evidence for faulting or displacement was encountered during those excavations. The observed offset was investigated by core drilling and surface mapping and determined to be a northeast striking joint that was insignificantly displaced during the joint set formation. In RAI 2.5.1-2, the staff asked the applicant to explain the age of the vertical offset.

In its response to RAI 2.5.1-2, the applicant stated that the relative age of the vertical offset observed during excavation for BLN 1 and 2 is Late Paleozoic (354 to 248 Ma). In addition, the applicant stated that the offset joint, joint J2, is one of many joints and fractures in the site area that most likely formed due to the same orogenic processes responsible for the formation of the Sequatchie Valley anticline. The applicant provided a reference by Wiltschko (1989) that described the regional jointing in the Southern Appalachians as well as a reference by Coulson (1977) that evaluated the specific joint offset in question. The applicant provided the following conclusion from Coulson (1977):

> …the feature is not a significant fault, but is a joint that received minor shear displacement during the process that developed the entire joint set…

Based on its review of the applicant's response to RAI 2.5.1-2, the staff concurs with the applicant that the vertically offset joint most likely formed at the same time as other similarly oriented joints in the site area. However, the applicant did not provide an adequate description of the basis for its assumption that the offset joint was Late Paleozoic in age, other than to restate the previous conclusion from Coulson (1977).

In response to RAI 2.5.1-2, the applicant provided a copy of the Coulson (1977) report to the staff for further consideration. In its evaluation of the Coulson (1977) report, the staff determined that the vertically offset joint was one of four joints, J1-J4, described by the author, each of which had a similar northeast trending strike. The joint showing vertical offset, joint J2, terminates against another joint, J5. J5 has a more northerly strike than J1-J4 and more closely parallels the trend of the Sequatchie anticline, formed during the Late Paleozoic. The termination of joint J2 against joint J5 suggests that J2 formed after J5, and is, therefore, younger than J5. Field evidence suggests that joint J2 could not have formed by strike slip motion because it did not offset joint J5 and that it must have formed due to normal dip-slip motion. Given that the present day compressive stress field trends northeast throughout most of the CEUS, and joint J2 strikes northeast, J2 must be older than the present day stress field. In addition, joints J1-J4 are long, straight, parallel, and show no evidence of curvature that would be expected in the modern, shallow stress field. The only other time, since the Late Paleozoic, when normal faulting (offset) was likely to have occurred, given the orientation of joints J1-J4, was during the Mesozoic (248 to 65 Ma) opening of the southern Atlantic Ocean and the Gulf of Mexico. Therefore, joint J2 most likely formed sometime between the Late Paleozoic and the Mesozoic extensional period.

Based on the staff's confirmatory analysis of the vertical offset on joint J2 during its site visit, the staff finds that the applicant may have inappropriately estimated the age of vertical offset on joint J2 by assuming that it was the same age as the regional joint set, Late Paleozoic. The staff's evaluation of the Coulson (1977) report leads it to conclude that joint J2 may be Late Paleozoic, or Mesozoic in age. However, the staff concurs with the applicant that joint J2 is not a significant fault and that the fault is most likely millions of years old and does not indicate a seismic hazard at the BLN site.

Based upon its review of BLN COL FSAR Section 2.5.1.2.5, and the applicant's response to RAI 2.5.1-2, the staff concludes that the applicant provided a thorough and complete description of the site structural geology in support of its COL application as required by 10 CFR 52.79 and 10 CFR 100.23. Because of the potential for displacements to be present in the rock underlying the BLN site, the staff proposes a condition that the COL holder perform geologic mapping (based on guidance provided in RG 1.208) and geophysical exploration (discussed in Section 2.5.4 of this SER) of future excavations for safety-related structures, evaluate any unforeseen geologic features that are encountered, and notify the NRC no later than 30 days before any excavations for safety-related structures are open for the NRC's examinations and evaluation. The addition of this commitment to the FSAR is **Open Item 2.5.1-1.** This is proposed **Commitment 2.5.1-1**. The staff believes that this commitment will be captured as a license condition upon resolution of Open Item 1-2 in this report.

Site Engineering Geology

BLN COL FSAR Section 2.5.1.2.6 describes the site engineering geology evaluation that the applicant performed. The applicant reviewed published maps and reports, performed a visual reconnaissance of the area and reviewed data from the BLN 2006 field exploration program in order to evaluate the engineering geology at the site, which included geologic hazards. The applicant identified two potential geologic hazards at the BLN site; karst-related ground failure and earthquake activity with resulting ground motion effects.

The applicant stated that it anticipates geologic hazard due to karst-related ground failure to be minor at the site and that this type of hazard will be mitigated during excavation and construction activities. The applicant compared exploration data for BLN 3 and 4 with conditions encountered at BLN 1 and 2 as a basis for its conclusion that any potential karst-related ground failures can be mitigated with proper excavation methods. The applicant further developed its discussion of karst and the associated potential for causing ground failure in BLN COL FSAR Section 2.5.4.1.

The applicant accounted for the potential that large earthquakes could affect the site in its development of the site GMRS, discussed in detail in BLN COL FSAR Section 2.5.2. The applicant stated that there are no potential hazards at the BLN site due to human-induced activities including groundwater withdrawal, petroleum production, or subsurface mining. Limestone and Chert quarries are present 3 to 8 km (2 to 5 miles) from the BLN site but the applicant stated that there are no activities associated with these quarries that could cause a potential hazard to the BLN site.

Based upon its review of BLN COL FSAR Section 2.5.1.2.6, the staff concludes (pending resolution of open item) that the applicant provided an adequate description of the site engineering geology, including human activities near the BLN site in support of the BLN COL application. SER Section 2.5.4.4 provides the staff’s detailed evaluation of the potential for ground failure due to karst and SER Section 2.5.2.4 provides the staff’s evaluation of the applicant’s GMRS for the BLN site. The staff concludes that there is no potential for the effects of human activity, such as subsidence or collapse due to groundwater withdrawal, petroleum production or subsurface mining operations that could compromise the safety of the site based on the applicant’s assertion that these activities are not present near the BLN site.

2.5.1.4.3 Staff Conclusions Regarding Regional and Site Geology

As set forth above, the NRC staff reviewed the basic geologic and seismic information submitted by the applicant in BLN COL FSAR Section 2.5.1. On the basis of its review, (pending resolution of the open item) the staff finds that the applicant provided a thorough characterization of the geologic and seismic characteristics of the BLN 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 the 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 vicinity and the 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 (pending resolution of the open item) that the proposed COL site is acceptable from a geologic and seismic standpoint and meets the requirements of 10 CFR 100.23. Furthermore, the staff concluded that this information sufficiently addresses BLN COL 2.5-1 to resolve COL Information Item 2.5-1.

2.5.1.5 Post Combined License Activities

The following items were identified as the responsibility of the COL license holder:

- **Proposed Commitment 2.5.1-1** the applicant must perform geologic mapping and geophysical exploration of future excavations for safety-related structures, evaluate any unforeseen geologic features that are encountered, and notify the NRC no later than 30 days before any excavations for safety-related structures are open for the NRC's examinations and evaluation.

2.5.1.6 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 the basic geologic and seismic information, and there is no outstanding information expected to be addressed in the BLN COL FSAR related to this subsection.

Section 2.1 of Revision 17 of the AP1000 DCD is identical to Section 2.1 of Revision 15 of the AP1000 DCD, which is incorporated by reference into 10 CFR Part 52, Appendix D. This subsection is not affected by the changes that Westinghouse proposed in Revision 17 to the AP1000 DCD. Pursuant to 10 CFR 52.63(a)(5) and 10 CFR Part 52, Appendix D, Section VI.B.1, all nuclear safety issues relating to the basic geologic and seismic information that were incorporated by reference have been resolved.

In addition, pending the resolution of Confirmatory Item 2.5.1-1 above and Open Item 2.5.1-1 to include a commitment in the FSAR regarding geological mapping, the staff concludes that the relevant information presented within the BLN COL FSAR is acceptable and meets the requirements of 10 CFR 100.23 and 10 CFR 52.79(a)(1)(iii) and the guidance provided in RG 1.208. The staff based its conclusion on the following:

- BLN COL 2.5-1, involving evaluation of regional and site-specific geologic, seismic, and geophysical information, as well as conditions caused by human activities is acceptable to the staff because the applicant has identified and appropriately characterized all seismic sources significant for determining the GMRS or SSE for the COL site, in accordance with the regulations provided in 10 CFR 100.23 and 10 CFR 52.79(a)(1)(iii) and the guidance provided in RG 1.208.

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 mile) 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) probabilistic seismic hazard analysis and controlling earthquakes; (5) seismic wave transmission characteristics of the site; (6) site-specific ground motion response spectra; and (7) any additional information requirements prescribed within the “Contents of Application” sections of the applicable subparts of 10 CFR Part 52.

2.5.2.2 Summary of Application

Section 2.5.2 of the BLN COL FSAR incorporates by reference Section 2.5.2 of the AP1000 DCD, Revision 17.

In addition, in BLN COL FSAR Section 2.5.2, the applicant provided the following:

AP1000 COL Information Item

- BLN COL 2.5-2

The applicant provided additional information in BLN COL 2.5-2 to address COL Information Item 2.5-2 [COL Action Item 2.5.2-1]. BLN COL 2.5-2 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, probabilistic seismic hazard analysis, seismic wave transmission characteristics and the SSE ground motion.

- BLN COL 2.5-3

The applicant provided additional information in BLN 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 GMRS at foundation level exceed the response spectra in 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 applicant stated that it developed the GMRS based on the performance based approach recommended by RG 1.208.

2.5.2.2.1 Seismicity

To characterize the seismic hazard for the BLN site, the applicant followed the methodology provided in the PSHA study conducted by the EPRI-SOG in the 1980s for the CEUS. The EPRI-SOG PSHA study used an earthquake catalog compiled through mid-1985 covering the CEUS. BLN COL FSAR Section 2.5.2.1 describes the applicant's efforts to develop an updated earthquake catalog, which the applicant then used to compare with the original EPRI catalog to identify any potential seismicity changes near the BLN site. To perform this comparison, the applicant extended the earthquake catalog from 1985 through 2005 and also evaluated the completeness of the EPRI-SOG catalog for earthquakes occurring before March 1985. The applicant referred to its updated seismicity catalog as the BLN earthquake catalog.

Based on a comparison of the EPRI-SOG catalog with the newly generated BLN catalog, the applicant concluded that there are no major differences in the spatial patterns of seismicity (Figure 2.5.2-1).

Development of the BLN Earthquake Catalog

BLN COL FSAR Subsection 2.5.2.1.1 describes the details of the development of the BLN earthquake catalog. To develop the BLN catalog, the applicant primarily used the earthquake catalog developed by the 2004 TVA Dam Safety Seismic Hazard Assessment project. The TVA Dam Safety catalog is a composite of several earthquake catalogs developed for the CEUS, including the 2002 USGS catalog developed for the National Seismic Hazard Mapping project. As part of its development of the BLN catalog, the applicant also converted various earthquake magnitude scales (generally body-wave magnitude, m_b) to the now commonly-used moment magnitude scale, $\mathbf{M}_w$. The applicant updated the TVA catalog with new earthquakes that postdate the catalog, and with newly identified historical earthquakes that came from two different sources: 1) a report on new historical earthquakes in the central US by Metzger et al.; and 2) an unpublished listing of newly identified historical earthquakes compiled by TVA in 2005. Based on an extensive review of microfilm records of historical newspapers, Metzger et al. identified 103 new earthquakes and provided new information on 22 previously reported earthquakes that occurred between 1826 and 1899. TVA's update came from keyword searches of online versions of historical newspapers. The update identified 152 historical earthquakes occurring between 1758 and 1923. In addition, the applicant added 10 more earthquakes that occurred in 2004 and early 2005 to its BLN catalog.

In BLN COL FSAR Subsection 2.5.2.1.2 the applicant concluded that there are no major differences in the spatial patterns of earthquakes observed in the original EPRI-SOG earthquake catalog and the updated BLN catalog. Figure 2.5.2-1 (FSAR Figure 2.5-233) shows the seismic activity in the BLN site region and its surroundings based on the updated catalog.

Significant Recent and Historical Earthquakes

BLN COL FSAR Subsection 2.5.2.1.2 discusses the newly identified significant earthquakes (earthquakes with magnitudes greater than 4.0) that occurred within the 320 km (200 mile) radius of the BLN site. The BLN catalog shows that there are three earthquakes with magnitudes greater than 4.0 in the post-1985 time period and that there are six more newly identified historical earthquakes, with similar magnitudes, within the 320 km (200 mile) radius of the BLN site. SER Table 2.5.2-1 lists these earthquakes.

Of note is the April 29, 2003 Fort Payne, Alabama earthquake with an $\mathbf{M_w}$ magnitude of 4.6. The Fort Payne earthquake occurred about 36 km (22 miles) southeast of the BLN site at the southern end of the ETSZ. This earthquake is one of the strongest events to have occurred in the ETSZ. As described by the applicant, the earthquake caused minor damage to chimneys, walls and foundations and triggered the collapse of a 9 meter wide (29 ft.) sinkhole. Post earthquake surveys did not identify any landslides. Damaged chimneys were in poor/weakened conditions and some old masonry buildings did not appear to be damaged. The estimated focal depth of the earthquake is between 9.5 and 13 km (5.9-8.1 miles).

2.5.2.2.2 Geologic and Tectonic Characteristics of the Site and Region

In BLN COL FSAR Subsection 2.5.2.2 the applicant described the seismic source characterization efforts from prior PSHA work affecting the BLN site. The applicant's primary seismic source characterization efforts are from the EPRI-SOG seismic source models, which form the basis of the applicant's PSHA calculations. However, as specified in RG 1.208, the applicant evaluated more recent seismic hazard studies for the region surrounding the site and compared them to the EPRI-SOG characterization. The newer hazard studies that the applicant evaluated were: (1) the 2002 Lawrence Livermore National Laboratory Trial Implementation Project (LLNL-TIP) study; (2) the 2002 USGS Earthquake Hazard Mapping Source Characterization Model; and (3) the 2004 TVA Dam Safety Seismic Source Model.

The 1989 EPRI-SOG PSHA study, which forms the basis of source characterization for the BLN site, used six independent Earth Science Teams (ESTs) to evaluate seismic hazard in the CEUS. Each of the six teams independently evaluated the geologic, geophysical, and seismic data and characterized the seismic sources in the CEUS. For each seismic source, the six ESTs characterized the potential hazard in terms of source geometry, recurrence, maximum magnitude, and probability of activity. For the BLN hazard study, the applicant included each of the seismic sources from the six ESTs that contributed at least 1 percent to the total hazard. The applicant stated that the EPRI-SOG study identified the ETSZ, crustal blocks surrounding the ETSZ, and the NMSZ as the most significant contributors to the total hazard at the BLN site. The EPRI-SOG study also identified the Charleston seismic source zone, one of the largest seismic zones in the CEUS, to be a slight contributor to the hazard at the BLN site.

A decade after the EPRI-SOG study, the NRC staff implemented the LLNL-TIP hazard study to evaluate the seismic hazard expert elicitation guidelines and processes, referred to as the Senior Seismic Hazard Analysis Committee (SSHAC) guidance. NUREG/CR-6607, "Guidance for Performing Probabilistic Seismic Hazard Analysis for a Nuclear Power Plant Site: Example Application to the Southeastern United States," describes the LLNL-TIP study. The LLNL-TIP study implemented a SSHAC Level IV expert elicitation process for two sites in the southeastern U.S. (Vogtle and Watts Bar). A SSHAC Level IV is the most rigorous SSHAC method for expert elicitation and involves a Technical Integrator who is responsible for the results of the PSHA, a panel of experts and expert proponents on different topics. The applicant stated that although the LLNL-TIP study was primarily focused on the trial implementation of the SSHAC expert elicitation process, the study "provided assessments for some of the seismic sources significant to the BLN site."

Another recent tectonic and source characterization study that provides information on potential hazard sources for the BLN site is the 2002 USGS National Seismic Hazard Map project. The applicant stated that the 2002 USGS study is a follow up study to the USGS's 1996 National Seismic Hazard Map project. The 2002 study includes essential updates for the location, size, and recurrence parameters of large earthquakes in the Charleston seismic source zone and the NMSZ, as well as updates to ground motion attenuation prediction models. The 2002 USGS study did not use a formal expert elicitation method, such as the SSHAC guidance. Instead the USGS evaluations were based on regional workshops designed to discuss new seismic hazard models and to achieve consensus views.

Lastly, the applicant described the TVA Dam Safety Seismic Source Model developed by Geomatrix Consultants in 2004 for all of the TVA's major dams. The applicant stated that Geomatrix consultants developed a PSHA model for the Tennessee Valley dams using a SSHAC Level II process. The TVA-Dam Safety Study (TVA-DSS) benefitted from several previous seismic hazard studies, including the EPRI-SOG evaluation, the LLNL-TIP study, and the USGS National Seismic Hazard Project.

2.5.2.2.3 Correlation of Earthquake Activity with Seismic Sources

BLN COL FSAR Subsection 2.5.2.3 describes the applicant's efforts to identify any potential correlation between the seismicity and the known geologic structures in the area. The applicant evaluated the spatial patterns of earthquakes identified in the updated BLN earthquake catalog and compared them with the locations of the known geologic features. The applicant found no evidence of correlation between the seismicity and geologic structures and made the following conclusions.

- The updated catalog does not show any earthquakes within the site region that can be associated with a known geologic structure. Most of the seismicity in the region appears to be occurring at the depth beneath the Appalachian décollement. The largest earthquake within a 25-mile radius of the site, the 2003 $\mathbf{M}_w$ 4.6 Fort Payne earthquake, is likely a reactivated structure within the basement rock, but cannot be clearly associated with any of the major identified basement structures.

- The updated earthquake catalog does not show a pattern of seismicity different from that exhibited by earthquakes in the EPRI-SOG catalog. This suggests that there is no need to add a new seismic source to the EPRI-SOG source characterizations.

2.5.2.2.4 Probabilistic Seismic Hazard Analysis and Controlling Earthquakes

BLN COL FSAR Subsection 2.5.2.4 describes the applicant's PSHA and the controlling earthquake determination for the BLN site. The applicant followed RG 1.208 for the development of its PSHA and controlling earthquakes. As part of its PSHA analysis, the applicant evaluated the significance of new information made available since the 1989 EPRI-SOG study. The applicant provided summaries of its evaluation of new information on seismic source characterization in BLN COL FSAR Subsection 2.5.2.4.1. In BLN COL FSAR Subsection 2.5.2.4.2, the applicant summarized its evaluation results on new information related to ground motion characterization and in BLN COL FSAR Subsections 2.5.2.4.3 and 2.5.2.4.4 the applicant summarized its PSHA sensitivity analysis results and PSHA calculations. The applicant concluded that although there was no need for new seismic sources in the region surrounding the BLN site, the NMSZ and the Charleston seismic source zone models required updating. The applicant also determined that the original EPRI attenuation models needed to be updated.

New Information Relative to Seismic Source Evaluations

BLN COL FSAR Subsection 2.5.2.4.1 describes the new seismic source information that the applicant evaluated to determine if it needed to update the original EPRI-SOG seismic source characterization for the BLN site. The three key seismic source characterization data that the applicant evaluated were: (1) identification of potential new seismic sources; (2) changes in the rate of earthquake occurrence; and (3) changes in maximum magnitude for seismic sources. The applicant concluded that based on its own analysis; there are no additional seismic sources that need to be included in the updated PSHA for the BLN site. In addition, the applicant concluded that the earthquake recurrence parameters determined by the original EPRI-SOG PSHA study within the 320-km (200-mile) radius were still valid. However, based on the results of new paleoliquefaction studies, the applicant concluded that the earthquake recurrence rates for the NMSZ and the Charleston seismic source, both of which are beyond the 320 km (200 mile) radius, should be increased.

New Seismic Sources. Regarding the identification of potential new seismic sources, the applicant stated that it looked at more recent subsurface data (e.g., industry seismic reflection profiles and deep wells) as well as the updated BLN earthquake catalog to better understand the geologic structures within the 320-km (200-mile) radius of the BLN site. The applicant stated that it focused on the foreland Appalachian fold-thrust belt and the possible relationships to subdetachment basement faults and zones of concentrated seismicity. In particular, the applicant examined the ETSZ in detail to determine if the EPRI-SOG seismic source models adequately characterize the concentrated seismicity within this zone. The applicant also focused on the recent Fort Payne earthquake with an $\mathbf{M}_w$ magnitude of 4.6, which occurred at the southern end of the ETSZ. The applicant noted that the Fort Payne earthquake lies within the ETSZ defined by three of the EPRI-SOG ESTs and outside the ETSZ defined by the other three teams and, therefore, concluded that the EPRI source zone interpretations adequately represent the ETSZ. The applicant stated that based on its review there are "no additional specific seismic sources" that need to be considered for the updated PSHA study.

Evaluation of Change in Earthquake Recurrence Rates. Regarding earthquake recurrence rates, the applicant evaluated its BLN earthquake catalog described in SER Subsection 2.5.2.2.1 and compared the earthquake recurrence rates calculated from the BLN catalog to those calculated using the original EPRI-SOG seismicity catalog. In order to accommodate the incompleteness of earthquake catalogs, especially in historical time periods, the original EPRI-SOG proposed a methodology to calculate recurrence rates based on both the period of complete catalog reporting and the period of incomplete recording. The original EPRI-SOG study divided the CEUS into 13 "completeness" regions that represented histories of earthquake reporting. The BLN site and the 320-km (200-mile) radius fall within two completeness regions. Within these two completeness regions the applicant conducted recurrence evaluations using the BLN catalog and compared these recurrence parameters to those from the original EPRI catalog. The applicant stated that in one of the completeness regions, the earthquake recurrence parameters from the two different catalogs are essentially the same. In the other region, the recurrence parameters using the updated BLN catalog are lower than the values obtained from the original EPRI-SOG catalog. Since the earthquake recurrence parameters from the BLN catalog are the same or lower, the applicant concluded that the earthquake occurrence rate parameters developed as part of the EPRI-SOG evaluation adequately represent the seismicity rates within the 320-km (200-mile) radius of the BLN site.

In addition, the applicant conducted earthquake recurrence rate evaluations for important seismic sources that are beyond the 320-km (200-mile) radius, such as the NMSZ and the

Charleston seismic source. For both the NMSZ and the Charleston seismic source, paleoliquifaction studies conducted in recent years provided new information related to earthquake recurrence rates for these two sources. The applicant stated that the original EPRI-SOG earthquake recurrence rates for these two seismic sources underestimated the recurrence rates of large magnitude earthquakes and, therefore, concluded that the EPRI-SOG recurrence rates for earthquakes in these seismic zones needed to be revised.

Maximum Magnitudes. Regarding the assessment of maximum magnitude values for the various EPRI-SOG seismic source zones that impact the BLN site, the applicant focused on four areas:

- Representations of the ETSZ
- Local host/background seismic zone
- Representations of the NMSZ
- Representations of the Charleston seismic source

The more recent PSHAs that the applicant used for its comparison are: (1) the USGS 2002 National Seismic Hazard Maps; (2) the LLNL-TIP study for the southeastern U.S.; and (3) the TVA Dam Safety Seismic Source Model developed by Geomatrix consultants in 2004 for all of TVA's major dams. By comparing the maximum magnitude assessments provided in these studies for the four focus areas, listed above, with the EPRI-SOG maximum magnitude assessments, the applicant concluded that for the ETSZ and local host/background seismic source zones, the EPRI-SOG maximum magnitude ranges spanned a range similar to those used for these more recent PSHA studies. However, the applicant indicated that while the range of the maximum magnitudes for the ETSZ and the local host/background sources in the most recent studies is about the same, the three later PSHA studies placed more weight on higher magnitudes. Because there have been no large historical or prehistorical earthquakes in these source zones, the applicant decided not to update the EPRI-SOG maximum magnitude values. However, the applicant did update the lower end of the maximum magnitude range for the Law and Woodward-Clyde local source zones from m_b 4.2 to m_b 5.2 to be consistent with the largest observed earthquake in these source zones.

For the remaining two focus areas, the NMSZ and Charleston seismic source, the applicant concluded that the EPRI-SOG maximum magnitudes were consistent with more recent assessments.

New Information Regarding CEUS Ground Motion Characteristics

BLN COL FSAR Subsection 2.5.2.4.2 describes applicant's assessments of the new CEUS ground motion prediction models developed since the original EPRI-SOG PSHA study. The original EPRI-SOG study used a ground motion prediction model composed of three separate ground motion prediction equations. Since the original EPRI-SOG PSHA study, EPRI sponsored an SSHAC Level III study in 2004. This study weighed 13 recently published CEUS ground motion prediction equations to develop four new composite ground motion models for the CEUS. In 2006, EPRI revised the EPRI 2004 models in order to further refine the aleatory variability. For its PSHA for the BLN site, the applicant used the EPRI 2004 ground motion model with the EPRI 2006 correction.

PSHA Sensitivity Analyses and Revisions

BLN COL FSAR Subsection 2.5.2.4.3 describes the applicant's sensitivity assessment of the impact of the new seismic source and ground motion prediction models on the original EPRI-SOG PSHA results for the BLN site. The applicant evaluated the impacts of three different types of new data and information on the original EPRI-SOG hazard results for the BLN site: (1) maximum magnitude updates applied to some of the local EPRI-SOG seismic source models; (2) recurrence parameter updates for the NMSZ and the Charleston seismic source; and (3) the EPRI 2004-2006 ground motion prediction equations. Based on its evaluation, the applicant concluded that the updates to the original EPRI-SOG source models for the NMSZ impacted the BLN seismic hazard the most, followed by the recent EPRI ground motion prediction equations, the updates to the Charleston seismic source model, and finally the maximum magnitude updates for the local sources near the BLN site.

The applicant's first assessment in this category focused on the impact of updating the maximum magnitudes of a few local seismic sources near the BLN site. The updated BLN earthquake catalog indicated that some of the EPRI-SOG assigned maximum magnitudes for a few of the smaller seismic sources near the BLN site were lower than the largest magnitude earthquakes associated with those sources. As described previously, the applicant updated these M_{max} values to make them match the largest earthquakes observed in each of these source zones (m_b 4.2 to m_b 5.2). The results of this update indicated that these M_{max} updates increased the hazard only minimally (less than 0.5 percent).

The second assessment conducted by the applicant included the impacts of the new recurrence models for the NMSZ, as implemented by Exelon for the Clinton ESP (ML061100285). In addition, the applicant assessed the impact of new recurrence models for the Charleston seismic source zone, as implemented by Geomatrix for the TVA-DSS. Recent paleoliquifaction studies show that the recurrence rates for large magnitude earthquakes in these two zones are approximately 500 to 550 years, as opposed to several thousands of years. The applicant assessed the impacts of this new information in two different ways. The first approach was to simply add the repeating large earthquake sources, with their shorter recurrence intervals, as new sources and to keep the original EPRI-SOG source models unchanged. This produced a significant increase in the seismic hazard curves for the BLN site. The increase was mainly due to the NMSZ source model updates. The Charleston seismic source model update did not significantly impact the hazard at the BLN site, as the distance from this source to the BLN site is large and the maximum magnitude is slightly lower compared to NMSZ. The second approach, which the applicant ultimately adopted for the BLN site, was to retain the original EPRI-SOG NMSZ and Charleston seismic source models only up to the maximum magnitude values of 6.75 and 6.5, respectively. The applicant then used the newer NMSZ and Charleston seismic source models, with their shorter recurrence intervals, for the larger magnitude events. The use of this second approach avoided the double counting of the larger magnitude NMSZ and Charleston seismic sources to the PSHA. The applicant stated that the elimination of this double counting resulted in only a small reduction (less than 2 percent) to the total mean hazard.

The applicant's third sensitivity assessment focused on the impact of the use of the new ground motion prediction models on the BLN PSHA results. Using the new and old EPRI ground motion prediction models, the applicant calculated the 10 Hz and 1 Hz hazard curves at the BLN site for comparison. These results showed that the updated EPRI 2004 ground motion prediction models produced higher mean and median hazard curves for 10 Hz ground motions.

The updated ground motion models also produced higher median 1 Hz hazard curves, but somewhat lower mean hazard curves.

The applicant concluded that it considered all of the PSHA sensitivity results in its updated PSHA calculations and provided the results in BLN COL FSAR Subsection 2.5.2.4.4, which is summarized in the next section.

Updated PSHA

In BLN COL FSAR Subsection 2.5.2.4.4 the applicant described its methodology for calculating the PSHA results for the BLN site. As stated above, the applicant conducted several sensitivity analyses and determined the three main updates that impact the PSHA calculations for the BLN site. These are: (1) characterization and size of the NMSZ events; (2) characterization and size of the Charleston events; and (3) new ground motion prediction equations. Although the Charleston seismic source introduced only a slight increase in the total hazard, the applicant updated the source and included it in its PSHA calculations. For both the NMSZ and the Charleston seismic source zone, the applicant categorized its updates into three groups: source geometries, maximum magnitudes, and recurrence parameters. The following sections summarize the applicant's efforts in these areas.

New Madrid Repeated Large Magnitude Earthquake Source. In BLN COL FSAR Subsection 2.5.2.4.4.1, the applicant stated that the EPRI-SOG source characterization adequately addressed the uncertainties in source geometries, earthquake magnitudes, and recurrence parameters for the smaller New Madrid area seismic sources (m_b < 6.7). Hence, the applicant focused its source characterization study for the New Madrid region on the large-magnitude New Madrid seismic events like the ones that occurred in the 1811-1812 earthquake sequence, which included three large magnitude earthquakes (M>7) occurring within a few months of each other. Paleoliquefaction studies in the area indicate that similar earthquake sequences occurred in the region with an average return time of about 500 years. In its NMSZ large-earthquake source characterization, the applicant followed the model developed by Exelon for the Clinton ESP application. The applicant stated that although there had been a number of new studies of the NMSZ since the preparation of the Clinton ESP, these new data and information would not significantly change the characterization of the NMSZ implemented by Exelon for the Clinton ESP. The following three subsections summarize the applicant's assessments of the source characteristics of the NMSZ in terms of source geometry, maximum magnitude, and recurrence.

New Madrid Central Faults Source Geometry

In BLN COL FSAR Subsection 2.5.2.4.4.1.1, the applicant described the NMSZ as being a composite of three fault zones: the New Madrid South fault (NS), the New Madrid North fault (NN), and the Reelfoot fault. The most recent seismic sequence, which occurred in 1811-1812, is believed to have ruptured all of the three fault segments. However, the order of the sequence and length of fault rupture on each segment still remains unresolved. In order to incorporate the uncertainty inherent in the modeling of large magnitude NMSZ earthquakes, the applicant used a logic tree approach with the most recent scientific evidence available in the literature. The applicant considered two alternative locations for the NS fault, and two alternative lengths for the NN and the Reelfoot faults, giving different weights to each of these alternative interpretations.

NMSZ Central Faults Maximum Earthquake Magnitude

BLN COL FSAR Subsection 2.5.2.4.4.1.2 describes the applicant's development of a range of maximum magnitude estimates for the NMSZ. Large magnitude earthquakes occurred in the NMSZ throughout the history. The most recent large earthquakes in the area occurred in 1811 and 1812 as a sequence in which three large magnitude (M>7) occurred within a few months of each other. Geologic data show that this type of sequencing occurred in the past as well with similar magnitudes. Considering that these types of comparable-sized earthquakes occur periodically in the NMSZ, the applicant adopted the concept of "characteristic earthquakes" to represent the NMSZ in its PSHA study and used the largest magnitudes observed as the best estimates for the maximum magnitude determinations. The applicant conducted an extensive literature search to determine the scientific community's views on the estimated magnitudes of the earthquakes that occurred in the 1811-1812 sequence. As noted by the applicant, not all the scientific studies yielded the same magnitude estimates. For each fault segment of the NMSZ, the applicant determined a range of possible magnitudes incorporating differences in scientific opinions to capture epistemic uncertainty. SER Table 2.5.2-2 shows the applicant's final compilation for each of the three fault segments. The applicant incorporated all these magnitude estimates using a logic tree approach and weighed them to calculate the hazard posed by the large-sized characteristic earthquakes in the NMSZ.

NMSZ Central Faults Earthquake Recurrence

BLN COL FSAR Subsection 2.5.2.4.4.1.3 describes the recurrence intervals of the New Madrid large-magnitude characteristic earthquakes. As summarized in SER Subsection 2.5.2.2.4, the recurrence interval for these large-magnitude earthquakes would be significantly underestimated; if based solely on the extrapolation of the recurrence parameters for smaller earthquakes. Instead, the recurrence interval for the large-magnitude characteristic earthquakes is based on paleoliquefaction studies in the NMSZ region. As such, the applicant focused its efforts on gathering up-to-date scientific information on recent paleoliquefaction studies. The applicant discussed the results of several scientific studies, which showed that characteristic New Madrid earthquakes occur in sequences closely spaced in time (months) relative to the time span observed between the sequences (approximately 500 years). For example, the 1811-1812 sequence produced three large earthquakes (**M**>7) in the New Madrid region within a period of few months (December 1811 through February 1812). These earthquakes are thought to have ruptured the three fault segments (i.e., NN, NS, and Reelfoot fault). Paleoseismological studies indicate that there have been several similar event sequences separated by time periods of 200 years to 800 years, with a combined average of about 500 years. These estimates come from studies of hundreds of earthquake-induced paleoliquefaction features, sediment rupture and deformation studies, as well as field mapping and dating of sequentially abandoned meander bands in the region. Paleoseisological data indicate that the sizes of the earthquakes observed in each sequence are similar to those observed in the 1811-1812 sequence. However, some scientific evidence suggests that some of the earlier sequences may have produced slightly smaller magnitude earthquakes, especially the ones that ruptured the NN and NS fault segments. As a result, the applicant used two alternative rupture models, as done in the Exelon ESP application. For what the applicant called Model A, the applicant used maximum magnitudes identical to those of the 1811-1812 sequence. For another model, Model B, the applicant used slightly reduced maximum magnitudes for the NN and NS fault segments. The applicant assigned a weight of 0.67 to Model A and a weight of 0.33 to Model B.

In addition, in order to incorporate the results of its findings into the BLN PSHA calculations, the applicant used two separate recurrence models and averaged the results. The first recurrence model is a Poisson model, in which large earthquake clusters are temporally independent of each other. This model can be considered “memoryless.” This is the traditional model used for most hazard calculations. The second model is a renewal model that uses a distribution form (e.g., lognormal) to represent the time elapsed between earthquake sequences. The applicant followed the model developed by Exelon for the Clinton ESP (FSAR References 294 and 356). In this model, the time between earthquake sequences are modeled using the Brownian Passage Time (BPT) model developed by Matthews et al. (2004, FSAR Reference 388). This model takes into account the build up of strain and release process between earthquake sequences. The only difference between the applicant’s approach and that of Exelon for the Clinton ESP is the value chosen for the “time period of interest,” which is the parameter used in the renewal model to estimate the probability of an event occurring within the time period of interest. Exelon used a value of 60 years; while the applicant used a value of 50 years. This value corresponds to the expected life span of a nuclear power plant. The applicant stated that it diverged from the Exelon ESP methodology because the expected start of operation of the BLN plant is 10 years prior to that of Exelon’s.

Charleston Repeating Large Magnitude Earthquake Source. BLN COL FSAR Subsection 2.5.2.4.4.2 describes the applicant’s efforts to assess and update the characteristics of the Charleston seismic source. Although the Charleston seismic source is a small contributor to the hazard at the BLN site, the applicant updated the source geometries and estimated the maximum magnitude the recurrence parameters based on new information and data available in the current scientific literature. The 1886 Charleston earthquake, with an estimated magnitude in the range of 6.8 to 7.5, is the largest known earthquake in the Eastern United States. Based on a review of the recent information, the applicant stated that the EPRI-SOG models do not adequately characterize the Charleston seismic source zone geometries and the large magnitude earthquake recurrence intervals. As such, the applicant implemented the TVA-DSS Charleston seismic source model and its uncertainties for its PSHA calculations. The following sections summarize the TVA-DSS model for the Charleston seismic source zone, including the source geometries, Mmax values, and the recurrence parameters.

Charleston Earthquake Source Geometry

In BLN COL FSAR Subsection 2.5.2.4.4.2.1, the applicant stated that the existing EPRI source models are generally centered in the meizoseismal area (the area where the concentration of shaking is the largest) of the 1886 Charleston earthquake, with some sources extending offshore and some extending into central South Carolina. However, based on the new information available, the applicant indicated that a revision to the Charleston seismic source geometry is necessary. The applicant primarily investigated two new scientific studies to determine the updated Charleston seismic source geometries. The applicant first assessed the LLNL-TIP study, which developed new seismic source models using the SSHAC guidelines and estimated the seismic hazard at Vogtle and the Watts Bar nuclear power plant sites. The LLNL-TIP study limited the Charleston seismic source to the costal plain area and along the postulated East Coast Fault System’s (ECFS) southern branch. The applicant also assessed the 2002 USGS National Seismic Hazard Mapping project’s characterization of the Charleston seismic source. The 2002 USGS study considered two alternative sources. One local source was centered on the Woodstock fault and the ECFS’s southern branch, and the other source covered a larger regional area.

The applicant stated that given the scientific uncertainty in the representation of the Charleston seismic source geometries, it considered two alternative approaches to model the Charleston seismic source. The first approach consisted of a fault model and the second approach consisted of an areal source model. The applicant also divided these two alternative approaches into sub elements. While the fault model included the Woodstock fault and the ECFS's southern branch, the areal source model included three sub elements representing the USGS's areal source, an areal source based on the Mesozoic basins defined by Geomatrix (FSAR Reference 269) and the costal zone defined by the LLNL-TIP study. The applicant utilized a weighted approach to define the contributions from all of these alternative models. The applicant assigned the fault source model a larger weight compared to the areal source model considering the presence of potentially active faults in the Middleton Place-Summerville area and the geomorphic evidence of Quaternary deformation in the region. Within the fault source, the applicant assigned the Woodstock source twice as much weight. Similarly, within the areal source model, the USGS areal seismic source and the Mesozoic basin seismic source had weights of 0.4 each, and the coastal zone areal seismic source had a lower weight of 0.2. The applicant assigned these weights to be consistent with the areal coverage of each of these seismic sources.

Charleston Source Maximum Magnitude

BLN COL FSAR Subsection 2.5.2.4.4.2.1 describes the applicant's efforts to determine the maximum magnitudes for the updated Charleston seismic source model. Similar to the New Madrid seismic source, the applicant applied the concept of characteristic earthquakes to the Charleston seismic source. Although the sizes of the pre-historic earthquakes in the Charleston region are less certain than the New Madrid earthquakes, the applicant stated that interpretations do not indicate that earlier earthquakes had any larger magnitudes than the one that took place in 1886. Therefore, the applicant used the 1886 earthquake magnitude as the maximum magnitude for this source.

The published magnitudes of the 1886 Charleston earthquake vary from 6.8 to 7.3. These estimates come from studies involving intensity measurements and analyses of paleoliquefaction features. The applicant ranked these estimates based on the methodology and the number of observations used by the original authors. The applicant used a higher ranking for estimates obtained from the intensity measurements, and a lower ranking for estimates obtained from paleoliquefaction studies. Based on these rankings, the applicant assigned different weights to different study results and incorporated them in its Charleston seismic source updates. The applicant established the following M_{max} values and their corresponding weights for the Charleston seismic source: M_{max}= 7.3 with a weight of 0.25, M_{max}= 7.25 with a weight of 0.1, M_{max}= 7.0 with a weight of 0.1, M_{max}= 6.9 with a weight of 0. 35, and M_{max}= 6.8 with a weight of 0.2.

Charleston Earthquake Source Recurrence

BLN COL FSAR Subsection 2.5.2.4.4.2.1 describes the applicant's efforts to determine the recurrence interval of the Charleston characteristic earthquakes using liquefaction features along the Atlantic seaboard. Because there are significant uncertainties in estimating the timing of the liquefaction events and uncertainties related to the completeness of liquefaction records, the applicant described three different possible recurrence scenarios for two different completeness records. The applicant cited a 2001 study by Talwani and Schaeffer (FSAR Reference 317), which indicated that the sea level change in the Holocene (the past 10,000 years) may have affected the completeness of the liquefaction features. Due to variations in sea levels during the Holocene, groundwater levels beneath potential liquefaction sites may have varied. With a low sea level, even if there was a large earthquake in the area, liquefaction may not have occurred due to lower groundwater levels. The applicant stated that as the sea levels in the past 2000 years stayed the same, the liquefaction data can be considered complete from the present to about 2000 years ago. However, there are liquefaction features identified in the area that go back almost 6000 years. The applicant also indicated that it is likely that there were no large earthquakes during certain time periods in history, and the liquefaction record may actually be complete back to about 6000 years. In order to accommodate this uncertainty, the applicant grouped its recurrence estimates into 2000-year recurrence calculations and 6000-year recurrence calculations and assigned them the weights of 0.9 and 0.1, respectively.

In each of the two recurrence intervals, the applicant calculated three different recurrence scenarios developed based on available information in the literature. While Scenarios 1 and 2 assume all large earthquakes occurred on the Charleston seismic source proper, Scenario 3 assumes both the Charleston source and the additional northern and southern branches also produced large earthquakes that contributed to liquefaction features. The applicant listed its findings for all these scenarios in BLN COL FSAR Table 2.5-217, which is duplicated in this document as SER Table 2.5.2-3. The applicant concluded that the recurrence interval for the 2000-year completeness period is 493 years for Scenario 1, 562 years for Scenario 2, and 513 years for Scenario 3. The applicant assigned different weights to these recurrence intervals in its PSHA calculation based on how the scenarios explain the observations. Scenario 3 is the applicant's preference with an assigned weight of 0.5, followed by Scenario 2 with a weight of 0.3 and Scenario 1 with a weight of 0.2. For the 6000-year recurrence intervals the mean repeat times increased significantly. The applicant also stated that in its hazard analysis that it used two recurrence models as it did with New Madrid. In the first round of calculations, the applicant used the Poisson model and in the second round of calculations it used a renewal model.

Ground Motion Models. In BLN COL FSAR Subsection 2.5.2.4.4.3, the applicant stated that it used the CEUS ground motion prediction model developed by EPRI in 2004 for its PSHA calculations, with the recent model update published by EPRI in 2006. The applicant stated that it also used the Cumulative Absolute Velocity (CAV) model in its final hazard calculations. The use of the CAV methodology in PSHA studies is specified in RG 1.208 as the method to eliminate the effects of non-damaging earthquakes with ground motions less than a pre-defined level of 0.16g-sec.

PSHA Results. BLN COL FSAR Subsection 2.5.2.4.4.4 describes the applicant's PSHA results calculated using the updated source and ground motion models. The applicant used the EPRI source models with updated M_{max} values and the EPRI 2004 ground motion prediction models with the EPRI 2006 updates. In addition, the applicant included the updated repeating large-magnitude earthquake sources at New Madrid and Charleston.

The applicant assumed that the entire length of the central New Madrid faults rupture during an earthquake, and used the closest location of the fault to the site in its distance calculations in the PSHA. Due to the large distance between the BLN site and the Charleston seismic source zone, the applicant simplified the Charleston seismic source by representing it with a single fault, the Woodstock fault, and eliminating the areal source zones, described above. The applicant stated that the Charleston seismic source contributes only slightly to the hazard at the BLN site. In summary, the applicant concluded that the updated sources (New Madrid and Charleston) and ground motion prediction models (EPRI 2004, 2006) affected the PSHA total mean hazard curves significantly at 10^{-4} and 10^{-5} exceedance frequencies, which are important in defining the GMRS for the site.

The applicant compared the hazard curves calculated using the original EPRI ground motion models and the updated ground motion models. In this sensitivity analysis, the applicant used only the original EPRI source geometries. The applicant provided the results for ground motion frequencies of 1 Hz and 10 Hz. The results showed that while the 10 Hz hazard curves increased by 10 percent to 50 percent using the new ground motion models, the 1 Hz hazard curves decreased by 25 percent to 40 percent in the exceedance frequency range of 10^{-4} and 10^{-5}.

As an illustration of the individual source contributions, the applicant provided hazard curves calculated using one of the EPRI ESTs seismic source models, the Weston model, along with the updated New Madrid and Charleston seismic sources. This illustration showed that the New Madrid source is the dominant hazard at the site at low frequencies (1 Hz) and the local Weston sources are the dominant hazard at high frequencies (10 Hz).

<u>Rock Uniform Hazard Response Spectra (UHRS) and Controlling Earthquakes</u>. BLN COL FSAR Subsection 2.5.2.4.4.5 describes the applicant's PSHA results in the form of the rock UHRS curves and the controlling earthquakes for the BLN site. The applicant used the hazard curves calculated at 0.5, 1.0, 2.5, 5.0, 10, and 25 Hz, as well as the peak ground acceleration (PGA) (100 Hz), using the updated sources and ground motion models, and determined the rock uniform hazard response spectra at 10^{-6}, 10^{-5}, and 10^{-4} annual exceedance frequencies. Figure 2.5.2-2 shows the applicant's rock UHRS curves.

Using the guidance provided in RG 1.208, the applicant calculated the controlling earthquakes' distances and magnitudes for both the low and high frequency components. The applicant deaggregated the mean hazard curves and the calculated percent contribution to the hazard at various magnitudes and distances. Using these deaggregation results, the applicant calculated the controlling earthquakes for the BLN site. SER Table 2.5.2-4 shows the applicant's results. For the low frequency hazard (1-2.5 Hz), the applicant stated that the magnitude and distance values calculated for distances greater than 100 km produced similar results at 10^{-4} and 10^{-5} exceedance frequencies. The applicant adopted these values (**M**=7.7 and R=360 km) as the nominal values for the low frequency controlling earthquake. For the high frequency controlling earthquake, the applicant calculated the mean magnitude and distance values for distances less than 100 km and used them to select the nominal magnitude and distance values. The applicant determined that the high frequency controlling earthquake at the BLN site is at a distance of 20 km with a magnitude of 5.9.

2.5.2.2.5 Seismic Wave Transmission Characteristics of the Site

In BLN COL FSAR Subsection 2.5.2.5, the applicant stated that the BLN site is a rock site with approximately 2/3 of the measured shear wave velocities above 9200 ft./sec (2800 km/s). The EPRI ground motion prediction models represent the ground motion levels expected at a hypothetical rock site, which is defined as a site with shear wave velocities of at least 9200 ft./sec. The applicant stated that because the nuclear island is located on hard rock with high shear wave velocities, site-specific response calculations are not necessary.

2.5.2.2.6 Ground Motion Response Spectra

BLN COL FSAR Subsection 2.5.2.6 describes the details of the horizontal and vertical GMRS calculations. The applicant used the approach described in RG 1.208 and the ASCE/SEI Standard 43-05 to calculate the GMRS at the BNL site. The applicant first calculated the horizontal GMRS and estimated the vertical GMRS using vertical-to-horizontal spectral ratios recommended in NUREG/CR-6728.

Horizontal GMRS Spectrum

BLN COL FSAR Subsection 2.5.2.6.1 describes the steps the applicant took to calculate the horizontal GMRS spectrum. The applicant used the controlling earthquakes' distance and magnitude values as shown in SER Table 2.5.2-4 and calculated the corresponding spectral shapes for the low frequency and high frequency controlling events. The applicant then anchored these spectral shapes to the UHRS values at 0.5, 1 and 2.5 Hz to obtain the low frequency response spectra, and to 10 Hz, 25 Hz, and 100 Hz UHRS values to obtain the high frequency response spectra for the hazard levels of 10^{-4}, 10^{-5}, and 10^{-6}. The applicant used the envelope of the low frequency and high frequency spectral shapes to obtain a continuous, smoothed hazard curve for all hazard levels. Using the performance-based methodology described in RG 1.208, the applicant then calculated the BLN horizontal GMRS.

The GMRS is calculated using the following relationship:

$$GMRS = UHRS * DF \text{ where DF is}$$
$$DF = \max \{ 1.0, 0.6 (A_R)^{0.8} \}$$
$$A_R = 1E\text{-}05 \text{ UHRS} / 1E\text{-}04 \text{ UHRS}$$

RG 1.208 states that if A_R is greater than 4.2, then this relationship is no longer valid. In this case RG 1.208 recommends setting the GMRS to 45 percent of the 10^{-5} site-specific surface UHRS curve. Figure 2.5.2-3 shows the horizontal GMRS curve calculated for the BLN site.

Vertical GMRS Spectrum

BLN COL FSAR Subsection 2.5.2.6.3 describes the applicant's methodology in calculating the vertical GMRS curve. The applicant obtained the CEUS vertical/horizontal spectral ratios from NUREG/CR-6728 and multiplied the horizontal UHRS with these ratios to obtain the vertical UHRS at the site. Then, using the same performance-based methodology described in RG 1.208, the applicant calculated the vertical GMRS. Figure 2.5.2-3 shows the vertical GMRS at the BLN site.

2.5.2.3 <u>Regulatory Basis</u>

The regulatory basis of the information incorporated by reference is addressed within the FSER related to the DCD.

In addition, the relevant requirements of the Commission regulations for the vibratory ground motion, and the associated acceptance criteria, 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 as follows:

- 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 probabilistic seismic hazard analysis. In complying with this regulation, the applicant also meets guidance in RG 1.132 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 subsection is accepted when the complete historical record of earthquakes in the region is listed and when all available parameters are given for each earthquake in the historical record.

- Geologic and Tectonic Characteristics of Site and Region: Seismic sources identified and characterized by the LLNL and the EPRI were used for studies in the CEUS in the past.

- Correlation of Earthquake Activity with Seismic Sources: To meet the requirements in 10 CFR 100.23, acceptance of this subsection 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.

- GMRS: In this subsection, the staff reviews the applicant's procedure to determine the GMRS.

In addition, the geologic characteristics should be consistent with appropriate sections from: RG 4.7, RG 1.60, "Design Response Spectra for Seismic Design of Nuclear Power Plants," RG 1.132, RG 1.206, and RG 1.208.

2.5.2.4 Technical Evaluation

The NRC staff reviewed Section 2.5.2 of the BLN COL FSAR and checked the referenced DCD to ensure that the combination of the DCD and the information in the COL represent the complete scope of information relating to this review topic.[1] The NRC staff's review confirmed that the information contained in the application and incorporated by reference addresses the required information relating to the vibratory ground motion. Section 2.5.2 of Revision 17 to the AP1000 DCD is being reviewed by the staff under Docket Number 52-006. The NRC staff's technical evaluation of the information incorporated by reference related to vibratory ground motion will be documented in the staff SER on the DC application for the AP1000 design.

The staff reviewed the information contained in the BLN COL FSAR:

AP1000 COL Information Item

- BLN COL 2.5-2

The NRC staff reviewed BLN 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, probabilistic seismic hazard analysis, seismic wave transmission characteristics and the SSE ground motion.

- BLN COL 2.5-3

The NRC staff reviewed BLN 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 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.

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 BLN 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 BLN site in October 2008, 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 BLN COL FSAR Section 2.5.1 and of the applicant's responses to RAIs is presented below.

2.5.2.4.1 Seismicity

To characterize the seismic hazard for the BLN site, the applicant followed the methodology provided in the PSHA study conducted by the EPRI-SOG in the 1980s for the CEUS. The EPRI-SOG PSHA study used an earthquake catalog compiled through mid-1985 covering the CEUS. BLN COL FSAR Subsection 2.5.2.1 describes the applicant's update of the original EPRI earthquake catalog to extend it from 1985 through February 2005. As part of the earthquake catalog update, the applicant also evaluated the completeness of the original EPRI catalog for earthquakes occurring before 1985. The applicant developed a comprehensive earthquake catalog, which it named the BLN catalog and compared the new catalog with the original EPRI catalog to identify any potential new seismic sources as well as any potential changes in earthquake recurrence rates. Based on its comparisons, the applicant found no major differences in the spatial pattern of earthquakes and that the original earthquake recurrence parameters and source geometries derived from the EPRI catalog are still valid for all but a few sources.

Based on the staff's review of the applicant's updated earthquake catalog, the staff concludes that the BLN catalog is comprehensive and accurately represents the seismicity in the region from 1758 to 2005 and is suitable for seismic hazard calculations for the BLN site. This conclusion is based on the staff's review of the events added by the applicant to the original EPRI catalog. This includes both historical earthquakes and recent events occurring after 1985. In addition, based on its own review of seismicity in the region surrounding the BLN site, the staff concludes that there are no significant differences in the spatial patterns of earthquakes between the applicant's revised BLN seismic catalog and the original EPRI catalog.

2.5.2.4.2 Geologic and Tectonic Characteristics of the Site and Region

In BLN COL FSAR Section 2.5.2.2, the applicant described the EPRI-SOG seismic hazard evaluation for the CEUS, completed in the 1980s. The EPRI-SOG study is a result of a formal elicitation process involving six independent ESTs. Each of the six teams evaluated the geologic, geophysical, and seismological data to characterize the seismic sources in the CEUS. For each seismic source, the six ESTs characterized potential hazard in terms of source geometry, recurrence, maximum magnitude, and probability of activity. For the BLN site, the applicant included each of the seismic sources from the six ESTs that contributed at least 1 percent to the total hazard. The applicant stated that the most significant contributors to the total hazard for the BLN site are local sources representing the ETSZ and the NMSZ. The applicant also indicated that the Charleston, South Carolina seismic source zone contributed slightly to the hazard at the BLN site.

As specified in RG 1.208, the applicant evaluated more recent seismic hazard studies available for the region surrounding the site for comparison to the EPRI-SOG determinations. The three other hazard studies that the applicant evaluated were the 2002 LLNL-TIP study, the 2002 USGS Earthquake Hazard Mapping Source Characterization Model, and the 2004 TVA Dam Safety Seismic Source Model. BLN COL FSAR Subsection 2.5.2.2 provides a description of these three more recent seismic hazard evaluations. In a later subsection (BLN COL FSAR Subsection 2.5.2.4) the applicant also provided comparisons of these three new studies' source characterizations to the EPRI-SOG hazard models and parameters.

The staff focused its review of BLN COL FSAR Section 2.5.2.2 on the applicant's description of the EPRI-SOG seismic source models and its selection of more recent PSHA studies for comparison to EPRI-SOG. Based on its review, the staff concludes that the applicant presented an accurate description of the seismic sources that could contribute to the seismic hazard of the BLN site. As described below in SER Subsection 2.5.2.4.4, the applicant used the EPRI seismic source models as its base model and updated the NMSZ and the Charleston seismic source as well as the ground motion models for its PSHA calculations for the BLN site. The staff's detailed review of the applicant's modifications of the original EPRI-SOG seismic source models and ground motion is provided in SER Subsection 2.5.2.4.4.

2.5.2.4.3 Correlation of Earthquake Activity with Seismic Sources

BLN COL FSAR Subsection 2.5.2.3 examines the BLN catalog (1758-2004) and compares it with the EPRI earthquake catalog (1758-1985) and the EPRI ESTs' seismic source model parameters, such as recurrence parameters and maximum magnitudes. The applicant presented comparative figures (BLN COL FSAR Figures 2.5-232, 2.5-333, and 2.5-234) showing differences between the original EPRI earthquake catalog and the BLN earthquake catalog. Based on the distribution of updated seismicity, the applicant concluded that its updated earthquake catalog illustrates similar spatial distribution of earthquakes as shown by the EPRI earthquake catalog and the updated catalog does not show any earthquakes within the site region that can be associated with a known geologic structure. BLN COL FSAR Section 2.5.2.3 states that the majority of seismicity in the region appears to be occurring at a depth beneath the local detachment surface, which decouples the shallow structures observed on geologic maps from the deeper crustal structures. The detachment surface is located at a depth of about 2 to 2.5 km.

In its review of BLN COL FSAR Subsection 2.5.2.3, the staff identified a number of issues and asked the applicant, in RAI 2.5.2-3, two main questions. The first question was about the location, especially the depth estimation, of the April 29, 2003, Fort Payne earthquake, which is the largest instrumentally recorded earthquake within 320 km (200 miles) of the BLN site. Because the seismic station distribution is not ideal for accurate hypocenter determinations in the region, the staff was concerned about the applicant's assessment that the earthquake was not related to any of the surface features identified in regional and local geologic maps. The applicant responded to RAI 2.5.2-3 by providing a summary of event location reports from three main seismic centers in the region: the Virginia Tech Seismological Observatory, Center for Earthquake Research and Information (CERI), and the St. Louis University Earthquake Center. Although there are discrepancies in the depth determinations from the three centers, there are additional studies that helped constrain the depth estimates. An aftershock study provided by Withers et al. (2004) estimated the depth of the aftershocks of the Fort Payne earthquake using a temporary seismic network in the vicinity of the main shock to be about 12 to 16 km, suggesting that the main seismic event was also within a similar depth range. Also, another study by Jemberie and Langston (2003) (FSAR Reference 346) estimated the depth of the Fort Payne earthquake to be around 9.5 to 13 km using a seismic waveform modeling technique, which is more sensitive to earthquake depth than the station arrival times used in traditional earthquake location methods. Given the wide range of determinations, the applicant concluded that the 2003 Fort Payne earthquake occurred within the basement rocks and not within the overlying Paleozoic rocks that reach a maximum depth of approximately 2.5 km (1.5 miles). For its own analysis the staff checked the reported location of the Fort Payne earthquake in the USGS national earthquake catalog and the International Seismological Centre's (ISC) global catalog. While the USGS location repeated the CERI location for this event, the ISC location, based on local, regional, and global observations indicated a depth of 18.4 km. Based on the information provided by the applicant and the staff's own analysis, the staff concluded that the 2003 Fort Payne earthquake was located within the mid-crustal levels and the hypocenter was well below the shallow surface structures mapped in the region.

In the second main question in RAI 2.5.2-3, the staff asked the applicant how it determined that the micro earthquake activity in the site vicinity is below the main tectonic detachment rather than within the shallow surface structures. In its response, the applicant provided an earthquake depth histogram shown in Figure 2.5.2-4, illustrating the depth distribution of earthquakes considered to have well-constrained depth estimations (i.e., at least one seismic station within a radius of 20 km or less and a maximum error estimation of 5 km in earthquake's depth). The 19 well-located events are distributed between the depths of 5 and 22 km (3.1 to 13.6 miles) with one event having a depth estimate of less than 4 km (2.4 miles). The applicant stated that this depth distribution is consistent with both the scientific consensus that the ETSZ exhibits 90 percent of focal depths deeper than 5 km and the understanding that basement rocks beneath the site are as shallow as about 2 to 2.5 km (1.2 to 1.5 miles). Therefore, the applicant concluded that earthquakes are associated with basement rocks beneath the shallow tectonic detachment and they are not associated with surficial geologic structures like those illustrated in BLN COL FSAR Figure 2.5-294.

Based on its review of the applicant's response to questions posed in RAI 2.5.2-3, the staff concludes that seismicity within and immediately surrounding the BLN vicinity, including the 2003 Fort Payne event, is predominately located beneath the shallow detachment. This is demonstrated by the applicant's review of depth estimations of several studies and also illustrated by the depth distribution histogram of well-constrained earthquake locations. Although there remain several earthquakes not used in the above histogram because of their poor depth determinations, limited reliable data do suggest that most of focal depths are beneath the shallow detachment and are located within upper to mid-crustal levels, significantly below the mapped surface faults and associated detachments.

In its review, the staff evaluated the completeness of the applicant's updated earthquake catalog and the applicant's subsequent conclusions by comparing the applicant's earthquake catalog to a compilation catalog derived from the USGS historic and present-day seismicity catalogs. The staff compiled a seismicity catalog from three USGS sources: (1) the USGS Preliminary Determinations of Epicenters (PDE) earthquake catalog (1978 to present); (2) USGS PDE-Q (January 8, 2009, to February 18, 2009), which reports quick epicenter determination for the most recent events; and (3) the USGS Significant US Earthquake catalog (1568 to 1989). The compilation catalog is shown in SER Figure 2.5.2.5 as the red circles. The applicant's updated seismicity catalog is illustrated by the blue circles. The comparison of these two datasets illustrates that the applicant's updated earthquake catalog adequately characterizes the seismicity within and around the BLN site region. Since the applicant updated its earthquake catalog through 2005, the staff reviewed more recent seismicity data to determine if there has been any significant seismicity since 2005 that would impact the applicant's conclusions. The yellow circles in SER Figure 2.5.2.4-1 illustrate the seismicity from the USGS catalog covering 2005 through January 2009. This recent seismicity does not show any significant deviations from the applicant's seismicity catalogs. Therefore, the staff concludes that the BLN earthquake catalog adequately characterizes the regional and local seismicity through January 2009. In addition, the staff agrees that the spatial distribution of earthquakes in the region has not changed since the publication of the EPRI earthquake catalog.

2.5.2.4.4 Probabilistic Seismic Hazard Analysis and Controlling Earthquakes

The applicant described the PSHA conducted for the BLN site in BLN COL FSAR Subsection 2.5.2.4. The applicant addressed key issues related to new information on seismic sources and ground motion prediction models that emerged after the EPRI studies of the late 1980's and conducted sensitivity tests to analyze the impact of the new information on the PSHA results for the BLN site.

Dames and Moore Seismic Models

BLN COL FSAR Subsection 2.5.2.2.1 discusses the EPRI seismic source models for the BLN site. In its evaluation of the EPRI source geometries and model parameters for the BLN site, the staff identified that one of the EPRI-SOG teams, Dames and Moore, had assigned lower probabilities of activity to Source Zones 41 and 53 in their source model characterizations. Although the applicant did not identify these two sources as significant contributors to the hazard at the BLN site, because of their low probabilities of activity, in RAI 2.5.2-8, the staff asked the applicant to justify how the Dames and Moore seismic source models adequately characterize the seismic hazard for the region surrounding the BLN site. In response to RAI 2.5.2-8, the applicant stated that the Dames and Moore seismic Sources 41 and 53 are located at a minimum distance of 110 km (68 miles) and 210 km (130 miles), respectively, from the BLN site. The applicant further stated that the Dames and Moore source model interpretation is one of six possible EPRI-SOG interpretations characterizing seismic hazards in the CEUS. Because these two source zones are somewhat distant from the BLN site and since the Dames and Moore source models are averaged with the other five EPRI-SOG source models for the final PSHA, the applicant concluded that the impact of the low probabilities of activity for Zones 41 and 53 is not significant. Based on this assessment, the applicant concluded that due to the distances of the Dames and Moore seismic Sources 41 and 53, versus Sources 4 and 4A from the site and from the dominance of Sources 4 and 4A on the BLN site hazard, increasing the probability of activity of Sources 41 and 53 would have negligible impact on the seismic hazard for the BLN site.

Based on the applicant's response and its own review, the staff concludes that the BLN site is located at a large enough distance from the Dames and Moore seismic source Zones 41 and 53 and that modification of these source zones' probability of activity would not significantly effect the seismic hazard estimations at the BLN site. The staff's assessment is also based on its earlier evaluation of these two source zones as part of the Vogtle ESP. The staff evaluated the impact of these two source zones for the Vogtle ESP and found that the impact of increasing the probabilities of activity of these two source zones produced only a slight increase in hazard at the Vogtle site. Since the BLN is significantly farther than the Vogtle site, their impact is lower.

New Madrid Seismic Zone

Recent paleoliquefaction studies show that the recurrence rates used by EPRI-SOG for the large-magnitude earthquakes in the NMSZ are inadequate, and the EPRI models underestimate the recurrence rates significantly. Several studies have shown that the recurrence rate of large magnitude earthquakes (M>7) in the NMSZ is around 500 years. The applicant in its sensitivity analysis as described in BLN COL FSAR Subsection 2.5.2.4 determined that the NMSZ is one of the largest contributors to the hazard at the BLN site. In its PSHA analysis to calculate the hazard from this important seismic source, the applicant utilized an approach similar to the one used in Exelon's Clinton ESP application.

In RAI 2.5.2-4 the staff asked the applicant to describe in detail the differences between the Clinton ESP model and the BLN model. In its response to RAI 2.5.2-4, the applicant responded by saying that it used the Clinton methodology, however, with slightly different calculation parameters. The Clinton ESP used two recurrence models in order to accommodate scientific evidence that not all the earthquake sequences in the past had magnitudes similar to those of the 1811-1812 sequence; some may have had smaller magnitudes than what was observed in the 1811-1812 sequence. Hence the Clinton ESP used two models: Model A, which had a weight of 67 percent and used maximum magnitudes similar to those of the 1811-1812 New Madrid earthquake sequence and Model B, which had a weight of 33 percent and captured the possibilities of three sequence types, one with magnitudes equivalent to Model A and the other two having smaller magnitudes than Model A. In its response to RAI 2.5.2-4, the applicant stated that it reduced the weight of Model B used in the Clinton ESP from 33 percent to zero percent, and increased the Model A weight to 100 percent. This simplification assumes that all earthquake magnitudes are similar in size to the 1811-1812 NM sequence and ignores the possibility of smaller magnitudes occurring during some of the sequences. Hence, this is a more conservative approach than the modeling approach used for the Clinton ESP.

In calculating the recurrence rates for the large magnitude earthquakes for the NMSZ, the applicant followed the process used for the Clinton ESP. The applicant used two separate recurrence models and averaged the results. The first recurrence model is a Poisson model, in which large earthquake clusters are temporally independent of each other. This model can be considered “memoryless.” This is the traditional model used for most hazard calculations. The second model is a renewal model that uses a distribution form (e.g., lognormal) to represent the time elapsed between earthquake sequences. Exelon also used the Brownian Passage Time, or BPT, model in its renewal model to represent the distribution of time between earthquake sequences. The BPT model, which was developed by Ellsworth et al. and Mathews et al. (FSAR references 387 and 388) may better represent physical properties, such as the build-up and release of strain, associated with seismic sources than other distribution forms, such as lognormal distributions. BLN COL FSAR Subsection 2.5.2.4.4.1.3 states that for the BPT-renewal model, a time-dependent equivalent Poisson rate for large repeating earthquakes may be obtained given the present time (t_0), which is measured from the date of the most recent earthquake, and a time period of interest (Δt), also defined as the exposure time to hazard. Ultimately, the applicant assigned equal weights to the Poisson and renewal recurrence models in order to reflect maximum uncertainty in choosing one model over the other as more representative of the NMSZ recurrence rates.

Since the equivalent Poisson rate is computed from the time-dependent renewal probability using BLN COL FSAR Equation 2.5.2-9, the computation of t_0 requires an assumption of “present time.” In its review the staff identified that the BLN COL FSAR does not provide what t_0 the applicant used. In RAI 2.5.2-5, the staff asked the applicant to describe what “present time” was used when estimating t_0. In response to RAI 2.5.2-5, the applicant stated that the starting time was January 1, 2003. The applicant also stated that this date represents the date of the calculations, not the start date of the plant’s operation. In its analysis, the applicant also assumed a power plant lifespan of 50 years, which is the time period of interest (Δt) used in the BPT model. In RAI 2.5.2-5, the staff also asked the applicant if increasing this Δt to 60 years might be more reasonable. The staff asked the applicant to show the effect of a joint increase in t_0 and the time period of interest (Δt) on the NMSZ event rates. In response to this portion of RAI 2.5.2-5, the applicant explained that the time period of interest is set to 50 years because, should the plant be licensed, the license period is 40 years plus 10 years of additional time for licensing and construction. To illustrate the effect of t_0 and Δt on the NMSZ event rates, the applicant presented a table, reproduced as SER Table 2.5.2-5, with a slight change, that lists occurrence rates for the NM earthquake sequences using varying assumptions of t_0 and Δt. Model A is the model used for the BLN site and Models B and C are different assumptions of t_0 and Δt to assess their effects on the occurrence rates for NM earthquakes.

The applicant stated that Model B in the table above represents a new t_0 and a 50-year time period of interest for plant licensing, construction and operation. Model C represents another case, where t_0 starts on October 1, 2018, but the time period of interest this time is 40 years for plant operation only. Model C assumption would be valid, if there were no large earthquakes until the t_0 time in the NMSZ. The applicant stated that the variations in these rates are only about a few percent. The applicant’s results show that when t_0 is pushed to a later date, the Poisson rates decrease slightly, while the BPT rates increase by about 7 percent in the case of Model C. However, the mean rate of recurrence stays either the same or increases by only 1.5 percent.

The staff is concerned with the applicant’s use of Model A, as it did not consider potential construction delays; neither did it consider the possibility of the prospective BLN nuclear power plant license being extended beyond the initial license period of 40 years. Seismic hazard analyses are not repeated during the license renewal process. The combined impact from using the applicant's present time and time period of interest may not be negligible. These parameters need to be properly determined for the lifecycle of a commercial nuclear power plant and used in calculating time dependent seismic hazard for NMSZ, which contributes significantly to the seismic hazard of the BLN site. This is identified as **Open Item 2.5.2-1**.

Eastern Tennessee Seismic Zone

In BLN COL FSAR Subsection 2.5.2.4 the applicant determined that another significant contributor to the hazard at the BLN site is the ETSZ. After comparisons to more recent PSHA studies, such as LLNL-TIP, USGS 2002, TVA Dam Safety, the applicant concluded that the original EPRI-SOG parameterization of the ETSZ including the source geometries, recurrence parameters, and maximum magnitudes adequately characterized the ETSZ. In RAI 2.5.2-1, the staff asked the applicant to clarify why it did not update the original EPRI-SOG source models for the ETSZ, particularly the maximum magnitude values. In response to RAI 2.5.2-1, the applicant referred the NRC staff to a recently produced study by the Nuclear Energy Institute (NEI) (ML081720144). This study, submitted to the NRC on May 14, 2008, is intended to address the issue of ETSZ M_{max} uncertainties in a generic manner. Based on the results of this study, the applicant concluded that potential changes resulting from updating the EPRI-SOG ETSZ M_{max} values are not significant and, therefore, the applicant chose not to update the original EPRI-SOG source models for the ETSZ for the BLN site.

NEI White Paper Study

The NEI study cited by the applicant (White Paper on 'Seismic Hazard in the Eastern Tennessee Seismic Zone,' 2008) provides the results of comparative analyses of hazard curves and GMRS values calculated using both the original EPRI source model parameters and updated ETSZ M_{max} values taken from the LLNL-TIP study and the TVA-DSS. To address the updated M_{max} issue generically, the NEI study selected a hypothetical test site location (84.2W, 35.5N) in the middle of the ETSZ to assess the impact of more recent maximum magnitude estimations for the ETSZ. The NEI study's assumption is that a hypothetical site in the middle of the ETSZ provides the most sensitive scenario for assessing the potential impact of the proposed updates. 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. An alternative approach of using the weighted averaging of the original EPRI-SOG results and the updated M_{max}, resulted in an increase of less than 1 percent in the GMRS values at the test site. Based on these calculations, the NEI study concludes that there is no need to revise the EPRI-SOG ETSZ M_{max} values.

The basis of the NEI sensitivity study is to analyze the impact of the proposed larger M_{max} values for the ETSZ. Two recent studies conducted by LLNL in 2002 and TVA-DSS in 2004 included higher M_{max} values for the ETSZ than what the original EPRI source models defined for this area. The LLNL study, also known as the TIP, consisted of a PSHA study to test the SSHAC Level 4 procedures and a comprehensive PSHA study for two nuclear power plant sites: Watts Bar and Vogtle. The Geomatrix study, also known as the TVA-DSS, aimed at developing site-specific dam safety seismic hazard assessments for all of the TVA's major dams. The NEI study focused on investigating whether the M_{max} and source geometry updates proposed in these two studies produced any significant changes in the total hazard compared to using the original EPRI ETSZ source geometries and M_{max} values. The range of ETSZ M_{max} values is about the same in the EPRI-SOG models and these two more recent studies. However, higher probabilities are assigned to higher M_{max} values in the LLNL and Geomatrix studies (Figure 2.5.2-6).

The ETSZ sensitivity study as outlined in the NEI study followed a four-step process. First, the study updated the seismic catalog in the region of interest, covering all the seismic source geometries enclosing the ETSZ. Then, the study recalculated the seismicity rates and modified the M_{max} values of each of the EPRI seismic sources covering the ETSZ. In the third step, the study determined the sensitivity to these alternative models, and in the final step the study proposed integration scenarios using these alternative interpretations.

The updated earthquake catalog used by the NEI study included 136 earthquakes with magnitudes larger than 3.0 in the region of interest. Using the updated earthquake catalog, the NEI study calculated revised earthquake recurrence parameters for each of the EPRI sources. The NEI study indicated that the updated earthquake catalog reduced the earthquake recurrence parameters used in the original EPRI source models only slightly.

The NEI study then determined the composite M_{max} values by averaging the LLNL and TVA-DSS M_{max} values and determined the updated, composite mean M_{max} values to be used for the sensitivity analyses. SER Table 2.5.2-6 shows the individual M_{max} values used in the NEI study. Using these composite M_{max} values and the original EPRI ETSZ M_{max} values, the NEI study calculated two different PSHA results for the test site located in the middle of the ETSZ. In addition to the seismic sources encompassing the ETSZ, the study also included the NMSZ and the Charleston seismic source zone. For simplicity purposes, the study excluded the hazard contributions from other smaller seismic sources in the area in its calculations. As a consequence, the study results are slightly more conservative. Since the NEI study looks at the final percentage increases in total hazard due to proposed higher M_{max} values for the ETSZ, if all the sources were included, the total hazard would be higher, and the resultant percentage change due to M_{max} increases in the ETSZ would be lower.

The NEI study first provided the results of seismic hazard calculations at the hypothetical site using the original EPRI seismic source models with the updated NMSZ and the Charleston seismic source zone geometries and recurrence parameters. These base results indicated that at high frequencies the ETSZ seismic sources generally dominate the hazard at the test site. However, at lower frequencies (e.g., 1 Hz) the NMSZ showed an important contribution to the hazard. The Charleston seismic source did not contribute much at either the higher or lower frequencies. The study then described the results of a second set of calculations using the updated ETSZ M_{max} values shown in SER Table 2.5.2-6 along with the updated NMSZ and Charleston seismic source models. SER Table 2.5.2-7 shows the comparisons of the results obtained in these two sets of calculations. The largest percentage increase calculated for the site GMRS is 6 percent at the ground motion frequency of 5 Hz.

Although the NEI study revised the original EPRI-SOG ETSZ M_{max} values, as indicated above, the study represented that the ETSZ M_{max} values used for the LLNL-TIP and TVA-DSS studies are not based on any new scientific data; but represent an alternative view of scientific opinion. Hence, the NEI study concludes it is not appropriate to modify the original EPRI-SOG M_{max} values. The NEI study states that a sound approach would be to incorporate the results of the LLNL-TIP and TVA-DSS interpretations with the original EPRI models to reach an encompassing determination in the seismic hazard potential of the ETSZ. To integrate the results, the NEI study weighted the EPRI results by ¾ and the results obtained by the two recent updates by ¼, representing the contributions from a total of 8 different models. With this approach, the maximum increase calculated for the GMRS values at the hypothetical site is no more than 1 percent across all frequencies of interest. SER Table 2.5.2-8 shows the results of these calculations.

The NEI study concluded that using either of the two approaches, described above, did not result in a significant increase in the GMRS for the hypothetical site. This relatively small impact of updating or revising the ETSZ M_{max} values for the hazard results of the hypothetical site is due to the dominance of the NMSZ over a wide area of the CEUS. Due to this small increase in the GMRS, the NEI study concluded that modifying the EPRI-SOG M_{max} values for the ETSZ would result in only insignificant increases to the GMRS for nuclear power plant sites near the ETSZ.

NRC ETSZ Sensitivity Study

The staff also conducted its own sensitivity study to determine the impact of the updated M_{max} values on the calculated hazard curves at the same hypothetical site used by the NEI study. However, unlike the NEI study, the staff used a different source geometry to represent the ETSZ. At the time of the original mid-1980's EPRI-SOG study, there was little known about the ETSZ. SER Figure 2.5.2-7 shows the EPRI-SOG source geometries that characterize the ETSZ. As SER Figure 2.5.2-7 shows, some of the ETSZ geometries defined by the EPRI-SOG are not completely centered over the area of the largest concentration of seismicity in the ETSZ. Rather than using the EPRI-SOG source geometries to define the ETSZ, the staff used a single source geometry that encompasses the current seismicity as shown in SER Figure 2.5.2-7. Using this representation of the ETSZ and the same composite M_{max} values determined by the NEI study, the staff calculated 1 Hz and 10 Hz hazard curves at the same hypothetical test site, located in the center of the ETSZ. SER Table 2.5.2-9 shows the results of these calculations.

In addition to performing its own sensitivity study for the ETSZ, the staff asked the applicant, in RAI 2.5.2-9, how the percentage increases shown for the GMRS would change if the test site were to be located outside the ETSZ, especially if a potential COL or ESP site were to be farther away from the NMSZ but still in close proximity to the ETSZ. The applicant responded to RAI 2.5.2-9 by stating that the BLN site is actually closer to the NMSZ than the hypothetical test site used in the NEI study and, hence, the percentage changes in the GMRS at the BLN site, due to the revised source geometries and M_{max} values, would be even smaller.

The staff concludes that because of relatively small increases observed in GMRS values (about 7 percent in the staff's assessment and about 1 percent in the White Paper's assessment) due to more recent updates to M_{max} values and source geometries, the use of the original EPRI source model parameters is adequate to represent the seismic hazard at the BLN site. However, the staff also concludes that this assumption may not be valid for all potential sites in the region and each site will require its own sensitivity study.

Charleston Seismic Source

BLN COL FSAR Subsection 2.5.2.2.4 describes the Charleston seismic source model used by the applicant to represent the large repeating, characteristic earthquakes in the Charleston seismic source zone. Recognizing that the EPRI-SOG source models for the Charleston seismic source zone are outdated, the applicant used the TVA-DSS, performed by Geomatrix. The TVA-DSS uses the LLNL-TIP study and the 2002 USGS National Seismic Hazard Map study to develop aerial seismic source zones for the Charleson seismic source. The TVA-DSS also represents the Charleston seismic source zone with two fault sources: a fault-based model centered on the Woodstock fault and one on the southern zone of river anomalies. The TVA-DSS weighed the fault-based sources, 67 percent, and the larger aerial seismic sources, 33 percent, to represent the source geometry model for the Charleston seismic source zone. The applicant used this Charleston model in its sensitivity calculations to determine the contribution of the Charleston seismic source to the total hazard at the BLN site. Based on its sensitivity study, the applicant concluded that the Charleston seismic source contributes only slightly to the total hazard at the BLN site. As a result, for its final PSHA for the BLN site, the applicant used only the Woodstock fault-based model to represent the source geometry for the Charleston seismic source zone.

Because the staff has not previously reviewed either the TVA-DSS or the simplified model used by the applicant to model the Charleston seismic source for its PSHA, the staff is concerned that both of these source models may not adequately characterize the seismic hazard of the Charleston seismic source. Specifically, the staff is concerned that assigning a weight of 67 percent to the smaller fault-based source models may not adequately represent the uncertainty in the location(s) of the large-magnitude Charleston earthquakes. This issue is further amplified by the applicant's decision to use the single Woodstock fault model for its final PSHA. Much of the present day seismic activity in the Charleston seismic source zone is located fairly close to the Woodstock fault; however, this may not be the location of the repeating large-magnitude earthquakes, such as the magnitude 6.8 to 7.5 1886 earthquake. In addition, the applicant's characterization of the Charleston seismic source zone differs significantly from the Charleston seismic source zone hazard model used by Southern Nuclear Operating Company for its Vogtle ESP and previously approved by the NRC staff.
In RAI 2.5.2-10, the staff asked the applicant to explain its use of the Woodstock fault as the sole source of the Charleston-type repeating large earthquakes and to provide hazard curves for the BLN site to show contribution of the Charleston seismic source to the total hazard. Because the staff has not yet reviewed the response to RAI 2.5.2-10, this is identified as **Open Item 2.5.2-2.**

Controlling Earthquakes

BLN COL FSAR 2.5.2.4.4.5 describes the deaggregation of final PSHA hazard curves to determine the controlling earthquakes for the BLN site. To determine the low- and high-frequency controlling earthquakes, the applicant followed the procedure outlined in Appendix D to RG 1.208. This procedure specifies that the controlling earthquakes are determined from the deaggregation of the PSHA results corresponding to the annual frequencies of 1E-4, 1E-5, and 1E-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 2.5.2-10 (reproduced from FSAR Table 2.5-218) lists the low- and high-frequency controlling earthquakes for the BLN site. For the high-frequency mean 1E-4, 1E-5, and 1E-6 hazard levels, the controlling earthquake is a magnitude 5.9 event occurring at a distance of 20 km (12.4 miles), corresponding to an earthquake from a local seismic source zone. In contrast, for the low-frequency mean 1E-4, 1E-5, and 1E-6 hazard levels, the controlling earthquake is an **M**=7.7 earthquake at a distance of 360 km (223.6 miles). This controlling earthquake corresponds to an event in the NMSZ. After review of these two 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.

Epsilon Value

BLN COL FSAR Figures 2.5-281 and 2.5-283 illustrate the mean deaggregation of 5 and 10 Hz structural frequencies and 1E-4 and 1E-5 annual frequencies of exceedance, respectively. The figures show the contribution from magnitude 5 to 5.5 earthquakes at distances of 0 to 20 km (12.4 miles) with the deaggregated epsilon (ε) values. Epsilon (ε) represents the number of standard deviations included in defining the distribution of ground motions for each magnitude and distance scenario. In RAI 2.5.2-6, the staff asked the applicant to explain the range of ε values for the magnitude and distance bins shown in these two figures. The staff asked if the low ε values in BLN COL FSAR Figure 2.5 -281, relative to the ε values in BLN COL FSAR Figure 2.5-283, imply that the probabilistic 1E-4 ground motion is primarily associated with ground motions that are smaller than the median motion for the magnitude and distance bin at 5 to 10 Hz. The staff also asked the applicant to explain the impact of the low ε values to the GMRS at frequencies greater than 5 Hz.

In its response to RAI 2.5.2-6, the applicant explained that controlling magnitude and distance values are used to scale spectral shapes between the spectral frequencies at which the hazard calculations were performed. The applicant stated that the low ε values have no appreciable impact on the GRMS calculation, because the aleatory uncertainties in ground motion equations are similar at 5, 10, 25 and 100 Hz and adjusting the spectral shape to account for different ε values would not have a significant effect, especially once the spectral shapes are anchored to the UHRS amplitudes at 5, 10, 25 and 100 Hz. Because the aleatory uncertainties in the ground motion equations are similar at 5, 10, 25, and 100 Hz, the staff concludes that the relative variability in the deaggregated epsilon values illustrated in BLN COL FSAR Figures 2.5-281 and 2.5-283 for magnitude 5 to 5.5 earthquakes at distances of 0 to 20 km (12.4 miles) do not have a significant effect on the hazard calculations at the BLN site.

The staff concludes that the applicant's PSHA adequately characterized the seismic hazard of the BLN site, with the exception of two open items: **Open Items 2.5.2-1 and 2.5.2-2**. Successful resolution of these open items will lead to a staff conclusion that the applicant's PSHA adequately characterizes the seismic hazards for the region surrounding the BLN 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

BLN COL FSAR Section 2.5.2.5 describes the method used by the applicant to develop the BLN site free-field ground motion spectrum. The seismic hazard curves generated by the applicant's PSHA are defined for hard rock conditions (characterized by a shear wave, V_S, velocity of 9,200 ft./s or greater). According to the applicant, two-thirds of the measured rock sections underlying the site exhibit shear wave velocities of 9,200 ft./s (2.8 km/s) or greater. Because the measured V_S reach 9,200 ft./s, the applicant used the hazard curves without a site-specific response analysis.

In BLN COL FSAR Section 2.5.4.1, the applicant presented data and analysis of the site stratigraphy, unit thickness, compressional wave velocities, and Vs. BLN COL FSAR Figure 2.5-299 shows a stratigraphic column at the site and illustrates a composite shear wave velocity (Vs) profile for six lithologic units (Units, or Layers, A through F). In that figure and in BLN COL FSAR Table 2.5-205, the Layer C unit appears as approximately 20.4 m (67 ft.) thick with an average Vs of 2.1 km/s (7,000 ft./s), which is considerably lower than the hard rock shear wave velocities assumed in the EPRI ground motion prediction models (i.e., 9200 ft./s).

Layer C is part of the southeast dipping (~ 17°) limb of the Sequatchie anticline. This unit comprises about 20 percent of the surface footprint of BLN Unit 3 with a thickness of less than 3 m (10 ft.) beneath the reactor unit foundation, as illustrated in BLN COL FSAR Figure 2.5-339. Beneath BLN Unit 4, Layer C lies approximately 42 m (138 ft.) beneath the structure's foundation with a layer thickness of about 75 ft. (BLN COL FSAR Figure 2.5-339). In RAI 2.5.2-2, the staff asked the applicant to explain whether the existence of the lower Vs for Layer C disqualifies the site as a hard rock site and to provide the basis for its decision not to conduct a site response analysis. The staff also asked the applicant to explain the potential impact of Layer C on the site response analysis and ultimately the GMRS calculation.

In response to RAI 2.5.2-2, the applicant explained that, in EPRI's (1993) (Ref. EPRI TR-102293) study of CEUS attenuation models for site response analyses, EPRI represented the Central and Eastern North America with a Mid-continental model. That model used a range of V_S about 2.60 km/s (8,500 ft./s) to 2.95 km/s (9600 ft./s) over 1 km. The applicant explained that when V_S for Layer C beneath BLN Unit 3 is averaged with velocities of underlying layers over a 100-ft. in depth, the average V_S is about 2.7 km/s (9,000 ft./s). In its response, the applicant concluded that this average is well within the range of averaged hard rock velocities incorporated into the EPRI (2004) ground motion prediction models.

To analyze the effect of Layer C on seismic hazard at the BLN site, the staff conducted a sensitivity analysis that incorporated Layer C beneath both reactor unit sites to calculate the amplification resulting from a hypothetical controlling earthquake with a magnitude of 6.5 at a distance of 10 km (6.2 miles). This hypothetical controlling earthquake is larger and closer than the high-frequency controlling earthquake estimated by the applicant (**M** 5.9 at **R** 20 km); therefore, the staff's hypothetical controlling earthquake is a more conservative assumption. For both BLN 3 and 4, the staff calculated the amplification function using the 1-D velocity structure taken from BLN COL FSAR Figure 2.5-339.

Beneath BLN Unit 4, the staff's sensitivity analysis assumed Layer C had a thickness of 23 m (75 ft.) with the top of the layer lying at a depth of 41 m (135 ft.) beneath the reactor foundation. SER Figure 2.5.2-7 shows the results of the staff's sensitivity analysis for BLN Unit 4. The figure shows that Layer C results in a slight amplification of 1.1 to 1.15 times at frequencies between 5 and 10 Hz and a slight deamplification at higher frequencies (> 12 Hz). Amplification factors of less than or equal to 1.15 are minimal factors. Therefore, the staff considers the lower V_S of Layer C to have no appreciable effect on the seismic hazard of BLN Unit 4. Beneath BLN Unit 3, the sensitivity analysis assumed Layer C had a thickness of 3 m (10 ft.) at the base of the foundation and spanned the entire footprint of the reactor unit. After excavation of top soil and rock beneath BLN Unit 3, Layer C will be < 10 ft. thick beneath BLN Unit 3. The results of the staff's sensitivity analysis for BLN Unit 3 revealed that the amplification ratio between the applicant's model and the staff's model, which included Layer C, is approximately equal to 1 over frequencies from 0 to 25 Hz. As such, the staff concludes that Layer C has no appreciable effect on the seismic hazard of BLN Unit 3.

Because the average velocities beneath BLN Unit 3 are consistent with the EPRI attenuation models for site response analyses and because the staff's sensitivity analyses illustrated a minimal effect of Layer C on the site amplification, the staff concludes that Layer C does not appreciably affect the BLN site seismic hazard and, therefore, the layer does not compromise the applicant's assumption of the BLN site as a hard rock site.

The staff focused its review of BLN COL FSAR Subsection 2.5.2.5, Seismic Wave Transmission Characteristics of the Site, on the applicant's assumptions of BLN being a hard rock site and the applicant's use of EPRI ground motion equations without a site-specific response analysis. Based on the staff's own analysis as explained above and the applicant's response to RAI 2.5.2-2, the staff concludes that the applicant's assumption of the BLN 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 ground motion response spectra calculations.

2.5.2.4.6 Ground Motion Response Spectra

As stated in SER Section 2.5.2.1, RG 1.208 defines the GMRS as the site-specific SSE to distinguish it from the certified seismic design response spectra (CSDRS), the design ground motion for the AP1000 certified design.

BLN 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. The applicant approximated dipping layers (15-17 °) at the site with a horizontal model and presented the horizontal GMRS in BLN COL FSAR Figure 2.5.2-290. The applicant stated that it used vertical to horizontal (V/H) response spectral ratios for CEUS rock conditions provided in NUREG/CR-6728 to develop the vertical GMRS. The V/H ratio for PGA < 0.2 g apply to the 10^{-4} UHRS and V/H ratio for 0.2 g < PGA < 0.5 g apply to the 10^{-5} UHRS. SER Figure 2.5.2-3 shows the final horizontal and vertical GMRS.

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.

In the SER with open items for Chapter 2 of the AP1000 DCD, Open Item OI2.5-RGS1-15 addresses the staff's concerns regarding an inconsistency between the applicant's committed changes in responses to DCD RAI-SRP 2.5-RGS1-15 and Revision 17 of the DCD regarding the SSE and CSDRS definitions as well as others. Since the amendment to the AP1000 DCD is still under review, the staff will monitor future resolutions of the corresponding Open Item and ensure that any subsequent changes to the DCD, and the staff's SER, are properly reflected in the BNL site-specific COL application. This is part of **Open Item 1-1.**

2.5.2.4.7 Staff Consclusions Regarding Vibratory Ground Motion

As set forth above, the staff reviewed the seismic information submitted by the applicant in BLN COL FSAR Section 2.5.2. On the basis of its review of FSAR Section 2.5.2 and upon resolution of Open Items 2.5.2-1 and 2.5.2-2, the staff finds that the applicant 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 that this PSHA follows the guidance provided in RG 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, resolution of these open items will lead to the staff finding 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 site subsurface properties. The staff concludes, pending the resolution of open items, that the proposed COL site is acceptable from a geologic and seismologic standpoint and meets the requirements of 10 CFR 100.23.

This information addresses BLN COL 2.5-2 to resolve COL Information Item 2.5-2, and BLN COL 2.5-3 to resolve COL Information Item 2.5-3. In conclusion, the applicant has provided sufficient information for satisfying 10 CFR 100.23.

2.5.2.5 Post Combined License Activities

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

2.5.2.6 Conclusions

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 with the exception of open and confirmatory items there is no outstanding information expected to be addressed in the BLN COL FSAR related to this subsection.

The Westinghouse application to amend Appendix D to 10 CFR Part 52 includes changes to Section 2.5.2 of the AP1000 DCD, as stated in Revision 17 of the AP1000 DCD. The staff is reviewing this information on Docket Number 52-006. The results of the NRC staff's technical evaluation of the information incorporated by reference in the BLN COL FSAR will be documented in a supplement to NUREG-1793. The supplement to NUREG-1793 is not yet complete, and this is being tracked as part of Open Item 1-1. The staff will update Section 2.5.2 of this SER to reflect the final disposition of the DC application.

As a result of the open and confirmatory items, the staff is unable to finalize its conclusions on vibratory ground motion at the COL site in accordance with the requirements of 10 CFR 100.23.

2.5.3 Surface Faulting

2.5.3.1 Introduction

BLN COL FSAR Section 2.5.3 is concerned with the potential for surface deformation due to faulting. The information related to such surface deformation is collected by the applicant during site characterization investigations. The information provided by the applicant 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 and characterization of those sources; ages of most recent deformation; relationships between tectonic structures in the site area and regional tectonic structures; designation of zones of Quaternary (less than 1.8 Ma) deformation in the site region; and potential for surface tectonic deformation at the site.

2.5.3.2 Summary of Application

Section 2.5.3 of the BLN COL FSAR incorporates by reference Section 2.5.3 of the AP1000 DCD, Revision 17.

In addition, in BLN COL FSAR, the applicant provided the following:

AP1000 COL Information Item

- BLN COL 2.5-4

The applicant provided additional information in BLN COL 2.5-4 to address COL Information Item 2.5-4 [COL Action Item 2.5.3-1]. BLN COL 2.5-4 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 BLN COL FSAR Section 2.5.3 for the BLN site based on its review of relevant published geologic literature; aerial photographic interpretation; lineament analyses; interviews with experts familiar with the geology, seismology, and tectonics of the site region; a review of seismicity data; and geologic field investigations. The field investigations performed by the applicant included geologic field reconnaissance, aerial reconnaissance, and geologic mapping of rock units and Quaternary deposits at the site. In addition, the applicant used the previous FSAR (TVA, 1986) as well as construction reports and interactions with personnel involved for BLN 1 and 2 to supplement its recent geologic and seismic investigations for the site.

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 aerial and field investigations.

2.5.3.2.1 Geologic, Seismic, and Geophysical Investigations

In BLN COL FSAR Section 2.5.3, the applicant discussed investigations performed to evaluate surface faulting due to tectonic and non-tectonic deformation within the site vicinity, or within a 40 km (25 mi) radius of the site. Based on the results of these investigations, the applicant concluded that no evidence exists to indicate the presence of geologically recent or active faulting in the site area, within an 8 km (5 mile) radius of the site, or within a 1 km (0.6 mile) radius of the BLN site.

The following subsections provide a summary of the geologic investigations performed by the applicant to investigate the potential for surface faulting at the BLN site.

Data and Literature Review

The applicant compiled and reviewed existing data and literature, which includes detailed geologic maps of the stratigraphy and structural geology within a 1 km (0.6 mile) and 8 km (5 mile) radius of the site, and subsurface information including geologic structures, tectonic features and regional stratigraphy. The applicant incorporated both recent and in-press publications into its review.

Aerial Photographic and Topographic Map Interpretation

The applicant interpreted aerial photography, including both pre- and post-construction aerial photographs for BLN 1 and 2, obtained from the USGS, TVA and the U.S. Department of Agriculture. The interpretation focused on tectonic surface deformation along the Sequatchie Valley and Wills Valley faults, the only two mapped faults within the site vicinity (40 km (25 mile) radius), and non-tectonic deformation such as karst and dissolution features, which are further discussed in BLN COL FSAR Section 2.5.4.1. The applicant used 1966 and 1935 aerial photographs to search for geomorphic features indicative of potential Quaternary activity along the only fault within an 8 km (5 mile) site radius, the Sequatchie Valley fault.

The applicant interpreted detailed pre-construction topographic maps and aerial photographs to generate a lineament map used to evaluate potential surface faulting. The applicant also used pre-development (1971) topographic maps and aerial photography to identify lineaments and drainage features. The applicant supplemented the above data with topographic maps generated in 2006.

Current Aerial and Field Reconnaissance

The applicant conducted two field reconnaissance investigations for the site region. The initial reconnaissance focused on a review of the geology of the site within a 1 km (0.6 mile) and 8 km (5 mile) radius of the power block construction zone, including a review of photographic lineaments and karst features as well as the Sequatchie Valley thrust fault and related folds. The second investigation used aerial reconnaissance to focus on the Appalachian fold and thrust belt within 40 km (25 miles) of the site and the epicentral region of the 2003 Fort Payne earthquake. The aerial reconnaissance included a review of the Quaternary deposits mapped along the Coosa River and Weiss Lake regions, approximately 32 km (20 miles) from the epicentral region of the Fort Payne earthquake, and the review of a historical landslide near the epicenter of the same earthquake. Finally, the applicant carried out an additional aerial reconnaissance, in 2006, to search for evidence of surface faulting and to identify lineaments. The reconnaissance confirmed the locations of several lineaments described in BLN COL FSAR Section 2.5.3.2.2.

Additional Investigation

In addition to its data and literature review and aerial and field investigations, the applicant contacted personnel involved with the previous site characterization for BLN 1 and 2 and researchers with current knowledge and expertise in the structural geology, tectonics and stratigraphy of the site region. Finally, the applicant reviewed earthquake distributions for the surrounding region, including instrumental and historical earthquake data.

2.5.3.2.2 Geologic Evidence, or Absence of Evidence, for Surface Deformation

BLN COL FSAR Section 2.5.3.2 addresses the potential for surface deformation within the site vicinity. The applicant focused its discussions on two Paleozoic bedrock faults, the Sequatchie Valley and Wills Valley thrust faults, located within a 40 km (25 mile) radius of the site. The applicant also provided a description of its lineament analysis, performed to evaluate the potential for surface faulting within the site area. The applicant concluded that no evidence exists for Quaternary surface deformation on, or associated with, structures identified within a 40 km (25 mile) radius of the BLN site.

The following subsections provide a summary of structures within the site vicinity, as described in BLN COL FSAR Section 2.5.3.2.1, and a summary of the lineament analysis performed by the applicant, as described in BLN COL FSAR Section 2.5.3.2.2.

Potential Tectonic Surface Deformation Features

In BLN COL FSAR Sections 2.5.3.2.1.1 through 2.5.3.2.1.3, the applicant discussed two Paleozoic (543-248 Ma) bedrock faults as well as basement faults that may have influenced development of these Paleozoic faults. Additional descriptions of the Sequatchie Valley and Wills Valley thrust faults and the basement faults are included in BLN COL FSAR Sections 2.5.1.1.4.2.1, 2.5.1.1.4.2.2 and 2.5.1.2.5. SER Figure 2.5.3-1 (reproduced from BLN COL FSAR Figure 2.5-294) shows the locations of these faults relative to the BLN site.

Sequatchie Anticline and Sequatchie Valley Thrust Fault. The Sequatchie Valley anticline, as described in BLN COL FSAR Section 2.5.3.2.1.1, is an elongated asymmetric feature that extends 400 km (250 miles) and is the most northwesterly structure of the southern Appalachians. The Sequatchie Valley fault is a northwest-verging thrust fault that extends southward along the northwest flank of the anticline from near its northern end. The displacement along the fault decreases toward the south to a point about 112 km (70 miles) southwest of the Alabama/Tennessee state line where the fault disappears completely. Stratigraphic observations in well and regional seismic data suggest that the structure merges into the regional detachment (zone separating overlying deformed strata from underlying undeformed strata) near the base of the Paleozoic cover sequence.

The Sequatchie Valley thrust fault is within 3.4 km (2.1 miles) of the site at its closest proximity. Excavations at the Scottsboro waste transfer facility, which is located approximately 5.8 km (3.6. miles) west of the BLN site, provide good exposures of steeply dipping strata and deformation in the hanging wall of the fault.

Wills Valley Anticline and Thrust Fault. In BLN COL FSAR Section 2.5.3.2.1.2, the applicant provided detailed information on the Wills Valley anticline and associated thrust fault. The Wills Valley anticline and thrust fault also lie within the northwestern part of the Appalachian thrust belt, which is characterized by broad, flat-bottomed synclines and large-scale northeast trending narrow asymmetric anticlines. The Wills Valley fault is located 27 km (17 miles) southeast of the BLN site. The Wills Valley fault is of regional extent, it merges into the regional detachment at a depth of about 3 km (1.9 miles), and it crops out at the western margin of the Wills Valley.

Sub-detachment basement faults. In BLN COL FSAR Section 2.5.3.2.1.3, the applicant described the sub-detachment basement faults, identified by others using seismic reflection data. These faults beneath the regional detachment appear to control the location of the Sequatchie Valley and Wills Valley thrust faults and folds. The inferred sub-detachment basement fault associated with the Sequatchie Valley fault is shown to lie at the depth about 3.2-4.8 km (2-3 miles) from the BLN site. The fault location is based on correlations between picks on seismic lines that are located approximately 37 km (23 miles) and 52.8 km (33 miles) to the northeast and southeast of the site, respectively.

Based on its literature review and aerial and field reconnaissance, the applicant found no geologic or seismic evidence that these structures have been reactivated in the current tectonic stress regime. Furthermore, no deformation or geomorphic features associated with the structures indicate that they have been active during the past 1.8 million years (Quaternary time period).

Lineament Analysis

In BLN COL FSAR Section 2.5.3.2.2, the applicant described its lineament analysis and the results. The applicant focused its investigations on two topographic lineaments, lineaments #4 and #12, located within the vicinity of the power block for the proposed BLN 3 and 4. These lineaments are shown in SER Figure 2.5.3-2 (reproduced from BLN COL FSAR Figure 2.5-291).

Lineament #4 is located along the axis of a small linear valley, which is parallel to the strike of bedding and follows a lithologic contact. The proposed BLN Unit 4 power block directly overlies this lineament. Lineament #12 follows the trough of a linear valley that trends N25°E. It is 365.8 meters (1200 ft.) in length, and is located parallel and adjacent to lineaments #11 and #13. It is located outside of the power block construction zone, but projects toward the center of BLN Unit 3. The applicant stated that investigations show that lineament #12 represents a zone of enhanced weathering and erosion, associated with a high angle joint along which some minor shearing may have taken place. The joint does not continue into the power block construction zone.

The applicant concluded that lineaments mapped within the BLN site are primarily associated with bedding and jointing in the bedrock. There is no geomorphic or geologic evidence to suggest that any of these lineaments are associated with a capable tectonic fault or pose a surface rupture hazard.

2.5.3.2.3 Correlation of Earthquakes with Capable Tectonic Sources

In BLN COL FSAR Section 2.5.3.3, the applicant stated that based on its combined review of seismicity data and mapped surface fault traces, there is no spatial correlation between historic earthquakes within a 40 km (25 mile) radius of the site and any mapped fault. Neither epicentral projections of historic earthquakes nor earthquake focal depths correlate with any of the mapped faults. Both the Sequatchie Valley and Wills Valley faults are believed to taper into the regional detachment zone at about 3 km (1.86 miles) depth while most focal depths for historic earthquakes are greater than 3 km (1.86 miles) depth. The applicant stated that the Sequatchie and Wills Valley faults, therefore, are too shallow to be the source of historical seismicity.

The M 4.6 Fort Payne earthquake that occurred in 2003 is thought to be associated with basement faults; however, the applicant stated that no correlation exists between this earthquake and any inferred sub-detachment basement faults. The applicant concluded that no capable tectonic sources are present that could extend to within 8 km (5 miles) of the site and cause surface deformation.

2.5.3.2.4 Ages of Most Recent Deformations

The applicant stated in BLN COL FSAR Section 2.5.3.4 that none of the faults within a 40 km (25 mile) radius of the BLN site exhibit evidence for Quaternary activity. The mapped faults mainly formed during the Alleghanian orogeny (323-248 Ma) at the end of the Paleozoic era (about 248 Ma). The youngest deformed foreland unit, the Dunkard Group, is between 286-266 million years old. The sub-detachment basement faults are interpreted to be older faults that initially formed during the late Proterozoic (900-543 Ma) and early Paleozoic (about 543-490 Ma) eras and may have reactivated in later orogenies. These basement faults show no evidence of post-Alleghanian deformation.

2.5.3.2.5 Relationship of Tectonic Structures in the Site Area to Regional Tectonic Structures

The applicant stated in BLN COL FSAR Section 2.5.3.5 that bedrock faults within a 40 km (25 mile) radius of the site are part of the regional Appalachian Foreland fold-thrust belt and developed during the Alleghanian orogeny. There is no new information to indicate that the thrust faults within the Appalachian foreland thrust belt are capable tectonic structures. In addition, basement faults are inferred to represent the most cratonward Iapetan normal faults. The cratonward limit of large normal faults in the passive margin of the late Proterozoic to early Paleozoic Iapetus Ocean is a fundamental boundary for assessing seismic hazards in eastern North America.

2.5.3.2.6 Characterization of Capable Tectonic Sources

In BLN COL FSAR Section 2.5.3.6, the applicant stated that it used RG 1.208 criteria for defining a capable fault to characterize the structures found in the site area. The applicant summarized that two mapped faults, the Sequatchie Valley and Wills Valley thrust faults are not capable faults based on the following evidence:

1) Both faults merge into the regional detachment at depths of about 2.6 km (1.6 miles) and 3.0 km (1.9 miles), respectively. These faults do not extend to the hypocentral depth at which moderate to large earthquakes typically nucleate. Instrumentally recorded earthquakes, including the 2003 Fort Payne earthquake, generally occur within the basement rocks below Paleozoic cover at a depth greater than 4.8 km (3 miles);

2) Northeast trending faults do not orient favorably for reactivation under the contemporary maximum horizontal compression, which orients northeast to east-northeast; and

3) There is no evidence of Quaternary deformation reported in the literature or observed during field and aerial reconnaissance.

The applicant also reviewed the FSAR for BLN 1 and 2 (TVA 1986), which concludes that structurally related major northeast-trending faults within the Valley and Ridge Province are inactive based on the following:

1) No description, implication, or inference of active faulting evidence since the Paleozoic is apparent from the detailed geologic mapping investigations conducted throughout the province;

2) A sample from the Copper Creek fault, near the Clinch River breeder reactor site, that was dated using Potassium–Argon methods, indicated that the last movement occurred 280-290 Ma;

3) A core boring through the Missionary Ridge fault (at Chickamauga Dam) indicating that material had recrystallized along the fault and core samples, from the Tellico Project, that showed rocks on the Knoxville fault as an unbroken sample at several locations.

Finally, the applicant concluded that the inferred basement faults within a 40 km (25 mile) radius are not capable tectonic sources. There is no apparent association of seismicity with these faults and there is no evidence of surface or near surface Quaternary deformation to suggest that these faults are capable tectonic sources.

2.5.3.2.7 Designation of Zones of Quaternary Deformation in the Site Region

The applicant indicated in BLN COL FSAR Section 2.5.3.7 that it has not identified any significant zones of Quaternary deformation that would require additional investigation within a 40 km (25 mile) radius of the site. The applicant has not observed any evidence of surface deformation at the site during the field investigation, lineament analysis, or aerial reconnaissance. The lineaments mapped at the site are likely related to lithologic differences, solution enlarged joints, and or fractures (older than 1.8 million years) that have facilitated groundwater movement and weathering in rocks of the Stones River Group rocks.

2.5.3.2.8 Potential for Surface Tectonic Deformation at the Site

The applicant concluded in BLN COL FSAR Section 2.5.3.8 that surface deformation at the site is negligible. The applicant based its conclusion on bedrock mapping in the region, lack of evidence for surface faulting or deformation within the BLN site area, and the absence of geomorphic features indicative of Quaternary deformation, as reported in the previous reports and literature. Observation and analyses made during the field and aerial reconnaissance and lineament analyses, as well as field investigations, are consistent with this finding. No evidence was found to support differential uplift or surface deformation (warping, tilting) associated with the lineaments that intersect or project to the site, indicating that these lineaments are not capable tectonic structures.

2.5.3.3 Regulatory Basis

The regulatory basis of the information incorporated by reference is addressed within the FSER related to the DCD.

In addition, the relevant requirements of the Commission regulations for surface faulting, and the associated acceptance criteria, 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 non-tectonic 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 1.165, RG 1.132, RG 1.198, RG 1.208, and RG 4.7, 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 1.165, RG 1.132, RG 1.198, RG 1.208, and RG 4.7 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 1.165 and 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 subsection 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 1.165, RG 1.208, RG 1.132, RG 1.198, RG 4.7, and RG 1.206.

2.5.3.4 <u>Technical Evaluation</u>

The NRC staff reviewed Section 2.5.3 of the BLN COL FSAR and checked the referenced DCD to ensure that the combination of the DCD and the information in the COL represent the complete scope of information relating to this review topic.[1] The NRC staff's review confirmed that the information contained in the application and incorporated by reference addresses the required information relating to surface faulting. Section 2.5.3 of Revision 17 to the AP1000 DCD is being reviewed by the staff under Docket Number 52-006. The NRC staff's technical evaluation of the information incorporated by reference related to surface faulting will be documented in the staff SER on the DC amendment application for the AP1000 design.

The staff reviewed the information contained in the BLN COL FSAR:

AP1000 COL Information Item

- BLN COL 2.5-4

The NRC staff reviewed BLN COL 2.5-4 included under Section 2.5.3 of the BLN COL FSAR. BLN COL FSAR Section 2.5.3 addresses the potential for surface or near-surface tectonic and non-tectonic deformation within an 8 km (5 mile) radius of the BLN site. The technical information presented in BLN COL FSAR Section 2.5.3 resulted from the applicant's surface and subsurface geologic investigations performed for the site area, supplemented by aerial and field reconnaissance studies undertaken within the site vicinity, or within a 40 km (25 mile) radius of the site. Through its review of BLN COL FSAR Section 2.5.3, the staff determined whether the applicant had complied with the applicable regulations and conducted its investigations with an appropriate level of detail in accordance with RG 1.208.

The NRC staff focused its review of BLN COL FSAR Section 2.5.3 on the applicant's descriptions of previous studies and data collection, as well as the applicant's own investigations conducted within the site area to assess the potential for surface tectonic deformation at the BLN site. During the early site investigation stage, the staff visited the site and interacted with the applicant regarding the potential for seismicity and solution cavity issues at the site. 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 BLN site in October 2008 to confirm interpretations, assumptions, and conclusions presented by the applicant related to the potential for surface or near-surface faulting and non-tectonic deformation. The staff's review of BLN COL FSAR Section 2.5.3 is presented below.

2.5.3.4.1 Geologic, Seismic and Geophysical Investigations

BLN COL FSAR Section 2.5.3.1 summarizes investigation methods used by the applicant to characterize the potential for surface and near surface deformation at the BLN site. The applicant compiled and reviewed existing data, interpreted aerial photography (including color infrared imagery) and implemented a detailed lineament analysis and field reconnaissance investigation. In addition, the applicant discussed pertinent issues with researchers familiar with the regional and site area tectonics, and reviewed seismic information including both instrumental and historic seismicity data.

Based on its review of BLN COL FSAR Section 2.5.3.1, verifications made during the staff's preliminary site visit and subsequent site audit, and a review of recent literature, the staff concludes that the applicant adequately investigated the potential for surface faulting in the site area as required by 10 CFR 100.23. The following sections document how these investigations were implemented by the applicant to characterize the potential for surface faulting at the BLN site.

2.5.3.4.2 Geological Evidence, or Absence of Evidence, for Surface Deformation

The staff focused its review of BLN COL FSAR Section 2.5.3.2 on the applicant's descriptions of two mapped thrust faults within 40 km (25 miles) of the site, basement faults interpreted from seismic reflection data, and a lineament analysis performed by the applicant in the BLN site area.

Sequatchie Valley Thrust Fault

The applicant discussed the Sequatchie Valley Anticline and thrust fault in BLN COL FSAR Section 2.5.3.2.1.1 and stated that the thrust fault is mapped within 3.4 km (2.1 miles) of the power block for the BLN site but no surface exposures were identified in recent investigations or in previous investigations performed for BLN 1 and 2. BLN COL FSAR Section 2.5.1.2.5 describes deformation associated with the Sequatchie Valley thrust fault as Paleozoic in age. The applicant concluded that no evidence of potential Quaternary age deformation exists for the Sequatchie Valley thrust fault in the literature and none was identified in the site investigations.

Wills Valley Thrust Fault

BLN COL FSAR Section 2.5.3.2.1.2 identifies the Wills Valley thrust fault that is located 27 km (17 miles) from the BLN site. Based on literature reviews and aerial and field reconnaissance conducted for the BLN site area, the applicant concluded that no evidence exists for Quaternary deformation on the Wills Valley fault.

Sub-detachment Basement Faults

The applicant stated, in BLN COL FSAR Section 2.5.3.2.1.3, that basement faults identified by Bayona et al. (2003) and Thomas and Bayona (2002), located beneath the regional detachment zone, appear to have controlled the Sequatchie Valley and Wills Valley thrust faults that merge into the detachment zone. BLN COL FSAR Section 2.5.3.2.1.3 concludes that no historic or instrumental seismicity aligns with these faults and no surface geologic evidence exists to indicate potential Quaternary activity on these structures. BLN COL FSAR Sections 2.5.1.1.4.2.4.2 and 2.5.3.3 state that historical seismicity surrounding the BLN site area is thought to be associated with basement structures at depths greater than 3 km and below the Appalachian detachment zone. However, the applicant stated that no historical seismicity within 40 km (25 miles) of the BLN site is associated with any known basement structures.

In RAI 2.5.3-6, the NRC staff asked the applicant to further explain how sub-detachment basement faults control the Sequatchie Valley and Wills Valley thrust faults and to also explain why the local seismicity does not concentrate along basement faults that have been identified within the site vicinity, such as those identified by Bayona et al. (2003) and Thomas and Bayona (2002).

In responding to RAI 2.5.3-6, the applicant stated that the association made between the Sequatchie Valley and Wills Valley thrust faults and the sub-detachment basement faults is based on spatial proximity between the thrust fault ramps and the underlying basement faults, and seismic reflection data that suggest the overlying Sequatchie Valley and Wills Valley thrust faults have along-strike and across-strike geometries that mimic the basement structural relief. The applicant stated that there is no definitive explanation for why historical seismicity, assumed to be associated with regional basement faults, is missing along basement faults associated with the Sequatchie and Wills Valley thrust faults; however, the applicant did suggest that the absence of seismicity along these faults supports its conclusion that these structures are not active.

Based on its review of the applicant's response to RAI 2.5.3-6, the staff concurs with the applicant's interpretation that the Sequatchie Valley and Wills Valley thrust faults are likely controlled by Precambrian basement faults located beneath the Appalachian detachment zone, based on similar geometries and a lack of evidence for reactivation within the current tectonic setting. In addition, the staff reviewed seismicity data presented by the applicant in BLN COL FSAR Section 2.5.3.3 related to tectonic structures in the site area and region. The staff concurs that there is a lack of historical and instrumentally recorded seismicity along the sub-detachment basement faults within 40 km (25 miles) of the BLN site, thus supporting the conclusion that these structures have not been recently active. The staff concludes, in agreement with the applicant, that a lack of seismicity associated with basement faults or the overlying thrust faults in the site vicinity as well as the lack of evidence for movement, or associated surface deformation, on the Sequatchie Valley and Wills Valley faults since the late Paleozoic (248 Ma) suggest that neither these two thrust faults nor the associated basement faults have been tectonically active during the Quaternary period, or during the past 1.8 million years.

Lineament Analysis

In BLN COL FSAR Section 2.5.3.2.2.1, the applicant discussed its lineament analysis conducted in the site area for the BLN COL application, focusing on two particular topographic lineaments, #12 and #4, that are located within the vicinity of the power block for the proposed BLN 3 and 4. Lineaments #12 and #4 are relatively short, less than 450 meters (1476 ft.) in length, and are strike parallel to the overall topographic expression. The applicant stated that these two joints represent zones of weathering associated with a bedding contact in lineament #4, and with a high angle joint in lineament #12. There is no geomorphic expression of surface faulting or tectonic deformation associated with either lineament #4 or #12. The applicant included a detailed analysis of karst-related deformation associated with lineament #4 in BLN COL FSAR Section 2.5.4.1. The staff's evaluation of BLN COL FSAR Section 2.5.4.1 follows in this SER in Section 2.5.4.4.

The applicant briefly discussed two other lineaments, #2 and #14, that are each more than 1.6 km (1 mile) in length and are strike perpendicular to the overall topographic expression. The applicant indicated that the location of these two major lineaments is most likely related to joint formation in the limestone bedrock that resulted from large-scale structural deformation. BLN COL FSAR Section 2.5.3.2.2.1 also states that these joints caused the bedrock to become weaker compared to the surrounding rocks and that they also became areas of preferential ground water flow.

In RAI 2.5.3-2, the staff asked the applicant to describe potential impacts to the reactor foundation resulting from weakened bedrock caused by joints that are not exposed at the surface. In response to RAI 2.5.3-2, the applicant stated that if primary bedrock joints and fractures, similar to those associated with lineaments #2 and #14, existed closer to the BLN 3 and 4 power block construction zone, that they would be expected to penetrate to the ground surface and be associated with some recognizable weathering features or surface expression. The applicant also noted that weathering along primary lineaments, such as lineaments #2 and #14, develops progressively downward and tapers at depth. Therefore, it is not likely that similar lineaments with no exposure at the ground surface would experience significant weathering at depth.

The applicant stated that geotechnical investigations, including borings and borehole and geotechnical surveys, did not identify any large scale jointing on the order of those associated with lineaments #2 and #14 and that rock units become more competent at depth, showing less frequent fracturing. The applicant stated that while these investigations did not identify primary features similar to lineaments #2 and #14, smaller features associated with secondary jointing and fracturing do occur. Lineaments #4 and #12, which are located closer to the BLN 3 and 4 power block construction zone, and discussed in BLN COL FSAR Section 2.5.3.2.2.2, are examples of such smaller features. The applicant concluded that it is unlikely that large scale jointing and fracturing exist beneath the BLN power block construction zone.

In its RAI response, the applicant also stated that it conservatively factored rock mass fracturing at the foundation into the site rock strength and deformation properties as part of its evaluation of foundation bearing capacity and settlement. Additional details of the geotechnical investigations and the applicant’s evaluation of foundation bearing capacity and settlement for BLN 3 and 4 are included in BLN COL FSAR Sections 2.5.4 1 and 2.5.4.2.3.3.

Based on its review of the applicant’s response to RAI 2.5.3-2, the staff determined that the applicant provided sufficient detail to rule out the likelihood of large scale jointing beneath the proposed BLN 3 and 4 that could weaken the foundation unit. The staff concluded that large scale jointing and fracturing are unlikely to occur at depth within the foundation for the proposed BLN 3 and 4 units, based on the absence of large scale jointing and fracturing exposed at the surface and identified from geotechnical investigations conducted beneath the proposed power block for BLN 3 and 4. The staff further acknowledges that small scale secondary jointing and fracturing is present in the foundation unit beneath BLN 3 and 4, as identified in geotechnical investigations conducted for the BLN site and described in more detail in BLN COL FSAR Sections 2.5.3.2.2.2 and 2.5.4.1. The staff’s review of the geotechnical investigations conducted by the applicant and the engineering properties associated with the foundation unit is included in Section 2.5.4.4 of this SER.

BLN COL FSAR Section 2.5.3.2.2.2 describes lineament #12 as a zone of enhanced weathering and erosion associated with a high angle joint along which some minor shearing may have taken place. The applicant concluded that the joint does not continue into the power block construction zone for proposed BLN Unit 3. In RAI 2.5.3-3, the staff asked the applicant to provide evidence that lineament #12 does not continue into the power block construction zone for BLN Unit 3. The staff also asked the applicant to provide the basis for stating that minor shearing might take place along the high angle joint.

In response to RAI 2.5.3-3, the applicant stated that lineament #12 is a relatively short feature, about 365 meters (1200 ft.) in length, expressed in the topography as a straight depression that ends about 90 meters (300 ft.) from the BLN Unit 3 power block construction zone. The applicant stated that topographic maps and aerial photographs provided no evidence that lineament #12 extended any further than shown in SER Figure 2.5.3-2. The applicant investigated test pits, performed angle borings and conducted seismic refraction and microgravity surveys to determine whether or not lineament #12 extended into the BLN Unit 3 construction zone. The applicant stated, based on the results of its investigations that no major joint or fracture zones were identified along the projection of lineament #12 into the BLN construction zone and there was no evidence for sub-surface faulting identified in the investigations.

Also in response to RAI 2.5.3-3, the applicant stated that references made in BLN COL FSAR Section 2.5.3.2.2.2, to shearing along the high angle joint associated with lineament #12, was based on early-1970's borehole data of boreholes drilled parallel to but not actually aligned with lineament #12. The applicant stated that shearing identified in the borehole data most likely represents deformation associated with formation of the Sequatchie anticline during the late-Paleozoic (248 Ma), is limited in extent to the area north of lineament #12, and does not extend toward the power block construction zone. The applicant identified no shearing or localized fissuring in residual soils present in the test pits excavated along strike of lineament #12.

Based on its review of the applicant's responses to RAI 2.5.3-3, the staff concludes that the applicant provided the appropriate level of detail for investigating lineament #12 and determining that lineament #12 most likely does not extend beneath the BLN Unit 3 construction zone. The staff concludes that it is unlikely that lineament #12 extends beneath the BLN Unit 3 construction zone based on the absence of topographic expression identified in both aerial and topographic imagery, the absence of major joint or fracture zones within the bedrock, and the absence of a localized zone of weathering along strike with the projected lineament #12. In addition, the staff verified that the applicant appropriately clarified its description of potential minor shearing associated with high angle jointing in Section 2.5.3.2.2.2 of Revision 1 to the BLN COL FSAR.

The staff concludes that the applicant presented adequate information in BLN COL FSAR Section 2.5.3.2.2 to analyze both tonal and topographic lineaments within the BLN site vicinity, or within a 40 km (25 mile) radius of the site. Furthermore, the staff concludes that geomorphic analysis and geophysical investigations of these lineaments indicate no evidence for tectonic surface deformation due to faulting at the BLN site. SER Section 2.5.4.4 provides the staff's evaluation and conclusions regarding karst features associated with lineament #4 and the potential for non-tectonic deformation related to dissolution at depth.

Conclusions

Based on its review of the information presented by the applicant in BLN COL FSAR Section 2.5.3.2, the applicant's responses to RAIs 2.5.3-6, 2.5.3-2 and 2.5.3-3, as well as information discussed in BLN COL FSAR Sections 2.5.1.2.5 and 2.5.1.1.4.2.2, the staff concludes that there is no evidence to indicate Quaternary age (1.8 Ma) tectonic surface deformation associated with two mapped faults, interpreted sub-detachment basement faults, or mapped lineaments within the BLN site vicinity, or within a 40 km (25 mile) radius of the BLN site. The staff further concludes that the applicant adequately described geologic evidence for surface deformation at the BLN site as required by 10 CFR 100.23.

2.5.3.4.3 Correlation of Earthquakes with Capable Tectonic Sources

In BLN COL FSAR Section 2.5.3.3 the applicant discussed the relationship between historical seismicity data and known faults within a 40 km (25 mile) radius of the BLN site, or the site vicinity. The applicant concluded that there are no known historical earthquakes associated with mapped traces of surface faults within the site vicinity and that earthquake epicenters do not indicate a spatial relationship with mapped surface faults or with inferred basement faults at depths greater than 3 km (1.86 miles).

The BLN site is located near the ETSZ, one of the most active seismic areas east of the Rocky Mountains. However, BLN COL FSAR Section 2.5.3.3 does not mention any paleoseismic investigations conducted within the site vicinity, or within 40 km (25 miles) of the BLN site that might identify surface deformation features associated with historic or prehistoric seismic events, and potentially associated with a capable tectonic source. In RAI 2.5.3-1, the staff asked the applicant if it carried out a systematic paleoseismic survey in the BLN site area based on its proximity to the ETSZ.

In response to RAI 2.5.3-1, the applicant stated that it conducted paleoseismic investigations at an increased level of detail closer to the BLN site. The applicant reviewed previous investigations conducted in the BLN site region and site vicinity, or within a 320 km (200 mile) and 40 km (25 mile) radius of the site. Whisner et al. (2003) found no evidence of prehistoric earthquakes within a 180 sq km (117 sq. mile) area within the most active portion of the ETSZ, and approximately 100 km (62 miles) from the BLN site.

The applicant performed aerial and field reconnaissance along the upper Coosa River located approximately 64 km (40 miles) southeast of the BLN site and found no definitive evidence of paleoseismic features although highly weathered terrace deposits, estimated to be older than several hundred thousand years, are present along the Coosa River.

The applicant stated that a preliminary investigation for the BLN site (TVA, 2006) identified potentially liquefiable deposits within an 8 km (5 mile) radius of the site, or site vicinity. These deposits are located within drainage valleys that are inundated by the adjacent Guntersville Reservoir due to damming of the Tennessee River and are therefore inaccessible. Other Quaternary deposits identified within the site vicinity are thin clays and residual soils that the applicant concludes are not likely to liquefy. Finally, the applicant stated that it performed detailed field mapping and subsurface explorations within the 1 km (0.6 mile) radius of the site and found no evidence of paleoseismic features within Quaternary soils and concluded that the residual soils present at the site have a low susceptibility to liquefaction due to the clay content and soil stiffness. Based on these investigations, the applicant concluded that no evidence of paleoseismic features was found within the 40 km (25 mile) site vicinity.

Based on its review of the applicant’s response to RAI 2.5.3-1, the staff concludes that the applicant sufficiently detailed its paleoseismic investigations performed in the BLN site area. A site visit conducted in October 2008 provided further justification to the staff that numerous accessible locations along drainage ditches and road cuts within the site vicinity did not show evidence of paleoliquefaction features.

Based on its review of BLN COL FSAR Section 2.5.3.3, and the applicant’s response to RAIs 2.5.3-1 and 2.5.3-6 (included in SER Section 2.5.3.4.2), the staff concludes that the applicant presented convincing data and logical interpretations related to a lack of correlation between earthquakes and tectonic sources at the BLN site. The staff concludes, based on the lack of evidence presented by the applicant and on information verified during the staff's site visit, that no spatial correlation exists between seismicity and mapped faults, or deformation features, within the site vicinity or site area.

2.5.3.4.4 Ages of Most Recent Deformations

BLN COL FSAR Section 2.5.3.4 discusses the ages of most recent deformation for the bedrock thrust faults and sub-detachment basement faults within the site vicinity, or within 40 km (25 miles) of the BLN site. The applicant concluded that all of the known faults within the BLN site vicinity are pre-Quaternary in age based on information presented in BLN COL FSAR Sections 2.5.1.1.4.2.1, 2.5.1.2.5, and 2.5.3.2. The applicant stated that the youngest deformation associated with Appalachian foreland thrust faults such as the Sequatchie Valley and Wills Valley thrust faults is Pennsylvanian to Permian in age (323-248 Ma). The applicant concluded that sub-detachment basement faults that formed during the late Proterozoic to early Paleozoic (900-543 Ma) may have reactivated over time; however, these basement faults provide no evidence of associated deformation since the Paleozoic Era (248 Ma).

The NRC staff concludes that the applicant presented accurate descriptions of the ages of deformation of the geologic features in order to enable an accurate assessment of Quaternary displacement along faults within 40 km (25 miles) of the BLN site. Rationale for the staff's conclusions in regard to the ages of most recent deformation is also presented in SER Section 2.5.1.4.2. The staff concludes that mapped thrust faults and sub-detachment basement faults within the BLN site vicinity do not exhibit geologically recent activity based on the absence of surface deformation as documented in the literature and interpreted from geomorphic evidence during aerial and field investigations. In addition, the applicant provided adequate justification from its lineament analysis that linear topographic and tonal features mapped in the site vicinity most likely do not represent recent deformation based on evidence from field and aerial investigations.

2.5.3.4.5 Relationship of Tectonic Structures in the Site Area to Regional Tectonic Structures

BLN COL FSAR Section 2.5.3.5 discusses the relationship of tectonic structures in the BLN site area, within 8 km (5 miles), to regional tectonic structures. The applicant stated that mapped bedrock faults within the site vicinity, or within a 40 km (25 mile) radius of the site, are interpreted to be part of the regional Appalachian foreland fold-thrust belt that developed during the late Paleozoic era (approximately 248 Ma) and that there is no evidence to suggest that any of these faults are capable tectonic structures. In addition, the applicant stated that basement faults located beneath the overlying Appalachian thrust belt are interpreted to be associated with late Proterozoic (900-543 Ma) to early Paleozoic (543-417 Ma) normal faulting.

Based on its review of BLN COL FSAR Section 2.5.3.5, as well as BLN COL FSAR Section 2.5.1.1.4.2.1, the staff concludes that the applicant has adequately characterized the mapped bedrock faults within the site vicinity with respect to the regional Appalachian fold-thrust belt. Additionally, the staff concurs with the applicant, based on geologic maps for the site region and geologic mapping of bedrock faults within the site vicinity, that the Sequatchie Valley and Wills Valley faults, both located within the 40 km (25 mile) BLN site vicinity and discussed in BLN COL FSAR Sections 2.5.1.1.4.2.1, 2.5.1.2.5, and 2.5.3.2, are thrust faults associated with the northwestern portion of the Appalachian thrust belt. The following section provides the staff's evaluation of capable tectonic sources within the site vicinity and includes further evaluation of the Sequatchie and Wills Valley thrust faults.

2.5.3.4.6 Characterization of Capable Tectonic Sources

BLN COL FSAR Section 2.5.3.6 discusses the applicant's characterization of capable tectonic sources. Based on information presented in BLN COL FSAR Sections 2.5.3.2 through 2.5.3.5, as derived from its review of published literature and previous investigations, and its recent lineament analysis and field and aerial investigations for the BLN site, the applicant concluded that there is no evidence of capable tectonic sources in the BLN site vicinity, i.e., within a 40 km (25 mile) radius of the BLN site. Based on the information presented in BLN COL FSAR Section 2.5.3.2, the applicant concluded that neither the Sequatchie Valley or Wills Valley thrust faults nor the inferred sub-detachment basement faults are capable tectonic sources in the site area, or structurally related to any known capable tectonic source.

In RAI 2.5.3-4, the staff asked the applicant to explain its statement in BLN COL FSAR Section 2.5.3.6 that Tellico Project core samples showed the Knoxville fault, located within the Valley and Ridge Province, to be an unbroken sample at several locations. The applicant did not clearly state the significance of the unbroken sample related to the Knoxville fault and how this provided evidence that the fault is not active.

In response to RAI 2.5.3-4, the applicant provided an excerpt from the BLN 1 and 2 FSAR (TVA, 1986) that forms the basis for the applicant's statement in BLN COL FSAR Section 2.5.3.6 and put the statement in context. The applicant explained that other core samples that crossed other faults within the Valley and Ridge Province showed evidence along the fault planes that loose material associated with the initial faulting had re-crystallized over time, indicating that these faults did not represent recent faulting events. The core samples along these other faults were unbroken. The core sample that crossed the Knoxville fault was also unbroken and did not contain loose fragments that might indicate recent shearing on the fault. Therefore, the FSAR for BLN 1 and 2 (TVA, 1986) concluded that the Knoxville fault must be of similar age to other faults in the Valley and Ridge Province. The applicant based its conclusion that these Valley and Ridge faults do not represent capable tectonic structures on evidence provided in the BLN 1 and 2 FSAR (TVA, 1986).

Based on its review of the applicant's response to RAI 2.5.3-4, the staff verified that the applicant adequately clarified its initial statement regarding the Knoxville fault in BLN COL FSAR Section 2.5.3.6 of Revision 1 to the BLN COL FSAR. The staff concurs with the applicant that the unbroken core sample that cuts across the Knoxville fault provides additional evidence to support the applicant's conclusion that faults within the Valley and Ridge Province do not exhibit geologically recent (i.e., Quaternary age (1.8 Ma)) deformation.

Based on its review of BLN COL FSAR Section 2.5.3.6 and the applicant's response to RAI 2.5.3-4, the staff concludes that the applicant has demonstrated in BLN COL FSAR Section 2.5.3.6 that there is no evidence to suggest that any capable tectonic sources exist in the BLN site vicinity, within 40 km (25 miles) of the site, or at the BLN site.

The staff's conclusion is based on information provided in BLN COL FSAR Sections 2.5.3.2 through 2.5.3.5, that the two mapped faults within the site vicinity, the Sequatchie Valley and Wills Valley thrust faults, do not exhibit evidence of Quaternary faulting or deformation. In addition, (1) there is no historical seismicity associated with any known geologic structures in the site vicinity and (2) structurally related faults within the Valley and Ridge Geologic Province, partially within the 320 km (200 mile) site area, do not show evidence of Quaternary faulting or deformation. The staff's review of BLN COL FSAR Sections 2.5.3.2 through 2.5.3.5 is included in Sections 2.5.3.4.2 through 2.5.2.4.5 of this SER.

2.5.3.4.7 Designation of Zones of Quaternary Deformation

In BLN COL FSAR Section 2.5.3.7, the applicant stated that no evidence of Quaternary deformation was identified within the site vicinity or site area, i.e., within a 40 km (25 mile) radius of the BLN site. The applicant based this determination on observations made during field and aerial reconnaissance investigations; previous reports and investigations conducted for the historical BLN 1 and 2; and on recent mapping and subsurface investigations conducted for the BLN COL application.

In RAI 2.5.3-5, the staff asked the applicant to clarify its statement in BLN COL FSAR Section 2.5.3.4.7 that no "significant" zones of Quaternary deformation existed at the BLN site to warrant further investigation. This clarification is important for fully evaluating the potential for Quaternary deformation features at the BLN site. In response to RAI 2.5.3-5, the applicant stated that "significant" was a qualifying term used for detectable Quaternary deformation features and that no Quaternary deformation features were identified, or detected, within the BLN site vicinity, within a 40 km (25 mile) radius, significant or other. The applicant further stated that it would provide a correction in the subsequent BLN COL FSAR revision.

Based on its review of the applicant's response to RAI 2.5.3-5, the staff concurs with the applicant's conclusion that no Quaternary deformation features were identified with a 40 km (25 mile) radius of the BLN site. In addition, the staff verified that the applicant clarified the statement in question in Section 2.5.3.4.7 of Revision 1 to the BLN COL FSAR.

Based on its review of BLN COL FSAR Section 2.5.3.7, the applicant's response to RAI 2.5.3-5, and information cross-referenced in BLN COL FSAR Section 2.5.4.1, the staff concludes that there are no known zones of Quaternary deformation within the site vicinity. The rationale for the staff's conclusion is based on a review of previous investigations, a review of the applicants aerial and field investigations, as well as a review of the applicant's lineament analysis all of which documented a lack of Quaternary deformation within the 40 km (25 mile) site radius, or site vicinity.

2.5.3.4.8 Potential for Surface Tectonic Deformation at the Site

BLN COL FSAR Section 2.5.3.8 discussed the potential surface tectonic deformation at the BLN site. The applicant stated that no evidence existed for active or geologically recent faulting in the site vicinity that would lead to surface deformation at the BLN site. The applicant based its conclusion on the lack of evidence for surface faulting or deformation identified on regional bedrock maps, and observed during field and aerial reconnaissance. Furthermore, the applicant stated that previous published reports and literature did not identify any geomorphic features that would indicate Quaternary age (less than 1.8 Ma) deformation in the site vicinity and site area, or within a 40 km (25 mile) radius of the BLN site. Finally, the lineament analysis and subsequent field investigations conducted by the applicant and described in BLN COL FSAR Section 2.5.3.2.2 did not identify any geomorphic features representative of faulting or surface deformation associated with any lineaments that intersect or project toward the BLN site.

Based on its review of BLN COL FSAR Section 2.5.3.8, the staff concludes that the potential for surface tectonic deformation is negligible at the BLN site. The rationale for the staff's conclusion regarding surface tectonic deformation is based on examination of the applicant's field investigations and data from the published literature as well as geologic mapping evidence, summarized by the applicant. All of these sources document a lack of Quaternary deformation that could lead to surface tectonic deformation at the BLN site. The staff reviewed the applicant's lineament analysis and related field investigations and determined that the applicant adequately assessed the potential for surface faulting and deformation associated with mapped linear features in the site vicinity and site area, or within 40 km (25 miles) of the BLN site. The staff concluded that the lineament analysis, in addition to recent and previous field investigations, was conducted at an appropriate level of detail and that the absence of surface faulting or surface deformation along these lineaments suggests that they are not tectonically active features and do not have the potential to cause surface tectonic deformation at the BLN site. SER Section 2.5.4.4 provides the staff's evaluation and conclusions regarding dissolution cavities at depth and their potential for causing non-tectonic deformation at the surface.

2.5.3.4.9 Staff Conclusions Regarding Surface Faulting

Based on its review of the geologic information presented in BLN COL FSAR Section 2.5.3, 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 with 10 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 further concludes that the site is suitable from the perspective of tectonic surface deformation and meets the requirements of 10 CFR 100.23 and 10 CFR 52.79(a)(1)(iii). This information addresses BLN COL 2.5-4 to resolve COL Information Item 2.5-4. In conclusion, the applicant has provided sufficient information for satisfying 10 CFR 100.23.

2.5.3.5 Post Combined License Activities

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

2.5.3.6 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 surface faulting, and there is no outstanding information expected to be addressed in the BLN COL FSAR related to this subsection.

Section 2.5.3 of Revision 17 of the AP1000 DCD is identical to Section 2.5.3 of Revision 15 of the AP1000 DCD, which is incorporated by reference into 10 CFR Part 52, Appendix D. This subsection is not affected by the changes that Westinghouse proposed in Revision 17 to the AP1000 DCD. Pursuant to 10 CFR 52.63(a)(5) and 10 CFR Part 52, Appendix D, Section VI.B.1, all nuclear safety issues relating to surface faulting that were incorporated by reference have been resolved.

In addition, the staff concludes that the relevant information presented within the BLN COL FSAR is acceptable and meets the requirements of 10 CFR 100.23 and 10 CFR 52.79(a)(1)(iii) and the guidance provided in RG 1.208. The staff based its conclusion on the following:

- BLN COL 2.5-2, involving evaluation of site-specific subsurface geologic, seismic, and geophysical information related to the potential for surface or near surface faulting affecting the site, is acceptable to the staff because the applicant investigated the potential for surface faulting in the site area as required by 10 CFR 100.23.

2.5.4 Stability of Subsurface Materials and Foundations

2.5.4.1 Introduction

BLN COL FSAR Section 2.5.4 presents the applicant's evaluation of the stability of subsurface materials and foundations that relate to the BLN COL 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 provided by the applicant in BLN COL FSAR Section 2.5.4 addresses: (1) geologic features in the site vicinity; (2) static and dynamic engineering properties of soil and rock strata underlying the site; (3) the relationship of the foundations for safety-related facilities and the engineering properties of underlying materials; (4) results of 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 they affect the loading and stability of foundation materials; (7) responses of site soils or rocks to dynamic loading; (8) liquefaction potential and consequences of liquefaction of all subsurface soils, including the settlement of foundations; (9) earthquake design bases; (10) results of investigations and analyses conducted to determine foundation material stability, deformation and settlement under static conditions; (11) criteria, references, and design methods used in static and seismic analyses of foundation materials; (12) techniques and specifications to improve subsurface conditions that 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.

2.5.4.2 Summary of Application

Section 2.5.4 of the BLN COL FSAR incorporates by reference Section 2.5.4 of the AP1000 DCD, Revision 17.

In addition, in BLN COL FSAR Section 2.5.4, the applicant provided the following:

- BLN COL 2.5-5

The applicant provided additional information in BLN COL 2.5-5 to address COL Information Item 2.5-5 [COL Action Item 2.5.1-1]. BLN 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.

- BLN COL 2.5-6

The applicant provided additional information in BLN COL 2.5-6 to resolve COL Information Item 2.5-6 [COL Action Item 2.6-3]. BLN COL 2.5-6 addresses the properties of the foundation soils to be within the range considered for design of the nuclear island basemat.

- BLN COL 2.5-7

The applicant provided additional information in BLN COL 2.5-7 to resolve COL Information Item 2.5-7 [COL Action Item 2.5.4-1]. BLN COL 2.5-7 addresses the information concerning the extent (horizontal and vertical) of Seismic Category I excavations, fills, and slopes.

- BLN COL 2.5-8

The applicant provided additional information in BLN COL 2.5-8 to resolve COL Information Item 2.5-8 [COL Action Item 2.4.1-1]. BLN COL 2.5-8 addresses the ground water conditions relative to the foundation stability of the safety-related structures at the site.

- BLN COL 2.5-9

The applicant provided additional information in BLN COL 2.5-9 to resolve COL Information Item 2.5-9 [COL Action Item 2.5.4.3-1]. BLN COL 2.5-9 addresses the provision of demonstration that the potential for liquefaction is negligible.

- BLN COL 2.5-10

The applicant provided additional information in BLN COL 2.5-10 to resolve COL Information Item 2.5-10 [COL Action Item 2.6-4]. BLN COL 2.5-10 addresses the verification that the maximum bearing reaction determined from the analyses described in DCD Appendix 3G is less than 35,000 pounds per square foot (psf) under all combined loads, including the SSE, for static and dynamic loads.

- BLN COL 2.5-11

The applicant provided additional information in BLN COL 2.5-11 to resolve COL Information Item 2.5-11 [COL Action Item 2.5.2-2]. BLN 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 subsections.

- BLN COL 2.5-12

The applicant provided additional information in BLN COL 2.5-12 to resolve COL Information Item 2.5-12 [COL Action Item 2.5.5-1]. BLN COL 2.5-12 addresses soil characteristics affecting the stability of the nuclear island including foundation rebound, settlement, and differential settlement.

- BLN COL 2.5-13

The applicant provided additional information in BLN COL 2.5-13 to resolve COL Information Item 2.5-13 [COL Action Item 2.6-5]. BLN 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.

- BLN COL 2.5-16

The applicant provided additional information in BLN COL 2.5-16 to resolve COL Information Item 2.5-16. BLN COL 2.5-16 addresses the provision of data on short-term (elastic) and long-term (heave and consolidation) settlement for soil sites for the history of loads imposed on the foundation consistent with the construction sequence.

In addition, BLN COL FSAR Section 2.5.4 addresses Interface Item 2.12 related to peak ground acceleration, response spectra, and Vs and Interface Item 2.13 related to the required bearing capacity of foundation materials.

2.5.4.2.1 Geologic Features

BLN COL FSAR Section 2.5.4.1 describes the non-tectonic processes and geologic features that have the potential to cause permanent ground deformation or foundation instability at the site of the safety-related structures for BLN 3 and 4. The applicant subdivided BLN COL FSAR Section 2.5.4.1 into five separate discussions: (1) geologic history and stress conditions; (2) soil and rock characteristics; (3) weathering processes and features; (4) effects of human activities; and (5) non-tectonic surface deformation. BLN COL FSAR Sections 2.5.1.1 and 2.5.1.2 provide a complete description of the regional and site geologic features for the BLN site.

Geologic History and Stress Conditions

BLN COL FSAR Subsection 2.5.4.1.1 provides a brief description of the geologic history and a summary of contemporary stress conditions at the BLN site, based on the information provided in BLN COL FSAR Section 2.5.1. The applicant stated that the most recent tectonic uplift experienced at the site took place in the late Paleozoic era (320 to 248 Ma), during the Alleghenian orogeny, discussed in BLN COL FSAR Section 2.5.1.1.2. The applicant stated that there is no geologic evidence of current or future uplift at the site.

Relatively uniform compressive stresses with an east-northeast trending horizontal shear (SHmax) direction dominate the current regional stress environment. A slow weathering and erosion cycle led to gradual unloading conditions and the gradual release of stresses in the site region. The combination of gradual surface denudation and active wetting and drying of near surface soils resulted in the preconsolidation of overburden soils at the BLN site.

Soil and Rock Characteristics

BLN COL FSAR Subsection 2.5.4.1.2 describes the physical and chemical properties of the soil and rock, including an evaluation of the zones of alteration and zones of potential weaknesses at the BLN site. The applicant derived the information from previous studies at the site as well as from the borehole data and other site investigations conducted as part of the BLN site exploration program. The applicant performed 122 borings at the BLN 3 and 4 site and provided the logs of those borings in BLN COL FSAR Appendix 2BB. The applicant's geologic descriptions, based on the 122 boring logs, are described below in the following section.

Based on the results from the borehole data, the applicant observed that construction of BLN 1 and 2 disturbed the 1.5 to 12.1 m (5 to 40 ft.) of residual silt and clays overlying the bedrock at the site. SER Figure 2.5.4-1 (reproduced from BLN COL FSAR Figure 2.5-295) shows an aerial view of the power block construction zone for proposed BLN 3 and 4 and illustrates the relationship between the location of existing BLN 1 and 2 and the proposed units.

The applicant identified the rock unit beneath the residual soils as the gently dipping beds of the Stones River Group, a 320 m (1050 ft.) thick, predominantly limestone unit composed of subunits of differing composition and texture. The applicant refers to the Stones River Group as an impure limestone because it contains portions of highly dolomitic limestone as well as interbedded silty, argillaceous, and cherty limestone layers. In BLN COL FSAR Section 2.5.1.2.4, the applicant identified and described six distinct lithologic units (Units A through F) within the Middle Stones River Group, present beneath the BLN site. SER Figure 2.5.4-2 (reproduced from BLN COL FSAR Figure 2.5-339) illustrates a cross-section (A-A') that the applicant developed from the borehole data that it collected at the site. In BLN COL FSAR Table 2.5-205 the applicant identified the lithology and thickness of the subsurface units, including each subunit of the Middle Stones River Group. The overall thickness of the Middle Stones River group is approximately 138 m (453 ft.).

The applicant described the laboratory investigations, including petrographic, chemical, and mineralogical analyses that were used to determine proper lithologic classification and rock characterization of core samples. Based on the analyses, the applicant concluded that other than limestone, which weathers mostly by dissolution, no rocks or soils that might be unstable are present at the site. In addition, the applicant found that there were no zones of alteration in the limestone at the time of the site investigations, but both primary sedimentary features and secondary diagenetic features are present. Zones of structural weakness, such as extensively fractured or faulted zones are not present; however, the applicant did observe evidence of joints and bedding planes, along with minor discontinuous shears. The applicant concluded that these discontinuities were not themselves a source of weakness but may serve as pathways for water, along which weathering and dissolution of the limestone can take place.

Weathering Processes and Features

BLN COL FSAR Subsection 2.5.4.1.3 describes the weathering processes and features encountered at the BLN site and states that the dissolution of limestone is the primary mechanism of weathering in the site area. The applicant used the results of site investigations to identify any dissolution features, such as caves, sinkholes, or other karst features. The results yielded no evidence of large-scale dissolution features. The applicant observed small-scale karst features within the Stones River Group, the limestone unit underlying the site, and noted that topographic relief, hydraulic gradient, and the impurity of the limestone play an essential role in controlling the size of karst features within this unit, and therefore at the BLN site. SER Figure 2.5.4-3 (reproduced from BLN COL FSAR Figure 2.5-303b) illustrates the locations of caves near the BLN site, the closest of which is 2.4 km (1.5 miles) from the proposed BLN 3 and 4.

The applicant developed a karst model for the BLN site, which identified groundwater flow within three different stratigraphic zones: overburden, the epikarst aquifer, and the karst zone. BLN COL FSAR Section 2.4.1.2 provides a more detailed description of the karst model developed for the BLN site. Based on the results of the BLN 3 and 4 exploration program, the applicant identified three specific karst-related features at the BLN site: (1) cavities in boreholes; (2) cavities and soft zones within the soil; and (3) irregularities in the bedrock surface beneath the soil. The applicant concluded that karst features are not well-developed within the power block construction zone and that the features that are present are small-scale karst features that will not affect the stability of foundations of safety-related structures at the BLN site.

The applicant stated that most of the dissolution cavities (based on borehole data) occur within 3.048 to 6.096 m (10 to 20 ft.) of the top of the bedrock, are small in size, and will be removed or remediated during excavation. The applicant encountered the largest cavity within the BLN construction zone in Boring B-1076, which measured 1.2 m (4 ft.) thick. The largest cavity within the BLN site area was a 2.4 m (8 ft.) thick cavity adjacent to the south cooling tower, as seen in Boring B-1072. BLN COL FSAR Table 2.5-226 lists and describes each cavity observed during the course of the exploration program for BLN 3 and 4. SER Figure 2.5.4-4 (reproduced from BLN COL FSAR Figure 2.5-306) illustrates the spatial relationship between the cavities discovered in the boreholes and the subsurface lithologic units beneath the power block construction zone.

The applicant stated that cavities and soft zones are common at the BLN site, especially in the residual soils. The applicant documented two soft zones in the soil within the BLN 3 and 4 construction zone the larger of the two at Boring B-1051 near the southwest edge of the BLN Unit 4 power block. Using additional exploration methods, the applicant further defined the geometry of this 1.5 m (5 ft.) thick feature as being between 15.24 and 30.48 m (50 and 100 ft.) wide and up to 9.14 m (30 ft.) thick in some places. The applicant identified a second soft zone in one borehole near the north corner of the BLN 3 and 4 power block construction zone.

The applicant described the use of borehole data and seismic refraction data to identify irregular bedrock surfaces within the power block construction zone for BLN 3 and 4. The applicant encountered bedrock at depths varying from 1.5 to 13.1 m (5 to 43 ft.), which is attributed to a dissolution weathering front, with deeper depressions along this irregular surface representing areas of concentrated groundwater. SER Figure 2.5.4-5 (reproduced from BLN COL FSAR Figure 2.5-310) shows a contour map of the bedrock surface based on the refusal depths of the auger and standard penetration testing (SPT) investigations as well as a 3-Dimensional (3D) model based on seismic reflection data.

The BLN Unit 3 power block is located down slope from BLN Unit 4; therefore, the ground surface and underlying bedrock surface (top-of-rock) occur at lower elevations. Seismic refraction 3D modeling shows areas beneath BLN Unit 3 where the top of the unweathered rock is below the foundation grade of 179.4 m (588.6 ft.). The applicant concluded that sufficient excavation beneath the BLN Unit 3 foundation will remove the weathered rock and establish the foundation on hard rock.

The applicant described the existence of depressions in the bedrock surface where dissolution is most active, usually where joints or bedding planes allow water to drain downward. Seismic refraction profiles and borehole logs, interpreted by the applicant, show the existence of such depressions; however, these exploration methods will require confirmation with geologic mapping and geophysical exploration during construction to detail the full depth and configuration of the dissolution depressions and cavities. The applicant stated that the remediation of karst features will follow the methods described in BLN COL FSAR Section 2.5.4.12.

Effects of Human Activities

Based on its review of human activities in and around the BLN site vicinity, the applicant concluded that there are no activities such as mining, hydrocarbon extraction, and groundwater withdrawal that could cause subsidence or collapse of the ground surface within the BLN 3 and 4 construction zone.

Non-tectonic Surface Deformation

In BLN COL FSAR Subsection 2.5.4.2.5, the applicant stated that dissolution and karst features are common near the BLN site, particularly in the upper 3 to 6 m (10 to 20 ft.), but that these features do not pose a potential hazard and karst development will be mitigated during the construction phase either by overexcavation, or with grouting and dental techniques. The applicant concluded that, since there is no evidence of significant alteration, structural weakness, unrelieved stresses, or major dissolution features and karst development, there is no significant stability or safety hazard in the BLN 3 and 4 site area.

2.5.4.2.2 Properties of Subsurface Materials

BLN COL FSAR Section 2.5.4.2 presents a summary of the field investigations and subsurface material properties encountered at the BLN site. The applicant stated that it performed the field and laboratory investigations following the guidance in RG 1.132 and RG 1.138, respectively. As previously mentioned, the applicant performed a total of 122 borings, the logs of which are included in BLN COL FSAR Appendix 2BB. The applicant discussed both its soil and rock investigations in BLN COL FSAR Section 2.5.4.2 based on the 122 site borings. The proposed BLN 3 and 4 structures will be founded on bedrock with the overlying soils removed. The applicant analyzed the soils at the BLN site and determined that they are unsuitable for use as fill or backfill components.

Soil Investigations

The soils at the BLN site are residual soils that formed in place due to weathering of the underlying bedrock and they vary in thickness across the BLN site from 1.5 to 12 m (5 to 40 ft.) with an average thickness of 4.6 m (15.3 ft.). These soils will be removed during excavation and the underlying Stones River Group limestone will provide the foundation for BLN 3 and 4. However, the applicant performed the following soil investigations in order to determine the suitability of soils for use as structural fill or backfill behind the below grade walls of the nuclear island, and to analyze the stability of temporary slopes in the nuclear island construction area.

BLN COL FSAR Subsection 2.5.4.2.2 discusses the soil investigations performed by the applicant at the BLN site, including: (1) hollow-stem auger borings with SPT; (2) split spoon sampling of disturbed soils; (3) Shelby tube sampling of undisturbed soils; (4) cone penetrometer tests (CPTs); and (5) test pits. For its investigations, the applicant collected soil samples from 41 boring locations. The applicant tested undisturbed soil samples for moisture content, Atterberg limits, percent fines, specific gravity, and other properties. The applicant also performed consolidated-undrained triaxial compression, unconfined compression, and load-controlled consolidation tests on the undisturbed samples. Based on the results of these tests, the applicant concluded that the soils in the BLN site area show limited variability in composition, layering and engineering properties.

BLN COL FSAR Subsection 2.5.4.2.2.1 describes the index properties of in-situ soils as determined by the applicant's laboratory testing. The applicant concluded that most of the soils in the BLN 3 and 4 site area are highly plastic clays with variable amounts of sand and gravel present. These soils generally have a liquid limit greater than 50, a plasticity index greater than 60 percent, and an average moisture content of about 20.7 percent. In BLN COL FSAR Sections 2.5.4.2.2.2 through 2.5.4.2.2.4, the applicant discussed moisture unit weight relationships, shear strengths and consolidation properties of in-situ soils, respectively. The applicant stated that the in-situ soil values from its investigations are generally consistent with those from previous investigations.

The applicant used the results of its soil investigations to evaluate the suitability of soils for use as structural fill or backfill behind the below grade walls of the nuclear island, and to analyze the stability of temporary slopes in the nuclear island construction area. Based on its soil investigation results, the applicant concluded that the soils in the site area are largely high plasticity clays and silts with minor sands and gravels. Soils that are ideal for use as stable backfill material are free-draining, contain only small amounts of fine-grained material (i.e., silts and clays), and have low plasticity. The applicant concluded that the on-site soils are not suitable for use as structural fill and/or backfill behind below grade walls because: (1) they are highly plastic clays and silts; (2) they are not free draining; (3) and they have a high potential for volume change, all of which lead to soil instability.

Rock Investigations

BLN COL FSAR Subsection 2.5.4.2.3 discusses the rock investigations that the applicant conducted at the BLN 3 and 4 site including: (1) rock core borings; (2) Goodman Jack testing; (3) geophysical logging; (4) seismic refraction data collection; (5) microgravity data collection; and (6) Packer pressure testing. The applicant recovered core samples from the borings in the BLN site area, noted the rock quality designation (RQD) for the recovered samples, and used Goodman Jack testing in four boreholes to determine the in-situ elastic modulus. The applicant also performed geophysical logging in 26 boreholes, and completed 40 seismic refraction arrays, and 11 transects of microgravity data collection.

Laboratory Testing. BLN COL FSAR Subsection 2.5.4.2.3.1 describes the laboratory tests that the applicant performed at the BLN site. The applicant selected rock core samples from 24 of its site borings to use in laboratory testing. The applicant described the measures taken to prepare the collected samples for the various tests that it performed. The applicant measured the rock cores for straightness, flatness, length and diameter prior to the start of laboratory testing. The applicant determined the compressive strength of the rock core by examining the relationship between the cross-sectional area of the samples and the maximum recorded load. The applicant obtained the elastic modulus by two means: (1) the placement of strain gages prior to loading of the sample; and (2) by recording the axial and lateral readings as the load is applied to sample.

Quality Assurance. BLN COL FSAR Subsection 2.5.4.2.3.2 describes the QA program implemented by the applicant during the laboratory investigations. The applicant described the methods for sample control, which included obtaining, classifying, and storing the collected samples. The applicant stated that it followed the handling procedures of American Society for Testing and Materials (ASTM) D5079 during the course of the site investigations and that it kept the samples under chain-of-custody control until delivered to the testing facility. BLN COL FSAR Subsection 2.5.4.2.3.2.2 states that all personnel conducting the laboratory testing on behalf of the subcontractor, MACTEC, were qualified under the MACTEC Quality Assurance Project Document, which also described the appropriate calibration procedures for the equipment used as part of the laboratory testing.

In-Situ Rock Mass Engineering Properties. Regarding in-situ rock mass properties of shear strength and deformation modulus, the applicant stated that it used the Hoek-Brown criterion incorporating the RocLab® program. The Hoek-Brown criterion is an empirically-based approach that develops non-linear shear strength envelopes for rock mass, and accounts for the strength-reducing influence of discontinuities, mineralogy and cementation, rock origin, level of induced disturbance from excavation/blasting, and weathering. The applicant provided the following inputs required by the Hoek-Brown criterion: (1) unconfined compressive strength; (2) material index; (3) geological strength index; (4) disturbance factor; and (5) Young's laboratory modulus of intact rock core samples. The applicant then compared the estimated rock mass Young's moduli to the in-situ Goodman Jack test and concluded that there was a good correlation between the estimates. However, the applicant noted that, since the Goodman Jack estimates are slightly higher than those from the Hoek-Brown analysis, the applicant used the Hoek-Brown estimates as input for its analysis of the bearing capacity, settlement and sliding performance of the nuclear island basemat that it discussed in BLN COL FSAR Section 2.5.4.10. SER Table 2.5.4-1 (reproduced from BLN COL FSAR Figure 2.5-236) presents the input values and output results of the applicant's Hoek-Brown analysis.

2.5.4.2.3 Foundation Interfaces

BLN COL FSAR Section 2.5.4.3 discusses the relationship between the foundation of the Seismic Category I structures and the site exploration and subsurface materials. The applicant based this comparison on the results of the field explorations at the BLN 3 and 4 site and the laboratory tests performed on recovered samples. The applicant also considered the results from previous field investigations for BLN 1 and 2 as part of the assessment. The applicant divided this section into five subsections, each discussing a particular aspect of the site exploration.

BLN COL FSAR Subsection 2.5.4.3.1 describes the exploration in the area of the power block construction zone, including surface geophysics, in-situ testing, and subsurface drilling and sampling, which was described in more detail in BLN COL FSAR Section 2.5.4.2. The applicant also noted that in-situ tests, such as borehole geophysics, Goodman Jack, and Packer permeability tests, as well as test pits excavations and CPTs, were completed within the power block construction area. SER Figure 2.5.4-2 shows the locations of surface geophysical exploration points and groundwater monitoring wells.

In BLN COL FSAR Subsection 2.5.4.3.2, the applicant described the exploration of the area surrounding and adjacent to the power block construction zone, including profile borings and monitoring wells. SER Figure 2.5.4-6 (reproduced from FSAR Figure 2.5-327) illustrates the locations of the exploration points outside of the power block construction zone.

BLN COL FSAR Subsection 2.5.4.3.3 describes the geotechnical data logs and records that were used by the applicant to compile the various geotechnical figures referenced in BLN COL FSAR Section 2.5.4.3. The applicant provided the logs from the boreholes and test pits in BLN COL FSAR Appendix 2BB and 2CC, respectively. The applicant also summarized the results of laboratory test in a series of figures and geotechnical cross-sections.

In BLN COL FSAR Subsection 2.5.4.3.4, the applicant provided nine borehole summaries of the geologic and geotechnical data collected at the site of BLN 3 and 4. The applicant included lithology, laboratory strength, and P-S velocity and natural-gamma geophysical logging, as well as SPT, RQD, and percent recovery in the summaries.

BLN COL FSAR Subsection 2.5.4.3.5 states that the borehole summaries developed in the previous section were used to construct geotechnical profiles. The applicant developed three profiles, the locations of which are shown on SER Figure 2.5.4-2. The applicant then summarized the soil, rock, and groundwater conditions illustrated in the profiles. BLN COL

FSAR Subsection 2.5.4.3.5.1 describes the soil conditions in the geotechnical profiles as residual soils with a thin layer of overlying fill material in some locations. In BLN COL FSAR Subsection 2.5.4.3.5.2, the applicant stated that the bedrock in the profiles is a dipping carbonate strata of the Stones River Group, a mostly limestone unit with some interbeds containing more clay particles. Finally, in BLN COL FSAR Subsection 2.5.4.3.5.3, the applicant stated that the groundwater levels were indicative of the stabilized measurements in the open boreholes. BLN COL FSAR Sections 2.4.12 and 2.5.4.6 provide additional details on the monitoring well water level measurements and the groundwater conditions at the site, respectively.

2.5.4.2.4 Geophysical Surveys

In BLN COL FSAR Section 2.5.4.4., the applicant presented the results of the geophysical surveys performed at the BLN site to characterize the subsurface conditions and to determine the dynamic properties of the subsurface materials. The applicant obtained this information from the results of surveys performed as part of the site investigations described in BLN COL FSAR Subsections 2.5.1.2, 2.5.3, and 2.5.4.1. The applicant also compared the results of seismic refraction surveys, seismic cone penetrometer tests, suspension and downhole logging test, microgravity surveys, and natural gamma borehole surveys to the results presented in the BLN 1 and 2 FSAR.

Seismic Refraction Surveys

The applicant conducted site seismic refraction surveys in three phases, the first of which was a pre-characterization study of the BLN 3 and 4 site area encompassing three transects on thirteen arrays covering 762 linear m (2500 linear ft.) of surveys. The second phase took place during the exploratory drilling investigation and the third upon completion of the drilling program. Phases two and three covered over 3,867 linear m (12,690 linear ft.). The applicant selected the locations of the seismic refraction surveys in order to obtain seismic compressional (Vp) data for bedrock rippability, to profile the top of rock, to provide comparison of Vp velocities with borehole surveys, and to verify the presence of any lineaments at the site.

BLN COL FSAR Subsections 2.5.4.4.1.1 through 2.5.4.4.1.3 describe the survey methods, results and 3-D interpretations. The velocity profile results indicated sub-horizontal velocity intervals, with some irregularities attributed to a weathering surface at the top of the bedrock. The applicant concluded that seismic velocity of 1828 and 4267 meters/second (m/s) (6,000 and 14,000 feet per second [fps]) best correlate with the top of weathered rock and the top of competent rock, respectively.

Seismic Cone Penetrometer Test (SCPT)

BLN COL FSAR Subsection 2.5.4.4.2 states that the SCPTs were performed within the footprint of each Annex building for BLN 3 and 4 allowing for the direct measurement of the Vs in the residual soils. The applicant noted that by measuring the interval Vs and the mass density of a soil, the dynamic shear modulus (G) could be determined. BLN COL FSAR Table 2.5-237 presents the results of the SCPTs. Based on the results, the applicant determined that the Vs of the overburden soils at the BLN site ranged from 167 to 233 m/s (550 to 767 fps).

Suspension and Downhole Logging Tests

The applicant performed compressional and shear (P-S) suspension logging tests in eight core holes at the BLN site. The applicant also performed downhole testing in two of the P-S holes, and summarized the results of the testing in BLN COL FSAR Table 2.5-238. The applicant performed these tests in order to obtain S-wave and P-wave velocities as a function of depth, which the applicant then used to determine whether or not it met the hard rock requirements discussed in BLN COL FSAR Section 2.5.2. The applicant also compared the data collected as part of the BLN 3 and 4 investigations with the data obtained for investigations completed as part of the construction of BLN 1 and 2.

The applicant stated that it followed GeoVision Procedures for the downhole and P-S suspension logging test at the BLN site. The applicant ensured borehole integrity by lining the borehole with steel casing through the soil, fill and weathered rock horizons. Since continuous sampling was not possible in all boreholes, the applicant conducted logging in adjacent boreholes to allow for a full profile to be obtained. The applicant measured the shear waves at 0.1524 m (0.5 ft.) intervals starting at 4.5 m (15 ft.) from the bottom of the borehole.

BLN COL FSAR Subsection 2.5.4.4.3.2 discusses the test results, which show that both shear and compressional wave velocities were relatively consistent with depth. The applicant concluded that most of the rock sections of the profiles agreed with the results from Natural Gamma surveys and had Vs values greater than 2804 m/s (9,200 ft./s) and Vp values greater than 4267 m/s (14,000 ft./s). BLN COL FSAR Section 2.5.4.7 provides a more in-depth discussion of the Vs profiles.

Microgravity Surveys

The applicant conducted microgravity surveys at the site in order to produce additional subsurface modeling. The applicant measured 121 stations along 11 transects as part of the microgravity surveys, with a distance between stations of either 3.048 or 6.096 m (10 or 20 ft.). The applicant analyzed the gravity data using the GravMaster computer program, the results of which agreed with the five overlapping seismic refraction surveys.

Televiewer and Natural Gamma Surveys

BLN COL FSAR Subsection 2.5.4.4.5 describes the 16 borehole televiewer (BHTV) and 15 optical televiewer (OPTV) surveys in open boreholes at the BLN site, as well as the seven companion Natural-Gamma (N-Gamma) surveys and 15 caliper test logs. The applicant measured borehole wall features using the acoustic methods of the BHTV, while the same parameters were measured using the optical techniques of the OPTV. The applicant used the Caliper log to measure borehole roughness and diameter and the N-Gamma method to measure gamma intensity as a function of clay-bearing rock units.

The applicant performed the N-Gamma surveys following the guidelines of ASTM D6274, and followed the Robertson Geologging Digital Optical Televiewer and the Technical Specification for the Robertson Geologging Hi Resolution Acoustic Televiewer guidance for the OPTV and BHTV, respectively. The applicant concluded that the N-Gamma results correlated well with the presence of interbedded limestone, a correlation that was confirmed when compared to the borehole logs used to determine the site stratigraphy.

2.5.4.2.5 Excavations and Backfill

BLN COL FSAR Section 2.5.4.5 describes the extent of excavations, fills, and slopes, the methods and control of groundwater, the sources and properties of the backfill materials, the compaction specifications, the quality control programs, and the foundation monitoring program to measure heave and rebound. SER Figures 2.5.4-7a and 2.5.4-7b (reproduced from BLN COL FSAR Figures 2.5-348a and 2.5-348b) show the lateral extent of the excavations for BLN 3 and 4, respectively.

Plans and Sections

BLN COL FSAR Subsection 2.5.4.5.1 describes the earthwork plans and sections for overall site development, excavation of the Seismic Category I structures, and the backfill placement for the nuclear islands. The applicant described these plans in two subsections discussing the overall site and the power block area.

Overall Site. BLN COL FSAR Subsection 2.5.4.5.1.1 describes the general arrangement of structures within the construction zone, an 807 by 539 m (2650 by 1770 ft.) area at the plant elevation of 191 m (628.6 ft.). The applicant noted that the ground surface in the area slopes down and away from the buildings, except to the southeast, where the ground slopes up. However, since the top edge of this slope is no closer than 91.4 m (300 ft.) to the nuclear island; the applicant concluded that the slope is too far away to adversely affect the safety-related structures of the nuclear islands. The applicant also noted that the composition of the soils in the construction area were suitable to support the nearby embankments without additional foundation designs.

Power Block. BLN COL FSAR Subsection 2.5.4.5.1.2 states that the site grading requires maximum fill depths of 6.096 and 12.19 m (20 and 40 ft.) for the Turbine, Annex, Radwaste, and Diesel Generator Buildings, and the Nuclear Island, respectively, although the applicant only discussed the Seismic Category I nuclear island structures as part of this FSAR section. The applicant noted that several excavation slopes will be maintained throughout the construction of the nuclear island basemat foundation and lower structural walls.

Construction Excavation and Dewatering

BLN COL FSAR Subsection 2.5.4.5.2 describes the excavation support and dewatering plans for the BLN site. The applicant also noted that there are no Seismic Category I fills or cut slopes in the site area.

Excavation Support. BLN COL FSAR Subsection 2.5.4.5.2.1 states that the soil overburden excavation at the BLN 3 and 4 site will be accomplished using scraper pans during the initial phases and track-mounted backhoes once excavation had reached a depth beyond which scraper pan use was practical. Due to the shallow depths of excavation, the applicant noted that the temporary slope method for slope retention will be used. The applicant concluded that the factors of safety for the temporary soil slopes in the BLN site area were greater than 2.0. The applicant also described plans to remove the areas of rock that were weathered to an advanced degree, and to remove hard rock using blasting or rock splitting methods once the conventional methods were no longer effective. The applicant concluded that by using both pre-drilling and blasting the damage to the rock bearing surface will be maintained at an acceptable level.

Dewatering. BLN COL FSAR Subsection 2.5.4.5.2.2 describes the use of monitoring well data to determine that the groundwater level was near the rock surface. The applicant noted a perched water zone at elevation 184.4 and 187.4 m (605 and 615 ft.) for BLN 3 and 4, respectively. The applicant described plans to manage groundwater infiltration during construction by pumping from sump pits at the low points of the excavation. BLN COL FSAR Subsection 2.5.4.6 provides an additional description of the groundwater conditions at the site. Based on the lithology of the hard rock at the site, as well as the observations of foundation rock as part of the construction of BLN 1 and 2, the applicant did not anticipate the degradation of foundation materials due to groundwater infiltration.

Backfill

BLN COL FSAR Subsection 2.5.4.5.3 states that in order to reach the final site grades, fill is necessary. The applicant stated that fill concrete will be used between the basemat and excavated rock slopes, while the remaining areas will be filled with 42,000 cubic meters (55,000 cubic yards) of fill from the identified borrow sources.

Materials and Sources. BLN COL FSAR Subsection 2.5.4.5.3.1 describes the onsite sources for backfill material, previously identified and investigated at the BLN site. The applicant noted that previous investigations of the borrow sources included borings and power and hand auger results. The applicant used the results of the current subsurface investigations to further define the subsurface conditions and to better classify the suitability of excavated materials (mostly soil overburden) for use as fill.

Material Properties. BLN COL FSAR Subsection 2.5.4.5.3.2 describes sample testing of subsurface materials to determine the engineering characteristics of the soil overburden. The applicant considered the results of previous studies as well as an additional 100 samples from the BLN 3 and 4 investigations. The applicant concluded that the low plasticity clays will be suitable for structural fill, while the higher plasticity materials will be suitable for use in non-structural, deeper fill areas. The applicant presented the properties of the Class I soils to be used as fill at the BLN 3 and 4 site and stated that any additional off-site borrow material will meet the criteria described in the following section of this SER. Finally, the applicant noted that rock fill may be used as structural fill in the vicinity of the Seismic Category I structures as long as the gradation requirements are met and the rock fill is not placed any closer than 1.2 m (4 ft.) to the base of a structure footing.

Recommended Backfill Material

BLN COL FSAR Subsection 2.5.4.5.4 describes the desirable characteristics for backfill at the BLN 3 and 4 site. The applicant noted that the material should be free-draining, low-plasticity, minor percentage of fines, and not susceptible to shrink and swell. Of the material available from on-site excavations, the applicant concluded that only Class I soils will be acceptable fill materials based on these properties. The applicant plans to use concrete fill between the nuclear island basemat and the rock excavation surface, while Class I soils and other soil material of similar properties will be used between the foundation walls and the soil excavation surface. SER Table 2.5.4-2 provides the backfill material property criteria. BLN COL FSAR Subsection 2.5.4.5.4.1 describes the placement criteria and compaction specifications. Finally, the applicant noted that, since only Class I soils are suitable for use, off-site backfill materials will be needed, although an off-site borrow source had yet to be identified.

<u>Compaction Requirements</u>. BLN COL FSAR Subsection 2.5.4.5.4.1 describes the soil and rock fill compaction criteria. The applicant stated that the soil fill, outside of the wall backfill zone, will be placed in horizontal lifts compacted to a minimum of 98 percent of the maximum dry density and having a moisture content between minus 1 and plus 2 percent of the optimum moisture content determined during the laboratory investigations. In structural areas, the applicant concluded that materials with more than 5 weight percent organic materials, liquid limit greater than 35, plasticity index greater than 15, or Standard Proctor maximum dry density less than 1.6 g/cm^3 (99.8 per cubic foot [pcf]) should not be used. The applicant also stated that soil fill should not be placed when conditions were too wet, frozen, or improperly compacted. Finally, the applicant identified the appropriate compaction equipment as sheeps-foot or smooth-drum vibratory compactors, with smaller equipment used for more confined areas between the nuclear island foundation walls and the rock/soil cuts. The applicant concluded that the maximum lift thickness will be limited to 15.24 cm (6 in.) in order to achieve the necessary degree of compaction with the smaller equipment.

BLN COL FSAR Subsection 2.5.4.5.4.1.2 describes the rock fill placement criteria. The applicant stated that rockfill may be used in the place of soil fill material below non-safety-related structures, except the Turbine building. In order to place rock fill, the applicant identified several criteria for rock fill placement, compaction requirement and fill constituents. First, the applicant stated that the exposed subgrade will be evaluated by a qualified geotechnical engineer. The applicant also identified the restrictions on the use of the maximum particle size of 45.72 cm (18 in.), which can be used up to 3.048 m (10 ft.) from the foundation grade, but between 3.048 and 1.2 m (10 and 4 ft.) the maximum particle size is decreased to 10.16 m (4 in.). To avoid interference with utility construction, the applicant concluded that rock fill was unsuitable for use in the upper 1.2 m (4 ft.). The applicant also limited the thickness of rock fill lifts to a maximum of 45.72 cm (18 in.). In order to achieve the necessary compaction, the applicant stated that 6 to 8 passes of heavy construction equipment will be needed, and that a test pad program would be completed at the start of construction to establish control methods and evaluate the thickness and number of passes. Finally, the applicant noted that the rock fill must have adequate percent fines in order to fill the voids and open spaces, but should not exceed the maximum value of 10 percent by volume.

<u>Quality Control Testing</u>. BLN COL FSAR Subsection 2.5.4.5.4.2 describes the quality control testing to be completed following the stripping of the surficial materials. The applicant described plans to evaluate the surfaces for suitability by proofrolling, which would be performed only after a period of dry weather to avoid degradation of the subgrade. Since temporary construction slopes are benched, it is not necessary to proofroll the temporary slopes.

The applicant also described plans to conduct field density testing during fill placement. Using the results of the density tests performed for each 232 sq. m (2500 sq. ft.) of lift area, the applicant planned to measure the degree of compaction. The applicant also noted that since subgrade soils can deteriorate rapidly, any deteriorated or softened surface would need to be proofrolled and recompacted prior to the placement of fill.

<u>Quality Assurance Program</u>. BLN COL FSAR Subsection 2.5.4.5.4.3 refers to BLN COL FSAR Section 17.5 for a description of the Quality Assurance Program at the BLN site.

Foundation Excavation Monitoring

BLN COL FSAR Subsection 2.5.4.5.5 states that the Seismic Category I structures will be founded on rock and detailed geologic maps of the subgrade conditions and bearing surface will be prepared prior to the placement of concrete or a mud mat. The applicant referred to BLN COL FSAR Subsection 2.5.4.12 for a more detailed discussion of the subsurface improvement techniques. The applicant concluded that, based on the construction experience of BLN 1 and 2, in which there was no heave or rebound documented, a foundation monitoring program was not necessary during the construction of BLN 3 and 4.

2.5.4.2.6 Groundwater Conditions

BLN COL FSAR Section 2.5.4.6 describes the relationship between the groundwater conditions at the site and the foundation stability for the safety-related structures. The applicant presented the results of the hydraulic conductivity tests and the construction dewatering plans for the BLN site.

Groundwater Occurrence

BLN COL FSAR Subsection 2.5.4.6.1 presents the groundwater information collected from boreholes and monitoring wells at the BLN site. The applicant determined the groundwater elevations from the monitoring wells, which were divided into three groups, A, B, and C, with A being the shallowest. BLN COL FSAR Figure 2.4.12-218 shows the groundwater elevations, with only minor fluctuations at any given location. BLN COL FSAR Tables 2.5-241 and 2.5-242 show water level data in the proximity of BLN 3 and 4, respectively. The applicant noted that the groundwater elevation ranged from 1.12 to 1.8 m (3.7 to 6.2 ft.) below the top of the rock for BLN Unit 3, and 2.25 and 0.85 m (7.4 and 2.8 ft.) below the top of the rock for BLN Unit 4. The applicant also noted that the piezometric levels in the shallower wells were higher than in the deeper wells terminating in rock. The applicant also concluded that the groundwater levels from the shallower wells reflected perched water within the soil layers, whereas the deeper wells reflected groundwater conditions and elevations within the bedrock. In BLN COL FSAR Table 2.5-244, the applicant recorded the highest and lowest groundwater levels for the deep (B and C) monitoring wells in the immediate vicinity of BLN 3 and 4. SER Table 2.5.4-3 summarizes the highest and lowest groundwater elevations for the A, B, and C-series wells near BLN 3 and 4.

Field Hydraulic Conductivity Testing

BLN COL FSAR Subsection 2.5.4.6.2 describes the field hydraulic conductivity testing performed at the site. The applicant performed in-situ testing using the double packer pressure testing in seven boreholes at the BLN site and used several depth intervals as part of the tests. Since sustained flow was not observed under the test pressures at certain depth intervals, the applicant concluded that there was insignificant flow through the rocks at depth. However, at depth intervals having sustained flow, the applicant noted that the effective hydraulic conductivity ranged from 236.5 to 1317.9 m per year (776.1 to 4323.9 ft. per year) and was controlled by the nature and frequency of joints in the rock mass. The applicant measured an effective hydraulic conductivity of 197.8 m/yr (649 ft./yr) at the BLN Unit 3 foundation elevation of 179.4 m (588.6 ft.). The applicant was not able to achieve sustained flow near the foundation elevation for BLN Unit 4, therefore, no effective hydraulic conductivity was determined.

Construction Dewatering

In BLN COL FSAR Subsection 2.5.4.6.3, the applicant stated that the excavation to the foundation level for BLN 3 and 4 extends into the bedrock, where water flows only along pre-existing joints and discontinuities, and that therefore seepage along the excavation sides is expected to be slight. The applicant also noted that, based on the construction experience from BLN 1 and 2, in which seepage was not a factor, no quantitative analysis of seepage flow was necessary during the construction of BLN 3 and 4. The applicant stated that construction dewatering will be accomplished by establishing and maintaining several low points during excavation towards which excavations will be sloped. In order to collect and pump out the water, the applicant plans to dig sump pits, a method that was successful during the construction of BLN 1 and 2.

Groundwater Impacts on Foundation Stability

BLN COL FSAR Subsection 2.5.4.6.4 states that changes in groundwater level will have no impact on the foundation settlement or bearing stability.

2.5.4.2.7 Response of Soil and Rock to Dynamic Loading

BLN COL FSAR Section 2.5.4.7 describes the response of soil and rock to dynamic loading. The applicant included investigations of historic earthquakes and their effect on soil and rock, shear and compressional wave velocity profiles from both surface and in-hole geophysical surveys, results from dynamic laboratory testing of soil and rock samples, foundation conditions and uniformity, and a presentation of dynamic profiles. The applicant developed the dynamic properties for the site based on the field measurements of rock and soil in boreholes within the power block construction zone for BLN 3 and 4, as well as on the results of laboratory testing and a review of the dynamic properties determined as part of previous investigations for BLN 1 and 2. The applicant then used the compilation of this data to develop dynamic velocity profiles and the site GMRS described in BLN COL FSAR Section 2.5.2.6.

Prior Earthquake Effects and Geologic Stability

BLN COL FSAR Subsection 2.5.4.7.1 states that there are no active or potentially active faults or seismic deformation zones at the BLN site. The applicant confirmed that the soil and rock materials have not experienced seismically-induced ground failure by geologic mapping and subsurface explorations at the BLN site. Furthermore, based on a review of available literature and field reconnaissance, the applicant concluded that there was no evidence of earthquake-induced ground failure at or near the site of BLN 3 and 4, and therefore, a low potential for earthquake-induced ground failure.

Field Dynamic Measurements

BLN COL FSAR Subsection 2.5.4.7.2 describes the techniques used to measure the dynamic properties within the power block construction zone for BLN 3 and 4. The applicant performed 13 P-S seismic velocity suspension logging surveys, two downhole seismic velocity surveys, two SCPT seismic velocity surveys, and surface refraction velocity surveys performed in a grid pattern with 3.048 m (10 ft.) spacings. BLN COL FSAR Section 2.5.4.4 describes the results in more detail.

Laboratory Dynamic Testing

In BLN COL FSAR Subsection 2.5.4.7.3, the applicant stated that resonance column torsional shear (RCTS) testing was used to measure the dynamic soil properties.

Foundation Conditions and Uniformity

BLN COL FSAR Subsection 2.5.4.7.4 states that the variability in foundation condition and geologic profiles beneath BLN 3 and 4 is due to alternately dipping layers of limestone and clayey limestone, variations in the depth to the rock surface, differing soil thicknesses, and topographic variability. The applicant noted that the basemat elevation of 179.4 m (588.6 ft.) requires that excavation be extended 1.524 m (5 ft.) into the bedrock with additional overexcavation required in some areas to remove weathered or dilated rock and reach the sound rock required for embedment. The applicant planned to fill these overexcavation areas with fill concrete up to the basemat elevation. Although the limestone bedrock is interbedded, the applicant concluded that the bedrock meets the definition of "Uniform" in Section 2.5.4.5 of the AP1000 DCD. The applicant also considered the groundwater table, which was mapped slightly above the bedrock surface, with an additional perched water table in the soil zone to be excavated. Finally, the applicant consolidated the borehole-specific velocity profiles and the downhole velocity profiles into BLN COL FSAR Figure 2.5-351, which shows the stratigraphic-velocity profile for the Vs rock data.

Dynamic Profiles

BLN COL FSAR Subsection 2.5.4.7.5 states that the applicant compiled and applied two dynamic velocity profiles from within the Seismic Category I area and an additional eight locations outside the nuclear island structures to develop the site-specific dynamic velocity profiles at the BLN site. The applicant considered the variability of site conditions, such as thickness and lateral variability, in the development of the base case dynamic velocity models. The applicant noted that the residual soils at the site were susceptible to softening but not liquefaction, and plotted the RCTS test results for the residual soils on standard plasticity index-correlated Vecetic and Dobry (V&D) shear modulus and damping curves. The applicant also plotted the RCTS test data on the V&D curves in order to select the best fit curves to represent the upper and lower residual soil. From these best fit curves, the applicant compared the plasticity index values against those values obtained from test samples and concluded that the values were in good agreement, which confirmed the suitability of the best fit curves. Based on the matching of field and laboratory results, the applicant selected RCTS data sets from the 1.0 times confining pressure to represent the residual soil conditions at the BLN site. The applicant also considered the properties of the borrow materials and assumed the standard EPRI curves for damping and shear modulus reduction for these materials at corresponding depths.

2.5.4.2.8 Liquefaction Potential

BLN COL FSAR Section 2.5.4.8 provides an overview of the liquefaction potential at the BLN site and discusses the geologically-based and soil texture-based liquefaction assessments.

Overview

BLN COL FSAR Subsection 2.5.4.8.1 states that, for a site to meet the requirements of 10 CFR Part 50 and 10 CFR Part 100, an analysis of the liquefaction potential at the site is needed if the foundation materials near Seismic Category I structures are saturated or the groundwater table is above bedrock. The applicant noted that the Units 3 and 4 safety-related basemat subgrades will be embedded up to 1.524 m (5 ft.) into the limestone bedrock and, therefore, not susceptible to liquefaction. The applicant also considered the liquefaction potential of the residual soil overlying the bedrock at the BLN site. Based on the percent fines and plasticity index, the applicant concluded that the residual soils have a low susceptibility to liquefaction. Finally, the applicant performed a liquefaction screening assessment in accordance with RG 1.198.

Geologically-Based Liquefaction Assessment

BLN COL FSAR Subsection 2.5.4.8.2 describes the geologically-based liquefaction assessment. Based on the results of geologic mapping and subsurface investigations, which found that the residual soils did not experience seismically-induced ground failure, the applicant concluded that liquefaction of the residual soils is not expected. The applicant used the geologic screening process of RG 1.198, which assumes a greater liquefaction potential for saturated deposits of loose sand and silt, and concluded that the clay residual soil and fill do not fall into the category of susceptible fill as described in RG 1.198. BLN COL FSAR Figure 2.5-358 shows the geologically-based screening chart that the applicant used to conclude that, based on factors such as past performance, age of deposit, percent granular material, and PGA during the SSE, the BLN soils have a very low liquefaction potential.

Soil Texture-Based Liquefaction Assessment

BLN COL FSAR Subsection 2.5.4.8.3 describes the second screening method used by the applicant to assess the liquefaction potential at the BLN site, the soil texture-based assessment. The applicant used this method to evaluate the liquefaction potential of both residual soils and fill material through the quantitative evaluation of percent fines, plasticity index, liquid limit, and water content. The applicant derived the input for this analysis from the results of 76 samples tested for mechanical and hydrometer grain sizes and the Atterberg indices, as part of the laboratory testing described in BLN COL FSAR Subsection 2.5.4.2. Sixty-five of the 76 samples plot outside of the area of liquefaction potential, based on the liquefaction screening chart presented by the applicant in BLN COL FSAR Figure 2.5-358. The applicant concluded that since nine of the remaining points plotted as marginally liquefiable and the remaining two points were only potentially liquefiable, the texture-based liquefaction assessment provided independent confirmation that the residual soils and fill had low liquefaction potential.

2.5.4.2.9 Earthquake Site Characteristics

In BLN COL FSAR Section 2.5.4.9, the applicant stated that the GMRS was developed in accordance with the guidelines of RG 1.208. BLN COL FSAR Section 2.5.2.6 describes the methodology and development of the GMRS in more detail.

2.5.4.2.10 Static Stability

BLN COL FSAR Section 2.5.4.10 evaluates the static stability for the BLN site for foundation settlement, foundation bearing capacity, and lateral pressures below grade. The applicant limited the static stability evaluation to the safety-related structures.

Bearing Capacity

The applicant stated that it evaluated the bearing capacity for each unit using two independent methods: ultimate bearing capacity using the Terzaghi approach and allowable bearing pressure using the Peck, Hanson & Thornburn approach.

The applicant used the following equation to compute the ultimate bearing capacity using the Terzaghi approach:

$$q_{ult} = cNc + 0.5\ \gamma BN_{\gamma} + \gamma DNq$$

Where: q_{ult} = the ultimate bearing capacity
γ= effective unit weight
B = width of foundation
D = depth of foundation below ground surface
c = the cohesion intercept for the rock mass
Nc, Nγ, and Nq are bearing capacity factors dependent of the internal angle of friction, which the applicant assumed was 46°.

The applicant described the Peck, Hanson & Thornburn approach as an empirical method in which the bearing capacity is related to the RQD. The applicant concluded that the bearing capacities under both static and dynamic conditions (12,017 kPa (251,000 psf) for the Terzaghi approach and 11,299 kPa (236,000 psf) for the Peck, Hanson & Thornburn approach) are well above the static and dynamic requirements provided in Table 2-1 of the AP1000 DCD.

The applicant described plans to construct a mud mat between the prepared rock foundation bearing surface and the structural foundation mat. The applicant stated the compressive strength of the concrete mud mat was 17.4 MPa (2,500 psi).

Resistance to Sliding

In BLN COL FSAR Subsection 2.5.4.10.2, the applicant stated that the resistance to sliding was determined by comparing the forces causing sliding to the resisting forces. For the BLN site, the applicant selected a minimum friction angle of 35°, which corresponds to a coefficient of friction of 0.7 for the mud mat. The applicant selected a lower bound friction of 46° for the rock mass.

Rebound Potential

BLN COL FSAR Subsection 2.5.4.10.3 states that the rebound at the BLN site was evaluated by comparing the vertical change due to the removal of overburden to the elastic properties of the material below the foundation level. The applicant noted that the total reduction in stress due to the removal of overlying material was very small, about 217 kPa (31 psi), compared to the elastic modulus of the rock, which was 3,316 MPa (481,000 psi). Therefore, the applicant concluded that the potential for significant rebound at the BLN site foundation was non-existent.

Settlement

In BLN COL FSAR Subsection 2.5.4.10.4, the applicant discussed the total and differential settlement at the BLN 3 and 4 site. FSAR Subsection 2.5.4.10.4.1 describes three methods used to determine the total settlement at the BLN site. The applicant used the Boussinesq, Corps of Engineers and Steinbrenner equations to estimate settlement from stating loading conditions on the nuclear island foundation. Using these equations, the applicant evaluated settlement at the site by dividing the subsurface into layers of similar elastic modulus values in order to calculate the change in stress using elastic theory. The applicant summed the layer results to obtain the total settlement at the site. Based on the results, the applicant concluded that the total maximum settlement under BLN 3 and 4 is 0.457 and 0.508 cm (0.18 and 0.20 in.), respectively. In BLN COL FSAR Subsection 2.5.4.10.4.2, the applicant stated that since the site meets the uniformity criteria in Table 2-1 of the AP1000 DCD, differential settlement was not a factor at the site of BLN 3 and 4.

Lateral Earth Pressures

BLN COL FSAR Subsection 2.5.4.10.5 states that lateral earth pressures develop in the subsurface due to the placement and compaction of soil materials against below grade walls. Using an at-rest pressure coefficient of 0.81 and the Rankine earth pressure theory, the applicant calculated the ultimate earth pressure. BLN COL FSAR Figure 2.5-360 shows the earth pressure distribution in the at-rest condition for the soil backfill and BLN COL FSAR Figure 2.5-361 illustrates the passive pressure distribution for the soil. The applicant noted that since the groundwater in the area has no shear strength and provides no passive resistance, it did not include hydrostatic pressure in the passive pressure analysis.

2.5.4.2.11 Design Criteria

BLN COL FSAR Section 2.5.4.11 refers to BLN COL FSAR Table 2.0-201 for a comparison of the AP1000 DCD site parameter criteria to the actual site characteristics, such as allowable static bearing capacity, liquefaction potential, and Vs. The applicant stated that the safety-related structures were designed to be founded on continuous rock, such as the limestone bedrock or concrete fill on top of limestone bedrock in the BLN site area. The applicant summarized the locations of the design criteria in the related sub-parts of BLN COL FSAR Section 2.5.4. Finally, the applicant noted that computer aided analyses were validated and verified by hand calculations or published inputs and solutions.

2.5.4.2.12 Techniques to Improve Subsurface Conditions

In BLN COL FSAR Section 2.5.4.12, the applicant described the mechanical cleanup, grouting and concrete dental repair, rock bolting, rock anchoring, and the foundation improvement verification program that can be implemented as part of the subsurface improvements.

The applicant stated that mechanical cleanup will be completed after excavation and will remove loose, broken, and displaced rock, and will also be used to determine whether grouting, rock bolting or anchoring, or removal is appropriate. BLN COL FSAR Subsection 2.5.4.12.3 states that in areas where grouting or concrete dental repair are needed, the area will be cleaned over two times the width until a wedging effect can be achieved with fill concrete. The applicant stated that rock bolting will be used to prevent raveling and to stabilize large blocks of rock that are loosened or displaced during construction excavation. The applicant did not anticipate the use of rock anchors, but stated that if rock anchors are needed, they will be installed to meet the design criteria and construction specification documents. Finally, the applicant stated that inspection and mapping of the completed excavation will be done using sounding, test holes or similar measurements to supplement the visual inspection of the excavation surface. The applicant also stated that, although specific milestones for the foundation improvement verification program are yet to be identified, the quality assurance program will be in place and will be followed during the course of the program.

2.5.4.3 Regulatory Basis

The regulatory basis of the information incorporated by reference is addressed within the FSER related to the DCD.

In addition, the relevant requirements of the Commission regulations for the stability of subsurface materials and foundations, and the associated acceptance criteria, 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 as follows:

- 10 CFR 50.55a, Codes and Standards, requires that SSCs be designed, fabricated, erected, constructed, tested and inspected in accordance with the requirement of applicable codes and standards commensurate with the importance of the safety function to be performed.

- 10 CFR Part 50, Appendix A, General Design Criterion 1 (GDC 1), "Quality Standards and Records," requires that structures, systems and components important to safety be designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety functions to be performed. It also requires that appropriate records of the design, fabrication, erection, and testing of structures, systems, and components important to safety be maintained by or under the control of the nuclear power unit licensee throughout the life of the unit.

- 10 CFR Part 50, Appendix A, GDC 2, "Design Bases for Protection Against Natural Phenomena," 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 A, GDC 44, "Cooling Water," requires that a system be provided with the safety function of transferring the combined heat load from SSCs important to safety to an ultimate heat sink under normal operating and accidental conditions.

- 10 CFR Part 50, Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Processing Plants," establishes QA requirements for the design, construction, and operation of those SSCs of nuclear power plants that prevent or mitigate the consequences of postulated accidents that could cause undue risk to the health and safety of the public.

- 10 CFR Part 50, Appendix S, "Earthquake Engineering Criteria for Nuclear Power Plants," as it applies to the design of nuclear power plant SSCs important to safety to withstand the effects of earthquakes.

- 10 CFR Part 100, "Reactor Site Criteria," provides the criteria, which guide the evaluation of the suitability of proposed sites for nuclear power and testing reactors.

- 10 CFR 100.23, "Geologic and Seismic Criteria," provides the nature of the investigations required to obtain the geologic and seismic data necessary to determine site suitability and identify geologic and seismic factors required to be taken into account in the siting and design of nuclear power plants.

The related acceptance criteria from Section 2.5.4 of NUREG-0800 are as follows:

- Geologic Features: In meeting the requirements of 10 CFR Part 50 and 10 CFR Part 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 Part 50 and 10 CFR Part 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 Part 50 and 10 CFR Part 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 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 QA program described and referenced; (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 Part 50 and 10 CFR Part 100, the analysis of groundwater conditions is acceptable if the following are included in this subsection or cross-referenced to the appropriate subsections 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; (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 Part 50 and 10 CFR Part 100, descriptions of the response of soil and rock to dynamic loading are acceptable if: (1) an investigation has been conducted and discussed to determine the effects of prior earthquakes on the soils and rocks in the vicinity of the site; (2) field seismic surveys (surface refraction and reflection and in-hole and cross-hole seismic explorations) have been accomplished and the data presented and interpreted to develop bounding P and S wave velocity profiles; (3) dynamic tests have been performed in the laboratory on undisturbed samples of the foundation soil and rock sufficient to develop strain-dependent modulus reduction and hysteretic damping properties of the soils and the results included.

- Liquefaction Potential: In meeting the requirements of 10 CFR Part 50 and 10 CFR Part 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 Part 50 and 10 CFR Part 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 geologic characteristics should be consistent with appropriate sections from: RG 1.27, RG 1.28, "Quality Assurance Program Requirements (Design and Construction)," RG 1.132, RG 1.138, RG 1.198, and RG 1.206.

2.5.4.4 Technical Evaluation

The NRC staff reviewed Section 2.5.4 of the BLN COL FSAR and checked the referenced DCD to ensure that the combination of the DCD and the information in the COL represent the complete scope of information relating to this review topic.[1] The NRC staff's review confirmed that the information contained in the application and incorporated by reference addresses the required information relating to the stability of subsurface materials and foundations. Section 2.5.4 of Revision 17 to the AP1000 DCD is being reviewed by the staff under Docket Number 52-006. The NRC staff's technical evaluation of the information incorporated by reference, related to stability of subsurface materials and foundations, will be documented in the staff SER on the DC amendment application for the AP1000 design.

This SER section presents the staff's evaluation of the geologic and geotechnical engineering information submitted by the applicant in BLN COL FSAR Section 2.5.4 to address the stability of the subsurface materials and foundations at the BLN site and to resolve BLN COL 2.5-5 through 2.5-13 and 2.5-16. The technical information presented in BLN COL FSAR Section 2.5.4 resulted from the applicant's surface and subsurface geologic and geophysical investigations performed within the site area. Through its review of BLN COL FSAR Section 2.5.4, the staff determined whether the applicant had complied with the applicable regulations and conducted its investigations at an appropriate level of detail in accordance with RG 1.132.

To thoroughly evaluate the geologic, seismic, and geophysical information presented by the applicant, the staff obtained the assistance of geotechnical engineers at Oak Ridge National Laboratory. The staff and its contractors visited the COL site to confirm interpretations, assumptions, and conclusions presented by the applicant related to the stability of subsurface materials and foundations at the site.

The staff reviewed the information contained in the BLN COL FSAR:

AP1000 COL Information Items

- BLN COL 2.5-5

The NRC staff reviewed BLN COL 2.5-5 related to COL Information Item 2.5-5 included under Section 2.5.4 of the BLN COL FSAR.

BLN COL 2.5-5 requires the applicant to provide site-specific information on the material properties, including the site plans and layout, as well as the geologic and topographic features identified at the site. Based on the applicant's assessments of the properties and the stability of the soils and rock that underlie the BLN site, in addition to the site conditions, geologic features, and the locations of Seismic Category I structures, described in BLN COL FSAR Section 2.5.4, the staff concludes that the applicant provided the information required to satisfy BLN COL 2.5-5.

2.5.4.4.1 Geologic Features

In BLN COL FSAR Section 2.5.4.1, the applicant described the non-tectonic processes and features that could cause permanent ground deformation or foundation instability at BLN 3 and 4. The applicant evaluated the contemporary stress conditions, soil and rock characteristics and weathering and erosion processes at the site. Based on its evaluations, the applicant concluded that the limestone of the Stones River Group is the only rock or soil that might be unstable at the site. Small-scale karst features, formed by limestone dissolution, are present beneath the site; however, the applicant concluded that these features will not affect the stability of the foundations for the BLN 3 and 4 safety-related structures. The applicant further stated that most dissolution cavities occur within 3 to 6 m (10 to 20 ft.) of the top of the bedrock and will be removed during excavation.

The staff focused its review of BLN COL FSAR Section 2.5.4.1 on the applicant's descriptions of: (1) the residual soils and lithologic units underlying the site; (2) dissolution features within the soil and rock units; (3) the site exploration program, in particular, the results of the borehole and seismic velocity profile data; (4) laboratory analyses; and (5) maps and profiles of the site features and investigations. BLN COL FSAR Section 2.5.1.1 provides a more thorough description and characterization of the regional and site geology. Section 2.5.1.4 of this SER contains the staff's technical evaluation of the regional and site geologic information.

Weathering Processes and Features

The applicant conducted a site exploration program that focused on the construction zone area and immediate surroundings for the proposed BLN 3 and 4. The applicant's investigations included borings, test pits and geophysical testing procedures. In BLN COL FSAR Section 2.5.4.1, the applicant described dissolution related cavities that it encountered in a number of boreholes at the BLN site. The applicant stated that geologic conditions at the site are "not favorable for the development of large cavern systems," but that "small-scale karst features are present." In RAI 2.5.4-1, the staff asked the applicant to explain the control level on the physical dimensions of cavities that may exist outside of the boreholes, given the variation in cavity dimensions encountered during the BLN site exploration program. In addition, the staff asked the applicant to explain any potential impact that such cavities could have on the stability of the site foundation and its structures.

In response to RAI 2.5.4-1, the applicant stated that there is no directly observable data on the physical dimensions of cavities beneath the BLN site, other than the information derived from the borehole investigations. As part of its COL investigations, the applicant drilled 75 boreholes within the BLN 3 and 4 power block construction zone. The applicant stated that 16 of the 75 boreholes contained at least one cavity. The applicant also stated that only one of the 16 boreholes encountered a cavity (3 cm (0.1 ft.) in height) below the excavation grade, or below elevation 179.4 m (588.6 ft.) amsl. In further response to RAI 2.5.4-1, the applicant presented several lines of evidence to support its conclusions that the cavities encountered in the 16 boreholes (and in 9 other boreholes outside of the BLN 3 and 4 construction area) are representative of the Stones River Group limestone beneath the site and that these cavities do not pose a safety hazard to the foundations and structures at the BLN site.

The applicant suggested that there are two primary mechanisms responsible for cavity formation. One of these mechanisms occurs in the epikarst, or the uppermost dissolution zone that is located within the top 1.5 m (5 ft.) of the bedrock surface. Cavity formation of this type is a response to meteoric (atmospheric) water that circulates through the soil and the upper bedrock. Cavities within this zone are typically small and average less than 0.15 m (0.5 ft.) in thickness. The applicant stated that it expects all features within this epikarst zone to be removed during excavation of the soil and weathered rock.

The second mechanism takes place within the bedrock as a response to vertical and lateral groundwater flow through joints and fractures, and along bedding planes. This type of cavity formation can result in large-scale karst features (including enterable caves) in areas with pure limestone, such as the Mississippian age (354 to 323 Ma) rocks that form mountains and bluffs away from the BLN site. Since limestone of the Ordovician age (490 to 433 Ma) Stones River Group form the bedrock beneath the BLN site, the staff was concerned that such large cavities could exist beneath the site, even though they were not captured in the applicant's borehole data. The applicant provided two primary justifications for why this is most likely not the case.

First, the source for groundwater, or the groundwater recharge, beneath the BLN site is limited to local runoff as there are no significant drainage systems or sinkholes identified at the site. Therefore, the amount of water available to create dissolution features along joints and bedding planes is minimal thus limiting potential cavity size. Second, the Stones River Group is not purely limestone as it contains interbedded layers with dolomite, silts, clays and chert, all of which promote rates of dissolution slower than that of pure limestone. In addition, the nature of the interbedded layers inhibits long continuous cavity formation as non-calcareous sediments such as silts and clays are not conducive to dissolution.

The staff reviewed the applicant's cavity analysis provided in response to RAI 2.5.4-1, as well as the borehole data presented in BLN COL FSAR Section 2.5.4.1 and in BLN COL FSAR Appendix 2BB. In addition, during the staff's visit to the BLN site (ML083250530) in October 2008, the staff reviewed a cavity distribution map of the area within 8 km (5 miles) of the site. The map shows no enterable cavities that are known to exist within the documented area. The staff concludes that the applicant's characterization of cavity features within the soils and weathered bedrock, as interpreted by the site exploration borehole data for the BLN site, is adequate and provides reasonable evidence that the features identified by the applicant are typical of the soils and weathered bedrock that were not sampled as part of the site exploration program.

The staff finds that the applicant provided adequate justification, based on borehole data from its COL investigation and from previous site investigations, that any cavities in the site area are likely to be concentrated in a 6 m (20 ft.) thick zone at the top of the bedrock. The staff notes that the response to RAI 2.5.4-1 includes a commitment to make a future revision to the FSAR to include a reference to a map with the known caves in the area around the BLN site and a explanation as to why there are no cave formations in the rock formation associated with the BLN site itself. This is **Confirmatory Item 2.5.4-1**.

Furthermore, the staff concludes that karst, or dissolution, features within the excavated zone should not pose a stability hazard to the BLN 3 and 4 foundations, based on the applicant's confirmation that any cavities that may exist will be removed during excavation, or remediated using acceptable grouting and dental techniques. However, because the applicant cannot rule out the existence of cavities beneath the excavation zone that could adversely impact the stability of the foundations, the staff concludes that a commitment by the applicant, to perform geologic mapping and geophysical exploration during the construction of BLN 3 and 4, is necessary, in order to fully detail the depth and configuration of any existing dissolution cavities, and their related features beneath the excavation surface. The applicant's commitment to perform geologic mapping and geophysical exploration during excavation was previously identified by the staff in Section 2.5.1.4.2 of this SER as proposed **Commitment 2.5.1-1**.

In BLN COL FSAR Section 2.5.4.1.3.1, the applicant stated that the foundation grade for proposed BLN 3 and 4 is 179 m, or 588.6 ft. elevation above mean sea level (amsl). The applicant concluded that its borehole investigations within the power block construction zone did not encounter dissolution cavities beneath an elevation of 168 m, or 550 ft. amsl. In RAI 2.5.4-2, the staff asked the applicant to describe the minimum dimensions of a cavity that could adversely impact both the static and the dynamic design for the foundation basemat and the intersecting walls. The staff asked the applicant to also discuss the possibility that it might encounter such cavities beneath the foundation basemat. Finally, the staff asked the applicant to describe the procedures that it will implement during excavation and construction to ensure that any cavities either do not exist beneath the BLN 3 and 4 foundation, or will not adversely affect the safety of BLN 3 and 4.

In response to RAI 2.5.4-2, the applicant explained that the majority of dissolution cavities encountered during the excavation process for BLN 3 and 4 are expected to be concentrated above 173.7 m (570 ft.) amsl, as stated in its response to RAI 2.5.4-1. The applicant stated that it will rely on geophysical explorations, to be conducted during the site excavations, to identify potential cavities beneath the foundation basemat. These geophysical methods include ground penetrating radar, electrical resistivity, and microgravity surveys and are expected to show any anomalies (potential cavities) beneath the excavation level that will indicate that further investigative measures are warranted, such as probing or core boring.

As part of its response to RAI 2.5.4-2, the applicant described the methods introduced by Obert, Duvall and Merrill (1960), combined with local rock conditions, to estimate the dimension of a cavity that could pose a threat to the safety of BLN 3 and 4. The applicant concluded that, for a cavity located 1.5 m (5 ft.) below the foundation basemat, the unsupported width corresponding to the maximum tensile stress is about 3.96 m (13 ft.) with a factor of safety of 1. The unsupported width decreases to 1.2 m (4 ft.) when the static uniform bearing pressure is added to the weight of the rock. For a cavity located 6.09 m (20 ft.) below the basemat, the unsupported width is about 4.26 m (14 ft.). The applicant considered that the possibility of encountering such a cavity at the site is remote and that most cavities are expected to be small and to be concentrated within the upper 3.04 m (10 ft.) of rock. The applicant concluded its response to RAI 2.5.4-2 by stating that any cavities identified during the excavation investigations will be removed, or remediated using the improvement methods described in BLN COL FSAR Section 2.5.4.12.6.

Based on its review of the response to RAI 2.5.4-2, the staff identified the following concerns regarding the applicability of the method developed by Obert, Duvall, and Merrill:

- The applicant did not provide sufficient information regarding the application of this method and how it represents the conditions at the BLN site.

- The method was introduced more than 40 years ago, and the applicant did not discuss any recent interpretations of the method or improvements to the method, and if it is widely used, or accepted.

- The BLN site conditions do not meet the assumed criteria required for this method (i.e., units cannot have a dip greater than 10 degrees).

- The BLN load-bearing rock units contain joints and fractures, as well as other cavities; therefore, they do not meet the method criteria that “rock in the layers is elastically perfect, isotropic and homogeneous,” precluding the possibility of any fracture in the roof.

The staff recognizes that the applicant will remove all material above the foundation basemat during excavation and that any cavities encountered beneath the foundation will be remediated using appropriate grouting and dental techniques. The staff concludes that the applicant’s plan for excavation and remediation is adequate to ensure that no observed cavities pose a safety hazard to the BLN 3 and 4 foundation and structures. However, the staff concludes that the applicant did not adequately demonstrate the minimum cavity dimensions that could exist beneath the foundation basemat that are not observed using exploration techniques and that may have an adverse impact on the BLN 3 and 4 foundation and its structures. The basis for the staff's conclusion regarding minimum cavity dimension is the fact that the applicant did not adequately describe the Obert, Duvall and Merrill method that it used to formulate its RAI response and the staff is concerned that this method's criteria do not represent the conditions present at the BLN site. Therefore, in order to resolve this issues the applicant has to adequately address the minimum dimensions of a cavity that could adversely impact both the static and the dynamic design for the foundation basemat and the intersecting walls for BLN 3 and 4. This is **Open Item 2.5.4-1.**

BLN COL FSAR Section 2.5.4.1.3.2 describes approximately 3.6 m (12 ft.) of boring rod drops that occurred during the applicant's site investigation in a borehole located at the edge of the BLN Unit 4 power block. In RAI 2.5.4-3, the staff asked the applicant to explain if the boring rod drops were related to dissolution cavities encountered at depth. In addition, the staff asked the applicant to explain if any of the soil soft zones, described in BLN COL FSAR Section 2.5.4.1.3.2, extend to depths below the foundation basemat. In response to RAI 2.5.4-3, the applicant clarified that Boring B-1051, located at the southwest edge of the proposed BLN Unit 4 turbine building (not a safety-related structure), did encounter a rod drop of 1.5 m (5 ft.), suggesting that the boring encountered an open cavity, or a very soft soil at a depth of 9.4 m (31 ft.). The boring then encountered 2.1 m (7 ft.) of soft, wet mud before reaching bedrock. Based on inclined and vertical borings, CPT probes, and monitoring wells investigated in the vicinity of Boring B-1051, the applicant determined that the cavity, or soft soil zone, is irregular in shape and that it does not extend northward toward the safety-related structures for BLN Unit 4. The applicant stated in response to RAI 2.5.4-3, that the only soft soil zone, encountered in Boring B-1051, extends to a depth of 13 m (43 ft.), or to the equivalent elevation of 178.6 m (586.1 ft.) amsl. The excavation grade for BLN 3 and 4 is 179.4 m (588.6 ft.) amsl. Therefore, the applicant concluded that the soft soil zone discovered in its COL investigations does not extend below the foundation basemat for BLN Unit 4.

Based on its review of the applicant's response to RAI 2.5.4-3, the staff concludes that the applicant adequately clarified that the boring rod drop, encountered in Boring B-1051, was 1.5 m (5 ft.) in extent as opposed to the 3.6 m (12 ft.) interpreted from the BLN COL FSAR description. In addition, the staff concurs with the applicant's conclusion that the boring rod drop was most likely due to a hollow cavity or soft sediment zone, either of which would cause extremely little to no resistance in boring rod penetration. The staff concurs with the applicant that the cavity encountered in Boring B-1051 will not affect the safety-related structures above the BLN Unit 4 foundation on the basis that the cavity is limited in dimension, as supported by additional exploratory investigations, and that the cavity does not extend within 91 m (300 ft.) of the BLN Unit 4 nuclear island perimeter. Finally, the staff concludes that the applicant adequately justified that soft soil zones encountered in the BLN borehole investigations should not affect the stability of the BLN site foundations because there is no evidence that the soft zones extend beneath the foundation basemat elevation of 179.4 m (588.6 ft.) amsl.

In BLN COL FSAR Section 2.5.4.1.3.3, the applicant discussed seismic refraction surveys that identified two zones, the Eastern and Western Anomaly Zones, of deep weathering. The applicant described these features as being up to 46 m (150 ft.) wide and up to 27 m (90 ft.) thick. In RAI 2.5.4-7, the staff asked the applicant to describe the location of these weathering zones in relation to BLN 3 and 4, and to explain what impact the weathering zones would have on the site GMRS calculation.

In response to RAI 2.5.4-7, the applicant explained that the Western and Eastern Anomaly Zones are weathering zones that were identified during site explorations performed for the "Southern Site," a site previously considered by the applicant and later abandoned. The applicant stated that the southern site is located 914 m (3000 ft.) south of BLN 3 and 4 and that the degree of rock weathering beneath the BLN 3 and 4 is considerably different and less extensive than that identified at the abandoned site. In addition, the applicant speculated that the extensive weathering at the abandoned southern site was most likely associated with its topographic positioning above an abandoned paleo-channel. The applicant concluded its response to RAI 2.5.4-7 by explaining that weathered bedrock does not exist beneath the foundation basemat for BLN 3 and 4, with the possible exception of localized weathering. If localized weathering is encountered during the excavation phase, the applicant stated that it will over excavate and use fill concrete to ensure that there is no threat to the stability of the reactor foundations for BLN 3 and 4 due to localized weathering conditions in the bedrock.

Based on its review of the applicant's response to RAI 2.5.4-7, the staff concurs with applicant's conclusion that, given the distance to the anomalous weathering zones, 914 m (3000 ft.), these zones will not affect the foundations for the safety-related structures at BLN 3 and 4. Furthermore, the staff concludes that there is no impact from these weathering features on the site GMRS, based on the fact that these features are so far away, they are not tectonic features, they are not identified in BLN 3 and 4 site exploration investigations, and they do not pose a hazard to the BLN 3 and 4 foundations for safety-related structures.

Based on its review of BLN COL FSAR Section 2.5.4.1 and the applicant's responses to RAIs 2.5.4-1, 2.5.4-2, 2.5.4-3 and 2.5.4-7, the staff concludes that the applicant adequately identified the potential for both small- and large-scale cavities, and soft soil zones to exist within the soil and weathered rock units that are beneath the BLN site. The staff concludes that the applicant adequately investigated and described cavities and soft soil zones that were encountered during site explorations and that the applicant provided adequate justification that large-scale cavities most likely do not exist, based on the hydrologic conditions present beneath the site and the nature of the Stones River Group limestone. The staff recognizes the applicant's intention to perform further exploratory investigations during the excavation stage in order to ensure that cavities beneath the BLN site will not pose a safety hazard to the BLN 3 and 4 foundation and its structures. The staff further concludes that resolution of **Confimatory Item 2.5.4-1** and **Open Item 2.5.4-1**, along with the applicant's commitment, in proposed **Commitment 2.5.1-1**, will ensure that any dissolution cavities beneath the site foundation will not adversely affect the stability of the safety-related structures at the BLN site.

2.5.4.4.2 Properties of Subsurface Materials

The staff focused its review of BLN COL FSAR Section 2.5.4.2 on the applicant's description of the static and dynamic engineering properties of the soil and rock strata underlying the BLN site and the methods that the applicant used to determine the site engineering properties. The staff reviewed the applicant's implementation of the latest field and laboratory methods to determine the properties of the subsurface materials, in accordance with RG 1.132 and RG 1.138.

Based on its review of the information presented in BLN COL FSAR Section 2.5.4.2, the staff concludes that the applicant relied on multiple effective technologies to investigate the in-situ and laboratory properties of the subsurface materials at the BLN site and that these properties meet the parameters prescribed by the AP1000 DCD. Accordingly, the staff concludes that the field investigations and laboratory testing performed by the applicant to determine the subsurface properties and conditions are in accordance with RG 1.132 and RG 1.138, and are sufficient to meet the criteria of 10 CFR 52.79 and 10 CFR 100.23.

- BLN COL 2.5-6

The NRC staff reviewed BLN COL 2.5-6 related to COL Information Item 2.5-6 included under Section 2.5.4 of the BLN COL FSAR.

BLN COL 2.5-6 requires the applicant to confirm that the properties of the subsurface materials are within the design values, which are outlined in the AP1000 DCD. BLN COL FSAR Section 2.5.4.2 describes the various methods that the applicant used to confirm that the material properties are within the design limits. The applicant utilized multiple field and laboratory investigations, including boring sample analysis, observation wells, and CPTs. Based on the field and laboratory tests performed, as well as the confirmation that the site-specific material properties are within the design values, the staff concludes that the applicant has satisfied the information requirements of BLN COL 2.5-6.

2.5.4.4.3 Foundation Interfaces

The staff focused its review of BLN COL FSAR Section 2.5.4.3 on the applicant's description of the static and dynamic engineering properties of the subsurface materials at the BLN site and on the relationship of these materials to the stability of the BLN 3 and 4 foundations for safety-related structures.

Based on the information and findings provided by the applicant in BLN COL FSAR Section 2.5.4.3, the staff concludes that the applicant implemented significant subsurface investigations in relation to AP1000 safety-related structures for the BLN site. The staff concludes that the applicant adequately investigated the subsurface materials beneath the power block construction zone for BLN 3 and 4 and beneath surrounding and adjacent structures. The staff based its conclusions on: (1) its review of plot plans showing the locations of all site explorations, such as borings, seismic lines, piezometers, geologic profiles, and excavations along with the locations of the safety-related facilities; (2) its review of the profiles presented by the applicant, illustrating the detailed relationship of the foundations of all Seismic Category I and other safety-related facilities to the subsurface materials; and (3) its review of core boring and test pit logs.

2.5.4.4.4 Geophysical Surveys

The staff focused its review of BLN COL FSAR Section 2.5.4.4 on the adequacy of the applicant's geophysical investigations to determine soil and rock dynamic properties. The applicant performed the following geophysical surveys to characterize the subsurface geology beneath the BLN site: (1) three phases of seismic refraction surveys (used to determine P-wave velocity structure) that coincided with its exploratory drilling and sampling program; (2) SCPTs to determine the shear wave velocities in the residuum or fill soils above the bedrock; (3) Compressional and Shear (P-S) suspension logging tests in 8 boreholes at the BLN site; (4) Downhole logging tests in 2 of the 8 boreholes selected for P-S suspension logging tests; (5) microgravity surveys to aid in modeling the subsurface; and (6) 16 Borehole Televiewer, 15 Optical Televiewer, 7 N-Gamma, and 16 Caliper test surveys.

BLN COL FSAR Sections 2.5.4.1.3.3 and 2.5.4.4.1.3 present seismic P-wave (body wave) velocity (Vp) contours for two surfaces at 1,829 m/s (6,000 ft./s) and 4,267 m/s (14,000 ft./s).

The applicant interpreted the velocities from seismic refraction data as shown in BLN COL FSAR Figures 2.5-312 and 2.5-313, respectively. BLN COL FSAR Section 2.5.4.4.3 describes the P-S suspension logging tests that the applicant performed to measure P-wave velocities at various borehole locations at the BLN site. BLN COL FSAR Figure 2.5-314 shows the surface of the 4,267 m/s (14,000 ft./s) bedrock layer at a depth below the BLN Unit 3 basemat excavation elevation of 179.4 m (588.6 ft.) amsl. However, BLN COL FSAR Figure 2.5-339 depicts the base of the BLN Unit 3 excavation at an elevation within the bedrock unit and defines the P-wave velocity for this bedrock layer as being approximately 4,877 m/s (16,000 ft./s).

In RAI 2.5.4-6, the staff asked the applicant to compare the P-wave velocity profiles interpreted from the seismic refraction surveys to the velocity profiles obtained from the P-S suspension logging tests. In addition, the staff asked the applicant to clarify the difference in P-wave velocity for the bedrock unit beneath the BLN Unit 3 foundation excavation, which was shown as 4,877 m/s (16,000 ft./s) in BLN COL FSAR Figure 2.5-339 and 4,267 meters per second (m/s) (14,000 ft./s) in BLN COL FSAR Figure 2.5-314. In response to RAI 2.5.4-6, the applicant stated that the P-S suspension logging and the seismic refraction survey methods can provide significantly different values of seismic P-wave velocity for the same rock layer. In addition, the applicant stated that the results from P-S suspension logging are systematically higher than the results based on seismic refraction data due to the fact that P-wave velocities are obtained at higher frequencies for the P-S Suspension logging. The applicant discussed a number of publications that examine discrepancies involved in calculating P-wave velocities and the biases involved in estimating the depths to soil and rock layers beneath the surface. The applicant stated that the biases present when estimating refractor depths from seismic refraction data has a tendency to overestimate the depths to the top of a rock surface by up to 6.1 m (20 ft.). The applicant concluded that this explains why the depth to the basement rock predicted by the seismic refraction results is deeper than that based on the P-S suspension borehole data. The applicant indicated that there is not a single straightforward method to estimate exact depth to a rock layer based on the P-wave velocity results and that estimates will vary even when using the same test approach in sequence. Consequently, the applicant concluded that it is always best to rely on the borehole data and the actual observed conditions during excavation as they will always provide less bias and more accurate information.

Based on its review of the applicant's response to RAI 2.5.4-6, the staff recognizes that a variety of geophysical approaches are available and widely used to produce P-wave velocity profiles. The staff concurs with the applicant that different criteria are used in the different approaches and that this leads to inconsistencies with the results. Therefore, the staff concurs with the applicant that it is acceptable that the applicant's depth to basement interpretations differ between the seismic refraction and the P-S suspension logging results. Furthermore, the staff concludes that the applicant's inclusion of the differing results in its descriptions of the velocity profiles is acceptable because the applicant ultimately relied on the more accurate borehole data results in its conclusion that the BLN Unit 3 foundation basemat will be seated in the competent bedrock at an elevation of 179.4 m (588.6 ft.) amsl.

Based on the information provided in BLN COL FSAR Section 2.5.4.4 and in the applicant's response to RAI 2.5.4-6, the staff concludes that the applicant has carried out significant geophysical exploratory investigations in order to define the static and dynamic properties of the subsurface materials beneath the BLN 3 and 4 foundations.

2.5.4.4.5 Excavations and Backfill

In BLN COL FSAR Section 2.5.4.5, the applicant described excavation and backfill plans for Seismic Category I structures, including: (1) the overall extent of the earthwork involved; (2) the excavation methods and dewatering controls; (3) the properties and sources of backfill materials; (4) compaction requirements of rock and soil used for backfill; (5) quality control testing of backfilled areas; and (6) foundation excavation monitoring plans. The staff focused its review of BLN COL FSAR Section 2.5.4.5 on the applicant's ability to show that its excavation and backfill plans will ensure that static and dynamic stability requirements for safety-related structures at the BLN site are met.

Construction Excavation

In BLN COL FSAR Section 2.5.4.5.2.1, the applicant described excavation slopes located at the perimeter of the BLN 3 and 4 foundations, as shown in BLN COL FSAR Figures 2.5-348a and 2.5-348b, respectively. The applicant assigned factors of safety greater than 2.0 to these soil slopes. In RAI 2.5.4-11, the staff asked the applicant to explain the slope analysis method that it used and to provide details of the slope safety factor evaluation. In response to RAI 2.5.4-11, the applicant stated that it used the Method of Slices–Simplified Bishop Method to perform its slope stability analysis. This method compares the shear stress on an assumed failure plane to the shear strength of the material. The applicant performed a total stress analysis, which applied a conservatively selected cohesion value of 500 psf and an angle of friction of 1.6 degrees as the input soil parameters. For the conservative total stress analyses, the applicant computed Factors of Safety of 3 and 2.1 for the 7.62 m (25 ft.) and 10.6 m (35 ft.) failure circle radii used in the stability analyses.

The staff reviewed the applicant's slope stability analysis provided in its response to RAI 2.5.4-11, and concluded that it is acceptable on the basis that the slopes are temporary and that the slopes will only be present during the excavation for the BLN 3 and 4 foundations. In addition, the staff concludes that these slopes, because they are temporary, will not affect the safety of the Seismic Category I (safety-related) structures at the BLN site.

In BLN COL FSAR Section 2.5.4.5.2.1, the applicant explained that rock surrounding the BLN 3 and 4 foundations, at the base of the foundations, will be excavated unsupported with an inclination of 85 degrees from horizontal. The applicant indicated that bedding plane failure of the unsupported rock will not occur based on Hoek-Brown evaluation properties and an average assumed interface friction value of 35 degrees. In RAI 2.5.4-12, the staff asked the applicant to provide its rationale for assuming an average interface friction value of 35 degrees and to provide further justification of its conclusion that "bedding plane failure is not a viable failure mode."

In response to RAI 2.5.4-12, the applicant stated that the 35-degree interface friction value is a conservatively-skewed average based on data sets reported in the literature that range in value between 33 degrees and 54.5 degrees, for limestone, and have a lower bound value of 46 degrees. The applicant considered its 35 degree average to be conservative. The applicant compared the literature-reported basal friction values to those encountered in recovered core borings and concluded that the friction angles based on the actual core borings are much higher due to the surface roughness in the limestone beneath the BLN site. The applicant stated this analysis as further justification that its use of literature-reported basal friction values is adequate and conservative for the BLN site. Finally, the applicant noted that the bedding plane surfaces of the Stones River group limestone dip at much lower angles (15 and 17 degrees) than the assumed basal friction angle of 35 degrees. Therefore, the applicant concluded that sliding along the bedding planes is not a failure mode that will affect the unsupported excavated rock adjacent to the BLN 3 and 4 foundations.

Based on its review of the applicant's response to RAI 2.5.4-12, the staff concurs with the applicant's selection of the 35 degree friction angle based on the fact that it represents a conservative value for the Stones River Group limestone that would typically be more resistant to sliding and have a higher frictional resistance, and therefore, a higher friction angle. The staff concurs with the applicant's conclusion that bedding plane failure should not affect unsupported rock excavations near the foundation based on the fact that the conservatively assumed friction angle of 35 degrees is much higher than the 15 to 17 angles of the bedding plane surfaces. Therefore, the staff concludes that the applicant adequately justified that unsupported excavated rock at the foundation excavation level will not affect the safety and stability of BLN 3 and 4 safety-related structures.

Backfill Material

In BLN COL FSAR Section 2.5.4.5.4, the applicant indicated it plans to use lean concrete in the backfill material that will be placed between the edge of the nuclear island concrete basemats and the excavated rock surface surrounding the foundations for BLN 3 and 4. In RAI 2.5.4-13, the staff asked the applicant to specify the strength of the concrete that will be used in the lean concrete backfill material. In its response to RAI 2.5.4-13, the applicant stated that the required strength for lean non-structural concrete is 17.4 MPa, or 2,500 psi and that this is the same value that will be applied to the space between the excavated rock and the concrete basemat for BLN 3 and 4. The applicant further stated the required concrete values are also discussed in BLN COL FSAR Sections 2.5.4.10.1 and 2.5.7. Based on its review of RAI 2.5.4-13, the staff concludes that the applicant adequately addressed the staff's request and specified the strength of the concrete that will be used as backfill material at the BLN site.

BLN COL FSAR Section 2.5.4.5.4 also states that backfill soil will be placed adjacent to the exterior walls of the BLN 3 and 4 nuclear islands. In RAI 2.5.4-14, the staff asked the applicant to evaluate additional compaction-induced loading that may influence the exterior walls of the nuclear island. In addition, the staff asked the applicant to explain why this additional loading is not included as part of the ITAAC to confirm that the in-situ properties of the backfill material are acceptable after compaction. In its response to RAI 2.5.4-14, the applicant stated that it considered the additional loads caused by compaction as a function of: (1) the weight of the compactor; (2) the compaction type (static or vibratory); (3) the distance that the compactor is operated from the wall; and (4) the soil types. Due to the granular nature of the backfill materials, the applicant concluded that the self propelled single-drum vibrator roller is the most appropriate compactor to use. The applicant compared two methods for calculating lateral earth pressures (the NAVFAC DM 7.2 and Duncan methods) and determined that it preferred the NAVFAC DM 7.2 because this method yields slightly higher pressures at the same distance from the wall. The applicant also compared stresses at the same depth, operating at varying distances from the wall, to the stress calculated using the static at-rest earth pressure calculated from BLN COL FSAR Figure 2.5-360. In conclusion, the applicant explained that the requirement for compaction control is designed such that the compacted soil achieves the predicted engineering properties.

Based on its review of the applicant's response to RAI 2.5.4-14, the staff concurs with the applicant that, since the compactor will be kept at least 1.5 m (5 ft.) from the wall that the additional stress will be negligible. The staff also agrees with the applicant's evaluation of the induced load from compaction near the exterior wall of the nuclear islands and agrees that an ITAAC is not needed for the compaction method. However, the staff concludes that the applicant needs to provide a commitment to ensure that the quality of the fill is sufficient to provide lateral stability to the nuclear island foundation basemat. This is identified as **Open Item 2.5.4-2 and Commitment 2.5.4-1**.

Based on the information provided in BLN COL FSAR Section 2.5.4.5 and the applicant's responses to RAIs 2.5.4-11, 2.5.4-12, 2.5.4-13, and 2.5.4-14, the staff concludes that the applicant provided sufficient information regarding: (1) its plans during the excavation of BLN 3 and 4; (2) the backfill material that will be used as well as its properties; and (3) the stability of temporary slopes. The staff further concludes that resolution of **Open Item 2.5.4-2** and **Commitment 2.5.4-1** will ensure that the quality of the fill is sufficient to provide lateral stability to the nuclear island foundation basemat.

- BLN COL 2.5-7

The NRC staff reviewed BLN COL 2.5-7 related to COL Information Item 2.5-7 included under Section 2.5.4 of the BLN COL FSAR.

BLN COL 2.5-7 requires the applicant to provide a description of the extent of excavations, fills, and slopes for all Seismic Category I structures at the site. In BLN COL FSAR Section 2.5.4.5, the applicant provided descriptions of the excavations, fills, and slopes, including the material properties of the backfill to be used, areal extents and volumetric measurements of the excavations, and plans for stabilizing temporary slopes for excavation and backfill purposes. The staff concludes that the applicant provided sufficient detail in BLN COL FSAR Section 2.5.4.5 to satisfy the information requirements of BLN COL 2.5-7.

- BLN COL 2.5-13

The NRC staff reviewed BLN COL 2.5-13 related to COL Information Item 2.5-13 included under Section 2.5.4 of the BLN COL FSAR.

BLN COL 2.5-13 requires the applicant to describe the subsurface instrumentation that will be used to monitor the foundation performance, including the location of benchmarks to be used in the monitoring program. In BLN COL FSAR Subsection 2.5.4.5.5, the applicant concluded that it has no plans to monitor foundation rebound and heave during the construction of BLN 3 and 4, based on the fact that there was no documented rebound or heave of the foundation following the construction of BLN 1 and 2. The staff concludes that the applicant has adequately addressed the subsurface instrumentation requirements for the BLN 3 and 4 site, and since heave and rebound are not anticipated, BLN COL 2.5-13 does not apply to this site.

2.5.4.4.6 Groundwater Conditions

In BLN COL FSAR Section 2.5.4.6, the applicant described the groundwater conditions and the piezometric pressures as they affect the loading and stability of foundation materials at the BLN site. The applicant discussed its plans for dewatering during construction as well as groundwater control throughout the life of the plant.

The staff focused its review of BLN COL FSAR Section 2.5.4.6 on the applicant's records of the historic fluctuations of groundwater at the site as obtained from the monitoring of local wells and by the analysis of piezometer and permeability data from tests that the applicant conducted at the site. The staff also reviewed the applicant's dewatering plans for BLN 3 and 4 construction and post-construction phases.

In RAI 2.5.4-15, the staff asked the applicant to provide the following: (1) a detailed dewatering plan for the BLN COL site; (2) an explanation of the water level reduction effort, and why the applicant described it as "slight;" and (3) evidence that the reduction in the perched water table will have only a minimum impact on the settlement of the adjacent ground surface during the construction and post-construction periods. In response to RAI 2.5.4-15, the applicant described the dewatering plan for the upper-soil portion of the excavation, including the use of a perimeter drainage ditch at the base of the soil slope, and the use of sump pits to remove water from the perimeter ditch using pumps at predetermined locations. For the excavation below the bedrock level, the applicant proposed the use of local ditching and sump pits to intercept seepage from the exposed bedrock face joints, fractures and bedding planes. The applicant explained that it used the term "slight" to refer to its water level reduction efforts because the soils and rock at the BLN site are not favorable for holding water, therefore, efforts to remove water will be minimal. The applicant based its assumption on experiences during the BLN 1 and 2 excavations and stated that the conditions at BLN 3 and 4 mimic those for BLN 1 and 2. Finally, the applicant stated that it incorrectly referred to "perched water" in BLN COL FSAR Section 2.5.4.6 when it was describing the "epikarst aquifer." Therefore, the applicant made the appropriate changes to the incorrect reference.

Based on its review of the applicant's response to RAI 2.5.4-15, the staff finds the applicant's basic dewatering plan acceptable based on the assumption that groundwater conditions for BLN 3 and 4 will not vary significantly from those encountered during the BLN 1 and 2 excavations. In addition, the staff concurs with the applicant that the dewatering effort is probably not significant at the BLN site based on the poor water-bearing characteristics of the soils and rock at the BLN site. The staff also concurs with the applicant's conclusion that the water level change in the "epikarst aquifer" will have a minimum impact on the settlement during and after the construction period. The staff concludes that the applicant has adequately addressed the information requested in RAI 2.5.4-15, and provided an acceptable overview of its assessment of the site groundwater conditions and its construction dewatering plans.

- BLN COL 2.5-8

The NRC staff reviewed BLN COL 2.5-8 related to COL Information Item 2.5-8 included under Section 2.5.4 of the BLN COL FSAR.

BLN COL 2.5-8 requires that the applicant provide information on the relationship between the groundwater conditions and the foundation stability at the site. In BLN COL FSAR Sections 2.5.4.5.2.2 and 2.5.4.6, the applicant indicated that groundwater may flow into the site excavation via isolated water pockets; however, the applicant anticipated that this water flow can be managed by pumping from sump pits at the low points of the excavation. In addition, the applicant indicated that the argillaceous and micritic limestone rock, at the foundation level, is not susceptible to degradation when exposed to water. The staff concludes that the applicant provided sufficient detail in BLN COL FSAR Section 2.5.4.6, to satisfy the information requirements of BLN COL 2.5-8.

2.5.4.4.7 Response of Soil and Rock to Dynamic Loading

In BLN COL FSAR Section 2.5.4.7, the applicant described the response of soils and rocks at the BLN site to dynamic loading. The applicant included the results of laboratory and field tests in this section, which it conducted to determine the properties of the site materials under dynamic loading conditions. The staff focused its review of BLN COL FSAR Section 2.5.4.7 on the applicant's results from laboratory and field testing in order to determine if they adequately define the mean material properties and their variability. The staff also reviewed the applicant's description of the effects of past earthquakes on the site soils and rocks.

In RAI 2.5.4-4, the staff asked the applicant to explain how the irregularity of the rock surface beneath the foundation compares to the uniformity criteria presented in the AP1000 DCD. In response to RAI 2.5.4-4, the applicant provided the following three uniformity criteria that are implicitly addressed in the AP1000 DCD for the upper 36.5 m (120 ft.) of material below finished grade of the nuclear island footprints:

1) The depth to soil/rock layer interfaces in the 36.5 m (120 ft.) depth profile should deviate no more than 5 percent from the average interface depth. If a deviation greater than 5 percent occurs, then the profile should be modified by adding additional layers/interfaces, or additional borings (to provide better resolution of the average layer interface depth(s)).

2) For layers exhibiting low strain Vs greater than or equal to 2,500 fps, the layer should have approximately uniform thicknesses and should have a dip no greater than 20 degrees, and the Vs within any layer should not vary from the average by more than 20 percent.

3) For a layer with a low strain Vs less than 2,500 fps, the layer should have approximately uniform thickness and should have a dip no greater than 20 degrees, and the Vs within the layer should not vary from the average by more than 10 percent.

The applicant stated that because the BLN 3 and 4 nuclear island basemats are to be supported on the fresh to slightly weathered, competent middle Stones River Group limestone, the weathered rock above the competent bedrock layer will be removed from the foundation footprint. The applicant further stated that the competent limestone bedrock Vs and the uniform thickness of the bedrock are within the appropriate DCD criteria and that the BLN site meets the criteria of the AP1000 DCD. In addition, the applicant reiterated the grouting and concrete dental repair procedures that it described in BLN COL FSAR Section 2.5.4.12.3 to treat any potential localized, weathered features that may extend beneath the BLN 3 and 4 excavations.

Based on its review of the applicant's response to RAI 2.5.4-4, the applicant's assurance that the BLN site will conform to the uniformity criteria of the AP1000 DCD, and the applicant's planned procedures to treat any potential localized, weathering-related features, the staff concludes that the applicant has adequately addressed the potential for the site to meet the criteria outlined in the AP1000 DCD.

In RAI 2.5.4-5, the staff asked the applicant to explain if the subsurface lateral variability at the BLN site meets the minimum requirements of the AP1000 DCD. In addition, the staff asked the applicant to clarify if the dipping geologic boundaries, beneath the foundation basemat, will affect the surface ground motion estimates. In response to RAI 2.5.4-5, the applicant stated that the lateral variability of the BLN site meets the minimum requirement of the AP1000 DCD, citing the small difference in the Vs and the shallow dip of the subsurface materials as supporting evidence. The applicant added that the leveling concrete to be used beneath the BLN Unit 3 foundation will have a Vs comparable to the lower Vs of the Stones River Group

Unit C. The applicant also stated that any amplification of the lower-velocity Unit C portion of the basemat will occur at frequencies greater than the highest frequency considered in the PSHA. Finally, the applicant noted that dipping strata beneath BLN Unit 3 and the impedance contrast between Units C and D will act to defocus any seismic forces and that this can be demonstrated by applying Snell's law.

Based on the staff's review of the applicant's response to RAI 2.5.4-5, which included its evaluation of the site variability with respect to the limits outlined in the AP1000 DCD and its update of BLN COL FSAR Section 2.5.4.7.4 with the information provided in its RAI response, the staff concurs with the applicant that the BLN site variability is within the design limits described in Revision 17 to the AP1000 DCD. The staff also concludes that the difference in Vs between dipping Layers C and D, beneath BLN Unit 3, will not cause seismic force concentration due to the plano-concave nature of the velocity structure present and the divergence created by inclination of Units C and D.

In BLN COL FSAR Section 2.5.4.10.4.2, the applicant stated that differential settlement is not an issue at the BLN site because the site meets the criteria for a uniform site, as outlined in AP1000 DCD Table 2-1. In RAI 2.5.4-20, the staff asked the applicant to explain how the BLN site can meet the uniformity criteria given that lithologic Subunits C and D, underlying BLN Unit 3, show a significant difference in Vs. In response to RAI 2.5.4-20, the applicant listed three uniformity criteria from Revision 17 to the AP1000 DCD, which were also referenced above as part of the applicant's response to RAI 2.5.4-4. With respect to Criterion 1, the applicant explained that the variation in depth to the interface between Subunits C and D, below the nuclear island basemats, exceeds 5 percent of the average depth to the interface. With respect to Criterion 2, the applicant stated that the interface between the middle Stones River Group Subunits C and D, and between the other middle Stones River Group subunits, exhibits an average dip of 17 degrees, which is less than the 20 degree maximum dip criteria.

Based on its review of the response to RAI 2.5.4-20, the staff concludes that the applicant provided adequate information to ensure that BLN 3 and 4, and the underlying geologic properties, meet the uniformity criteria defined in Revision 17 to the AP1000 DCD and, therefore, do not represent an inconsistency with the design criteria.

Based on its review of BLN COL FSAR Section 2.5.4.4.7, and the applicant's responses to RAIs 2.5.4-4, 2.5.4-5, and 2.5.4-20, the staff concludes that the applicant provided sufficient site-specific laboratory data to support its determination of the site response due to dynamic loading conditions.

2.5.4.4.8 Liquefaction Potential

In BLN COL FSAR Section 2.5.4.8, the applicant described its assessment of liquefaction potential at the site. The applicant based its assessment on geologic data and soil-texture properties. Based on the screening process the applicant concluded that there is very low liquefaction susceptibility associated with the BLN site residual soils.

The staff focused its review of BLN COL FSAR Section 2.5.4.8 on the results of the applicant's geotechnical investigations including boring logs, laboratory classification test data and soil profiles used to determine if any of the site soils are susceptible to liquefaction. The staff also reviewed the results of in-situ tests such as the standard penetration tests and the density and strength data obtained from undisturbed samples obtained in exploration borings are examined and, when appropriate, related to the liquefaction potential of in-situ soils.

In RAI 2.5.4-17, the staff asked the applicant to explain the reason for not using the SPT data obtained from the soil investigations to perform the liquefaction potential assessment at the BLN 3 and 4 site, to provide the adjusted N data from the SPT test for the BLN site, to justify that the liquefaction threshold criteria is satisfied from the BLN site data, including the Seismic Category I structures and other non-safety related construction sites, and to describe if the Vs was used as a threshold to evaluate the liquefaction potential at the BLN site.

In response to RAI 2.5.4-17, the applicant stated that the use of SPT data to evaluate the liquefaction threshold criteria is not appropriate for the fine-grained soils at the site and the empirical correlation methods using the SPT-based approach of Youd (1991) are specifically restricted to non-cohesive granular soils, and no industry accepted SPT data base has been developed for cohesive soils, such as soils encountered at this site. Therefore, the applicant performed two independent screening analyses to evaluate the liquefaction potential of the site both of which concluded that there is a low susceptibility or potential for liquefaction to occur at the site. The applicant explained that because SPT test results were not used in evaluating liquefaction potential, it did not present adjusted N value and did not use Vs, as measured from seismic CPTs and P-S suspension logging surveys, to evaluate the liquefaction potential at the BLN site.

Based on its review of the response to RAI 2.5.4-17, the staff agrees with the applicant's conclusion that the liquefaction susceptibility of soil materials at the site is low and that the screening of soils located outside of the safety-related structures is acceptable. In addition, the staff concurs with the applicant's conclusion that since the soil at the site is predominately categorized as fine grained, SPT data and Vs data were not needed to evaluate the liquefaction susceptibility of soil materials at the BLN site.

- BLN COL 2.5-9

The NRC staff reviewed BLN COL 2.5-9 related to COL Information Item 2.5-9 included under Section 2.5.4 of the BLN COL FSAR.

BLN COL 2.5-9 states that the applicant must demonstrate that the potential for liquefaction at the site is negligible. In BLN COL FSAR Section 2.5.4.8, the applicant described the assessment of the liquefaction potential at the site through the use of boring logs, geologic data and soil-texture properties. The applicant concluded that the soils, including the native soils and the fill adjacent to the nuclear island, in the BLN site area had a very low susceptibility for liquefaction. Based on the applicant's assessment of the soils at the BLN site, and the conclusion that the soils show a low susceptibility to liquefaction, the staff concludes that the applicant has adequately demonstrated that the potential for liquefaction at the BLN site is negligible and therefore has addressed the information requirements of BLN COL 2.5-9.

After review of this section and responses to corresponding RAIs, the staff concurs with the applicant on its conclusion on liquefaction susceptibility for safety-related structures and non-safety-related structures.

2.5.4.4.9 Earthquake Site Characteristics

BLN COL FSAR Section 2.5.4.9 describes the performance-based approach used by the applicant to determine the site-specific GMRS. This approach is also described in FSAR

Section 2.5.2.6. Section 2.5.2.4.6 of this SER provides the staff's evaluation of the site-specific GMRS, including the performance-based approach.

2.5.4.4.10 Static Stability

In BLN COL FSAR Section 2.5.4.10, the applicant presented the results of investigations and analyses conducted to determine foundation material stability, deformation and settlement under static conditions.

The staff focused its review of BLN COL FSAR Section 2.5.4.10 on methods of analyses used by the applicant to determine bearing capacity, settlement, differential settlement, resistance to sliding, lateral earth pressure and rebound potential.

Bearing Capacity

In RAI 2.5.4-18, the staff asked the applicant to explain whether the geometric correction factors were incorporated into the use of the Method 1 approach for the bearing capacity evaluation. If not, the applicant should update the bearing capacity values for the Method 1 approach with the correction factors, and discuss whether or not the effect of the eccentricity of the loading applied to the footing was considered for the bearing capacity investigation, and if it was not, to update the bearing capacity analysis with the eccentric loading consideration. In response to RAI 2.5.4-18, the applicant stated that the correction factors used for the calculation of the bearing capacity are provided in Table 6-1 of EM1110-1-2908. The applicant noted that, since the value of cohesion for the rock was taken as 0, the only correction factor used was Ny; using an equivalent length-to-width (L/B) ratio of 2, the corresponding correction factor is 0.9. The applicant also updated the BLN COL FSAR with the result of the static ultimate bearing pressure based on Method 1. The applicant stated that it considered the eccentric loading effect by computing the ultimate bearing capacity using a reduced footprint caused by transient overturning loading events (creating maximum stress at the edge of the reduced area). Then, the applicant compared this ultimate bearing capacity with the design bearing capacity. Based on its calculation, the reduced footprint is 51.7 by 146.7 ft., which yields L/B of 3 with a shape correction factor of 0.917. The ultimate bearing capacity is 368,000 psf, in comparison to the design value of 35,000 psf.

Based on the response to RAI 2.5.4-18, the staff agrees with the applicant that the assumptions used in the calculations and the updated values are acceptable. The staff concurs with the applicant's changes related to the bearing capacity, based on the Method 1, and with the applicant's explanation for the change. The staff also concurs with the applicant's consideration of eccentric loading on the ultimate bearing capacity and its comparison with the design capacity value. The staff notes that the RAI 2.5.4-18 includes a commitment by the applicant to make a future revision to the FSAR to include an explanation of Method 1. This is **Confirmatory Item 2.5.4-2**. The staff concludes that the applicant provided adequate information to ensure that the values presented in BLN COL FSAR Section 2.5.4.10 and in response to RAI 2.5.4-18, are appropriate for determining the bearing capacity using the Method 1 approach.

Settlement

In RAI 2.5.4-19, the staff asked the applicant to provide more details on the settlement calculations from each method, and compare the results obtained from each method. In response to RAI 2.5.4-19, the applicant stated that the estimated settlement was calculated for both units using three different equations with four common assumptions. The applicant computed the compression of each layer as the result of dividing the applied stress increment by the elastic modulus to obtain an incremental strain, then multiplying the incremental strain by the thickness. The applicant then summed the results to obtain the total settlement. The applicant used the lower bound modulus value for the argillaceous limestone, the weaker of the two rock types, to calculate settlements. Using the reduced modulus values of the in-situ rock, which are lower than those of the fill concrete, provides additional conservatism for the settlement estimate. The applicant also stated that settlement was evaluated at five locations for each method.

Based on its review of the response to RAI 2.5.4-19, the staff considers the applicant's assumptions and the methods used in calculating settlements to be acceptable. The staff concludes that the applicant incorporated appropriate values and methods for calculating total settlement at the BLN site.

In RAI 2.5.4-21, the staff asked the applicant to include the hydrostatic pressure in passive or at-rest earth pressure evaluations and to revise the contents of BLN COL FSAR Figures 2.5-360 and 2.5-361 accordingly. In response to RAI 2.5.4-21, the applicant stated that the inclusion of the hydrostatic pressure in the at-rest and passive earth pressure diagrams is appropriate for the analysis of the nuclear island basement walls and that FSAR Figures 2.5.4-360 and 2.5.4-361 will be revised to incorporate the hydrostatic pressure. Based on its review of the applicant's response to RAI 2.5.4-21, the staff agrees with the applicant's conclusion that the inclusion of hydrostatic pressure is appropriate. The staff concurs with the applicant's proposed changes to FSAR Figures 2.5.4-360 and 2.5.4-361, including the incorporation of hydrostatic pressure in the earth pressure diagrams.

Upon reviewing BLN COL FSAR Section 2.5.4.4.10 and the applicant's responses to RAIs 2.5.4-18, 2.5.4-19 and 2.5.4-21, the staff concludes that the applicant provided sufficient information to define the bearing capacity and settlement potential present at the BLN 3 and 4 site.

- BLN COL 2.5-10

The NRC staff reviewed BLN COL 2.5-10 related to COL Information Item 2.5-10 included under Section 2.5.4 of the BLN COL FSAR.

BLN COL 2.5-10 requires the applicant verify that the maximum bearing reaction is greater than 1,675 kPa (35,000 psf) under all combined loads. In BLN COL FSAR Section 2.5.4.10.1, the applicant stated that, using the lower bound rock properties and two different methods, the calculated bearing capacity was between 12,000 and 11,300 kPa (251,000 and 236,000 psf), both of which are in excess of the 1,675 kPa (35,000 psf) minimum design value. Based on the applicant's reported bearing capacities exceeding the design value, the staff concludes that the applicant has adequately verified that the maximum bearing reaction is greater than 1,675 kPa (35,000 psf) under all combined loads, thereby meeting the requirements of BLN COL 2.5-10.

- BLN COL 2.5-11

The NRC staff reviewed BLN COL 2.5-11 related to COL Information Item 2.5-11 included under Section 2.5.4 of the BLN COL FSAR.

BLN COL 2.5-11 requires the applicant to describe the method used to determine the static and dynamic lateral earth pressures as well as the hydrostatic groundwater pressures at the site. BLN COL FSAR Section 2.5.4.10.5 describes the information used to develop the lateral and hydrostatic pressures at the BLN site. These methods included assumptions of compaction and the use of an at-rest earth pressure coefficient in the calculations. The applicant used the Rankine earth pressure theory to compute the ultimate earth pressures. FSAR Figure 2.5-360 shows the distribution of the earth pressures in the soil backfill and the hydrostatic pressures below the water table. Based on the applicant's descriptions of the method of calculations used and the lateral and hydrostatic pressures presented in BLN COL FSAR Figure 2.5-360, the staff concludes that the applicant provided sufficient information regarding the methods that it used and the results of the earth pressure calculations to satisfy the requirements of BLN COL 2.5-11.

- BLN COL 2.5-12

The NRC staff reviewed BLN COL 2.5-12 related to COL Information Item 2.5-12 included under Section 2.5.4 of the BLN COL FSAR.

BLN COL 2.5-12 requires the applicant to describe the soil characteristics, rebound, settlement, and differential settlement at the site. BLN COL FSAR Section 2.5.4.10.4 describes the settlement calculations completed for BLN 3 and 4. The applicant stated that since the BLN 3 and 4 nuclear island structures will be founded on rock and fill concrete, total settlement will be minimal and differential settlement will not be a factor. Based on the descriptions provided, including the total expected settlement of less than 0.508 cm (0.20 in) and the fact that differential settlement was not a factor, the staff concludes that the applicant has adequately described the soil characteristics, rebound, and total and differential settlement at the BLN site to satisfy the criteria of BLN COL 2.5-12.

- BLN COL 2.5-16

The NRC staff reviewed BLN COL 2.5-16 related to COL Information Item 2.5-16 included under Section 2.5.4 of the BLN COL FSAR.

BLN COL 2.5-16 requires the applicant to assess the short-term elastic and long-term heave and consolidation settlement for soil sites. The applicant stated that the BLN 3 and 4 site is not a soil site. Therefore, the staff concludes that BLN COL 2.5-16 does not apply to BLN 3 and 4.

2.5.4.4.11 Design Criteria

The staff focused its review of BLN COL FSAR Section 2.5.4.11 on FSAR Table 2.0-201, in which the applicant compared the BLN site-specific characteristics such as allowable bearing capacities, shear wave velocities, properties of underlying materials and liquefaction potential, among others, to DCD site parameter criteria. In addition, the staff reviewed design criteria addressed in relevant sections of the BLN FSAR, as directed by the applicant in FSAR Section 2.5.4.11, and the staff reviewed the applicant's validation and verification techniques for confirming computer generated data used in its analyses.

The staff concludes that that the design criteria for the BLN site is sufficiently described by the applicant in BLN COL FSAR Section 2.5.4.11, in Table 2.0-201, and in the previously discussed subsections in FSAR Section 2.5.4. The staff further concludes that this information provides adequate assurance that the site-specific safety-related design values for allowable static and dynamic bearing capacity, Vs, lateral variability, soil angle of internal friction and liquefaction potential are within the AP1000 DCD site parameters.

2.5.4.4.12 Techniques to Improve Subsurface Conditions

In BLN COL FSAR Section 2.5.4.12, the applicant stated that the BLN 3 and 4 safety-related structures will be founded on good quality, competent bedrock that should only require minor repairs at the surface. The applicant will implement the following improvement techniques if needed: (1) mechanical cleanup of loose and broken rock leftover from the excavation; (2) grouting and concrete dental repair of weathered joints and fractures, and when needed to account for blasting damage; and (3) rock bolting or anchoring, if needed, to stabilize large blocks of loose rock.

In RAI 2.5.4-8, the staff asked the applicant to explain whether a visual inspection during excavation, as indicated in the BLN COL FSAR, can guarantee that no large-scale cavities exist beneath the excavation depth. Also, the staff asked the applicant to provide a detailed description of its grouting program, including any specifications, the cavity cleaning process and if the grouting procedure should be included in the ITAAC or post-COL activities. Furthermore, the staff asked the applicant to explain if there were any special criteria to be used for specification of dental grouting; and to clarify the basis for stating “to clean all cavities down to the minimum depth of two times the width,” and to provide more detail on the “wedging effect” described in the BLN COL FSAR.

In its response the applicant explained that, if there is no surface expression of the cavity, a visual inspection alone cannot determine the presence or absence of a subsurface cavity. The applicant further explained that the examination of the exposed excavation surface consists of visual examinations and involves geophysical tools such as test holes, ground penetrating radar, electricity resistivity and microgravity surveys. The applicant also referred its response to RAI 2.5.4-1, which states that the potential dimensions of the subsurface cavities is expected to be small. The applicant then described the grouting program in detail and explained that the grouting program would be similar to those used during the construction of BLN 1 and 2 and will be used as part of the foundation treatment if there is any indication of open seams, joints or cavities. The applicant noted that features treated with dental concrete are localized, unconnected areas with obvious physical edges. The applicant also explained that cleaning the fractures and joints down to twice the width is a normal engineering practice for rock foundations. The applicant stated that the wedging effect refers to creating a plug in a sloping or vertical opening such that the opening narrows with depth thereby preventing the plug from sliding down.

Based on its review of the applicant’s response to RAI 2.5.4-8, the staff agrees with the applicant’s conclusion that the grouting program does not meet the criteria for an ITAAC, but should be included in the NRC construction inspection portion of the post-COL activities. However, the staff has concerns regarding the grouting program because grouting pressure is dependent on the depth of a crack to be filled. A 34 kPa (5 psi) pressure, as indicated by the applicant, may not be sufficient to ensure a quality grouting (Army Corps of Engineers, 1984). Therefore, the need for further explanation of the grouting procedure proposed by the applicant is identified as **Open Item 2.5.4-3**. In addition, the staff agrees with the applicant’s explanation on the limitation of visual inspection and the necessity for geophysical methods in detecting subsurface cavities. Therefore, the staff concludes that a commitment should be made by the applicant in the FSAR to apply geophysical methods including resistivity, ground penetrating radar, or other exploratory methods to ensure that no cavities are present beneath safety-related structures, following excavation. This is **Open Item 2.5.4-4 and Commitment 2.5.4-2**.

In RAI 2.5.4-9, the staff asked the applicant to provide a detailed description of its blasting program and how the applicant plans to ensure that any unnecessary fracturing of the in-situ rock will not occur. In addition, the staff asked the applicant to explain why this program was not included as part of the ITAAC process. In response to RAI 2.5.4-9, the applicant indicated that although no blasting program or plan can ensure that unnecessary fracturing of the in-situ rock will not occur, the applicant provided the following standard language to describe blasting performance measures:

> All blasting before concrete placement shall be carefully done using the smallest practical charges to avoid opening joints, bedding planes or seams, or otherwise disturbing adjacent rock. Blasting to form a vertical face shall be done by pre-split or cushion blasting methods to produce a face without large irregularities. Procedures for blasting shall be modified as work progresses to minimize damage to rock left in place.

In addition, the applicant stated that techniques for observation and inspection of the foundation materials will be implemented for judgment towards the repair or treatment of areas that may be damaged. Although the analyses for foundation bearing capacity and settlement already account for some potential surface damage to the rock from blasting, the applicant stated that detailed geologic mapping would be performed to identify areas for treatment and to document the present conditions of the soil. Finally, the applicant stated that the blasting program does not meet the criteria for an ITAAC, and therefore, was not proposed.

Based on its review of the applicant’s response to RAI 2.5.4-9, the staff agrees with the applicant’s conclusion that the blasting program at the site does not meet the criteria for an ITAAC. However the staff concludes that a commitment should be made by the applicant, in the FSAR, to ensure that there is no unnecessary fracturing of the in-situ rock due to blasting damage and that any necessary post-blasting remediation will take place. This is **Open Item 2.5.4-5 and Commitment 2.5.4-3**.

In RAI 02.5.4-10, the staff requested that the applicant describe the criteria to be used for placement of fill concrete, including whether the Vs (stiffness and strength) will be equivalent to that of the hard rock and whether the fill concrete would be placed in lifts so as not to adversely influence its in-situ velocities. In response to RAI 2.5.4-10, the applicant explained that the fill concrete will serve to infill possible irregularities in the prepared sound rock surface to form a stable and level surface for construction of a reactor basemat. BLN FSAR Figures 2.5-348a and 2.5-348b illustrate the fill concrete placement, which the applicant will accomplish using the appropriate industry standards and laboratory and/or field tests to verify the average design Vs of the placed fill concrete. The applicant also stated that the Vs for the fill concrete should be in the range consistent with the foundation material of the middle Stone River Group Units A and C. In addition, the applicant stated that the concrete will be placed in controlled and tested layers that will result in a relatively uniform concrete section that does not adversely affect the final Vs or form layers with potentially significant lower Vs.

Based on the information presented in response to RAI 2.5.4-10, the staff agrees with the applicant’s conclusion that the mix design and placement criteria will follow American Concrete Institute (ACI) 38-02 and standard industry practice to provide a uniform concrete section that exhibits in-situ shear wave velocities consistent with the underlying bedrock. The staff also agrees with the applicant that the proposed changes to the BLN COL FSAR are acceptable to define the criteria to be used for the placement of fill concrete in the BLN site area. Finally, the staff agrees with the applicant's specification of Vs and the extent of fill concrete.

The staff focused its review of BLN COL FSAR Section 2.5.4.12 on applicant's specifications and techniques for performance and quality control for such soil improvement activities. The staff concludes that the methods described for subsurface improvements are acceptable to satisfy the requirements of 10 CFR Part 50, pending resolution of **Confimatory Item 2.5.4-2, and Open Items 2.5.4-1 through 2.5.4-5.** Furthermore, the staff concludes that **Commitments 2.5.4-1 through 2.5.4-3** will ensure that proper measures are taken during post-excavation to identify any unknown dissolution cavities and that the bedrock foundation was not damaged during blasting procedures.

2.5.4.4.13 Staff Conclusions Regarding Stability of Subsurface Materials and Foundations

Based on its review of BLN COL FSAR Section 2.5.4 and the applicant's responses to RAIs, the staff concludes that the applicant has adequately determined the engineering properties of the soil and rock underlying the COL site through its field and laboratory investigations, pending the resolution of the previously identified open items and commitments to be made by the applicant. In addition, the applicant used the latest field and laboratory methods, in accordance with RG 1.132, RG 1.138, and RG 1.198, to determine the required site-specific engineering properties for the BLN site and to ensure that those properties meet the design criteria outlined in the AP1000 DCD. Accordingly, the staff concludes that the applicant performed sufficient field investigations and laboratory testing to determine the overall subsurface profile and the properties of the soil and rock underlying the COL site. Specifically, the staff concludes that the applicant adequately determined: (1) the soil and rock dynamic properties through its field investigations and laboratory tests; (2) the response of the soil and rock to dynamic loading; and (3) the liquefaction potential of the soils.

The applicant presented significant evidence to ensure that the materials beneath the BLN 3 and 4 foundation basements will provide needed stability to support safety-related structures of the AP1000 design. Based on its review of the applicant's response to the RAIs and additional evidence presented during the site audit, the staff concurs with the applicant on the overall geotechnical characterization of subsurface materials, pending the resolution of the identified open items and successful implementation of the commitments made by the applicant.

As set forth above, the applicant presented and substantiated the necessary information to establish the geotechnical engineering characteristics of the BLN site. The staff reviewed the information provided and, for the reasons given above, concludes that the applicant performed sufficient investigations at the site to justify the soil and rock characteristics used in the AP1000 design. The staff also concludes that the design analyses contain adequate margins of safety for construction and operation of the nuclear power plant and meet the requirements of 10 CFR Part 50, 10 CFR Part 52, and 10 CFR 100.23.

This addresses BLN COL 2.5-5, BLN COL 2.5-6, BLN COL 2.5-7, BLN COL 2.5-8, BLN COL 2.5-9, BLN COL 2.5-10, BLN COL 2.5-11, BLN COL 2.5-12, BLN COL 2.5-13, and BLN COL 2.5-16. In conclusion, the applicant has provided sufficient information for satisfying 10 CFR Part 100.

2.5.4.5 Post Combined License Activities

The following items were identified as the responsibility of the COL license holder:

- Proposed Commitment 2.5.1-1 involving the applicant's commitment to perform geologic mapping and geophysical exploration during excavation as identified in Section 2.5.1.5 of this SER.

A post excavation program should be implemented to explore, monitor and remediate any solution cavities that will adversely impact a prospective reactor. Specifically, this program should include: (1) exploration of subsurface cavitys; (2) grouting of cracks, cavities and fissures; and (3) ensuring the quality of the backfill beneath or on the side of the basemat. Therefore, the staff proposes that the applicant commit, in its FSAR, to the following post-COL activities:

- **Commitment 2.5.4-1:** The applicant should commit to ensure that the backfill material has a similar shear wave velocity (Vs) and bearing capacity to the Stones River Group (RAIs 2.5.4-10 and 2.5.4-14) and that the impaction-induced load on the foundation exterior wall is negligible (RAI 2.5.4-14).

- **Commitment 2.5.4-2:** The applicant should commit to apply various geophysical methods including resistivity, ground penetrating radar, or other exploratory methods to ensure that no cavities are present beneath safety-related structures, following excavation, that pose a threat to the reactor safety (RAIs 2.5.4-1, 2.5.4-4 and 2.5.4-8).

- **Commitment 2.5.4-3:** The applicant should commit to monitor, modify and remediate bedrock (including the proper grouting of joints, cracks and cavities) following its blasting program, to ensure the integrity of the bedrock (RAIs 2.5.4-8 and 2.5.4-9).

The staff concludes that the implementation of a post-excavation program, including the above commitments, will ensure stability of the subsurface materials, and therefore, the safety of prospective reactors. These commitments should be properly addressed by the applicant in the BLN COL FSAR, to ensure their implementation.

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 the stability of subsurface materials and foundations, and with the exception of open and confirmatory items there is no outstanding information expected to be addressed in the BLN COL FSAR related to this subsection.

The Westinghouse application to amend Appendix D to 10 CFR Part 52 includes changes to Section 2.5.4 of the AP1000 DCD, as stated in Revision 17 of the AP1000 DCD. The staff is reviewing this information on Docket Number 52-006. The results of the NRC staff's technical evaluation of the information incorporated by reference in the BLN COL FSAR will be documented in a supplement to NUREG-1793. The supplement to NUREG-1793 is not yet complete, and this is being tracked as part of Open Item 1-1. The staff will update Section 2.5.4 of this SER to reflect the final disposition of the DC amendment application.

- As a result of the open and confirmatory items, the staff is unable to finalize its conclusions on the stability of subsurface materials and foundations in accordance with the applicable requirements of 10 CFR Part 50, 10 CFR Part 52, and 10 CFR Part 100.

2.5.5 Stability of Slopes

2.5.5.1 Introduction

BLN 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 following subjects are evaluated using the applicant's data 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, shafts, pits, trenches, and laboratory tests; (4) properties of borrow material, compaction and excavation specifications; and (5) any additional information requirements prescribed within the "Contents of Application" sections of the applicable subparts to 10 CFR Part 52.

2.5.5.2 Summary of Application

Section 2.5.5 of the BLN COL FSAR incorporates by reference Section 2.5.5 of the AP1000 DCD, Revision 17.

In addition, in BLN COL FSAR, the applicant provided the following:

AP1000 COL Information Items

- BLN COL 2.5-14

The applicant provided additional information in BLN COL 2.5-14 to resolve 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.

- BLN COL 2.5-15

The applicant provided additional information in BLN COL 2.5-15 to resolve 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

BLN COL FSAR Section 2.5.5.2, "Slope Characteristics," describes the characteristics of the slopes at the BLN site. The applicant stated that no permanent cut slopes or man-made fill slopes exist that could compromise the operation of the safety-related plant facilities. A height of approximately 4.8 m (16 ft.) and an inclination of 4:1 is the limit for the fill slopes at the perimeter of the fill pad. The applicant also stated that the steepest slope at the southeast pad margin is a 24.3 m (80 ft.) high cut at an inclination of approximately 3:1. The toe of this cutslope is at least 289.5 m (950 ft.) from the BLN Unit 4 turbine building, and 304.8 m (1000 ft.) from the BLN Unit 4 nuclear island. Since the minimum separation distance between the plant and cutslope toe is over 10 times the slope height, the applicant concluded that it provides a substantial safety buffer zone against possible slope failure under dynamic or static loading conditions. Therefore, the applicant concluded that this cut slope does not pose a potential safety hazard to the BLN Unit 4 Seismic Category I Structures.

The applicant referred to BLN COL FSAR Sections 2.5.4.1, 2.5.4.2, and 2.5.4.3, which describe the site investigations and subsurface geotechnical characterization used by the applicant for the slope stability evaluation. The applicant also referred to FSAR Section 2.4.12, which presents a detailed discussion of groundwater conditions, including water levels and in-situ rock mass transmissivity.

2.5.5.2.2 Design Criteria and Analyses

In BLN COL FSAR Section 2.5.5.2, the applicant stated that it did not perform stability analyses at the BLN 3 and 4 site, nor did the applicant identify design/performance criteria because the permanent slopes do not affect the safety of Seismic Category I structures.

2.5.5.2.3 Logs of Borings

BLN COL FSAR Section 2.5.5.3 refers to FSAR Subsections 2.5.4.2 and 2.5.4.3, which present a discussion of the applicant's exploration program, drilling and sampling procedures and boring logs of soil and rock borings in the vicinity of the excavations. The applicant included boring logs, which provide rock stratigraphy, soil and rock engineering classification, groundwater conditions, in-situ rock mass condition and engineering properties, soil in-situ properties (Standard Penetration Test), and laboratory geotechnical index and strength testing (soil and rock).

2.5.5.2.4 Compacted Fill

In BLN COL FSAR Section 2.5.5.4, the applicant stated that it did not identify specific sources of borrow material for the construction of the permanent fill slopes as part of the COL exploration. The applicant also referred to FSAR Section 2.5.4.5 for a discussion of the use of onsite soils for backfill in addition to the Quality Control and QA requirements, which include engineering properties of the soil and rock materials, confirmation by laboratory testing, placement and compaction requirements, field density testing, monitoring, and record keeping.

2.5.5.3 Regulatory Basis

The regulatory basis of the information incorporated by reference is addressed within the FSER related to the DCD.

In addition, the relevant requirements of the Commission regulations for the stability of slopes, and the associated acceptance criteria, 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 as follows:

- 10 CFR 50.55a, "Codes and Standards." This rule requires that SSCs shall be designed, fabricated, erected, constructed, tested, and inspected in accordance with the requirement of applicable codes and standards commensurate with the importance of the safety function to be performed.

- 10 CFR Part 50, Appendix A, GDC 1, "Quality Standards and Records," requires that SSCs important to safety be designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety functions to be performed. It also requires that appropriate records of the design, fabrication, erection, and testing of SSCs important to safety be maintained by or under the control of the nuclear power unit licensee throughout the life of the unit.

- 10 CFR Part 50, Appendix A, GDC 2, "Design Bases for Protection Against Natural Phenomena," 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 A, GDC 44, "Cooling Water," requires that a system be provided with the safety function of transferring the combined heat load from SSCs important to safety to an ultimate heat sink under normal operating and accidental conditions.

- 10 CFR Part 50, Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Processing Plants," establishes QA requirements for the design, construction, and operation of those SSCs of nuclear power plants that prevent or mitigate the consequences of postulated accidents that could cause undue risk to the health and safety of the public.

- 10 CFR Part 50, Appendix S, "Earthquake Engineering Criteria for Nuclear Power Plants," as it applies to the design of nuclear power plant SSCs important to safety to withstand the effects of earthquakes.

- 10 CFR Part 100, "Reactor Site Criteria," provides the criteria, which guide the evaluation of the suitability of proposed sites for nuclear power and testing reactors.

- 10 CFR 100.23, "Geologic and Seismic Criteria," provides the nature of the investigations required to obtain the geologic and seismic data necessary to determine site suitability and identify geologic and seismic factors required to be taken into account in the siting and design of nuclear power plants.

The related acceptance criteria from Section 2.5.5 of NUREG-0800 are as follows:

- Slope Characteristics: In meeting the requirements of 10 CFR Part 50 and 10 CFR Part 100, the discussion of slope characteristics is acceptable if the subsection includes: (1) cross sections and profiles of the slope in sufficient quantity and detail to represent the slope and foundation conditions; (2) a summary and description of static and dynamic properties of the soil and rock comprised by Seismic Category I embankment dams and their foundations, natural and cut slopes, and all soil or rock slopes whose stability would directly or indirectly affect safety-related and Seismic Category I facilities; and (3) a summary and description of groundwater, seepage, and high and low groundwater conditions.

- Design Criteria and Analyses: In meeting the requirements of 10 CFR Part 50 and 10 CFR Part 100, the discussion of design criteria and analyses is acceptable if the criteria for the stability and design of all Seismic Category I slopes are described and valid static and dynamic analyses have been presented to demonstrate that there is an adequate margin of safety.

- Boring Logs: In meeting the requirements of 10 CFR Part 50 and 10 CFR Part 100, the applicant should describe the borings and soil testing carried out for slope stability studies and dam and dike analyses.

- Compacted Fill: In meeting the requirements of 10 CFR Part 50, the applicant should describe the excavation, backfill, and borrow material planned for any dams, dikes, and embankment slopes.

In addition, the geologic characteristics should be consistent with appropriate sections from: RG 1.27, RG 1.28, RG 1.132, RG 1.138, RG 1.198, and RG 1.206.

2.5.5.4 Technical Evaluation

The NRC staff reviewed Section 2.5.5 of the BLN COL FSAR and checked the referenced DCD to ensure that the combination of the DCD and the information in the COL represent the complete scope of information relating to this review topic.[1] The NRC staff's review confirmed that the information contained in the application and incorporated by reference addresses the required information relating to the stability of slopes. Section 2.5.5 of the AP1000 DCD is being reviewed by the staff under Docket Number 52-006. The NRC staff's technical evaluation of the information incorporated by reference related to the stability of slopes will be documented in the staff SER on the DC amendment application for the AP1000 design.

The staff reviewed the information contained in the BLN COL FSAR:

AP1000 COL Information Items

- BLN COL 2.5-14

The NRC staff reviewed BLN COL 2.5-14 related to COL Information Item 2.5-14 included under Section 2.5.5 of the BLN COL FSAR.

- BLN COL 2.5-15

The NRC staff reviewed BLN COL 2.5-15 related to COL Information Item 2.5-15 included under Section 2.5.5 of the BLN COL FSAR.

2.5.5.4.1 Slope Characteristics

BLN COL FSAR Section 2.5.5.1 describes the characteristics of the existing and new slopes, their subsurface condition and impact of the slope instability on the Seismic Category I structures at the BLN 3 and 4 sites. The staff considered the results and interpretation of the borings, CPT, and observation wells conducted by the applicant at the site. Considering the staff's review and the observations during the Site Audit (ML083250530), the staff concludes that the information provided meets the requirements for slope characterization in 10 CFR Part 100. The staff further concludes that the subsurface investigations follow the criteria of RG 1.132, and are therefore acceptable.

2.5.5.4.2 Design Criteria and Analyses

In BLN COL FSAR Section 2.5.5.2, the applicant stated that it did not perform stability analyses, nor did it identify design/performance criteria because the permanent slopes do not affect the safety of Seismic Category I Structures.

The staff agrees that there are no permanent slopes in the site vicinity that will affect safety-related structures at the BLN site; therefore, the staff did not review design/performance criteria for the slope stability.

2.5.5.4.3 Boring Logs

The applicant provided boring logs in Appendix 2BB. The staff reviewed this information and concludes that the information provided satisfies the requirements of 10 CFR Part 50 and 10 CFR Part 100.

2.5.5.4.4 Compacted Fill

The applicant did not identify specific sources of borrow material for the construction of the permanent fill. Instead, the applicant described the on-site source for fill, which consists mainly of the nuclear island areas in BLN COL FSAR Subsection 2.5.4.5. The staff's review of this information is provided in Section 2.5.4 of this SER.

In BLN COL FSAR Section 2.5.5.4, the applicant stated that there were no safety-related retaining walls, bulkheads, or jetties at the BLN site, nor were there any natural or manmade slopes that could pose a potential hazard to BLN 3 and 4. The applicant also stated that there were no manmade earthen or rock dams present at the site, that could adversely affect the safety of BLN 3 and 4. Since there are no permanent cutslopes or man-made slopes at the BLN site that may impact safe operation of the proposed BLN 3 and 4, the staff concludes that BLN COL 2.5-14 does not apply to the site. Furthermore, since there are no dams or embankments, the staff also concludes that BLN COL 2.5-15 does not apply to the BLN 3 and 4 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 the stability of slopes, and there is no outstanding information expected to be addressed in the BLN COL FSAR related to this subsection.

Section 2.5.5 of Revision 17 of the AP1000 DCD is identical to Section 2.5.5 of Revision 15 of the AP1000 DCD, which is incorporated by reference into 10 CFR Part 52, Appendix D. This subsection is not affected by the changes that Westinghouse proposed in Revision 17 to the AP1000 DCD. Pursuant to 10 CFR 52.63(a)(5) and 10 CFR Part 52, Appendix D, Section VI.B.1, all nuclear safety issues relating to the stability of slopes that were incorporated by reference have been resolved.

In addition, the staff concludes that the relevant information presented within the BLN COL FSAR is acceptable and meets the requirements of 10 CFR Part 50, Appendix A of GDC 1, 2, and 44); Appendices B and S of 10 CFR Part 50; and 10 CFR 100.23. The staff based its conclusion on the following:

- BLN COL 2.5-14, involving evaluation of the static and dynamic stability of soil and rock slopes, is acceptable because there are no permanent cutslopes or man-made slopes at the BLN site.

- BLN COL 2.5-15, involving evaluation of static and dynamic stability of embankments and dams, is acceptable because there are no dams or embankments at the BLN 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 the stability of slopes, and there is no outstanding information expected to be addressed in the BLN COL FSAR related to this subsection.

Section 2.5.5 of Revision 17 of the AP1000 DCD is identical to Section 2.5.5 of Revision 15 of the AP1000 DCD, which is incorporated by reference into 10 CFR Part 52, Appendix D. This subsection is not affected by the changes that Westinghouse proposed in Revision 17 to the AP1000 DCD. Pursuant to 10 CFR 52.63(a)(5) and 10 CFR Part 52, Appendix D, Section VI.B.1, all nuclear safety issues relating to the stability of slopes that were incorporated by reference have been resolved.

In addition, the staff concludes that the relevant information presented within the BLN COL FSAR is acceptable and meets the requirements of 10 CFR Part 50, Appendix A of GDC 1, 2, and 44); Appendices B and S of 10 CFR Part 50; and 10 CFR 100.23. The staff based its conclusion on the following:

- BLN COL 2.5-14, involving evaluation of the static and dynamic stability of soil and rock slopes, is acceptable because there are no permanent cutslopes or man-made slopes at the BLN site.

- BLN COL 2.5-15, involving evaluation of static and dynamic stability of embankments and dams, is acceptable because there are no dams or embankments at the BLN site.

Package No.: ML091740241
Accession Nos.: ML091540376 (Text); ML091590086 (Fig. 1); ML091590093 (Fig 2); ML091590097 (SER Tables)

Sections 2.0, 2.3, 2.4					
OFFICE	**DNRL/NWE1**	**DNRL/NWE1**	**DSER/RSAC**	**OGC**	**DNRL/NWE1**
NAME	KGoldstein	JSebrosky	CLauron	AHodgdon	EMcKenna
DATE	8/13/09	8/13/09	8/13/09	8/13/09	8/13/09
Sections 2.1- 2.2					
OFFICE	**DNRL/NWE1**	**DNRL/NWE1**	**DSER/RSAC**	**OGC**	**DNRL/NWE1**
NAME	KGoldstein	JSebrosky	CLauron	AHodgdon	EMcKenna
DATE	8/18/09	8/18/09	8/18/09	8/18/09	8/18/09
Section 2.5.1-2.5.2					
OFFICE	**DNRL/NWE1**	**DNRL/NWE1**	**DSER/RGS1**	**OGC**	**DNRL/NWE1**
NAME	KGoldstein	JSebrosky	RKaras	AHodgdon	EMcKenna
DATE	8/21/09	8/21/09	8/21/09	8/21/09	8/21/09
Section 2.5.3-2.5.5					
OFFICE	**DNRL/NWE1**	**DNRL/NWE1**	**DSER/RGS1**	**OGC**	**DNRL/NWE1**
NAME	KGoldstein	JSebrosky	RKaras	AHodgdon	EMcKenna
DATE	8/28/09	8/31/09	8/28/09	9/3/09	8/28/09

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